The pharmacological and anticipated effects of sugar on behaviour

Thesis submitted in accordance with the requirements of the University of Liverpool
for the degree of Doctor in Philosophy by Emily Jane Jennings

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Declaration

No portion of this work has been submitted in support of any other application for degree or qualification at this or any other University or institute of learning.

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Abstract

Obesity levels are a significant public health and economic burden worldwide and sugar sweetened beverage (SSB) consumption is argued to be a major contributing factor. There is a wealth of evidence demonstrating sugar consumption influences several aspects of behaviour including, physical endurance, cognitive performance, subjective energy, and underlying appetitive motivational processes. However, there is limited knowledge of the impact of expectancy, which has been shown to be critical in other health behaviours.

One factor which may drive the consumption of sugar-sweetened beverages (SSBs) are people's beliefs about the short-term effects of SSBs (termed 'outcome expectancies'), for example, expected physical/cognitive improvement, increased energy, etc. Thus, the first aim of the thesis was to explore the anticipated effects of sugar on SSB consumption (chapter three). *Chapter three* indicated that SSB outcome expectancies could be described in terms of three expectancy factors; positive cognitive and physical effects, hydration and sugar craving. In study 3.1, all expectancy subscales were positively correlated with SSB consumption (ml/day), which was replicated in study 3.2 apart from the craving subscale and SSB consumption were not related. In both studies, high consumers had higher scores on the positive cognitive and physical effects and hydration subscale than non-consumers, but not on the craving subscale. This demonstrates that people's beliefs about the short-term effects of SSBs can influence the consumption of these beverages.

The aim of subsequent chapters was to explore both the pharmacological and anticipated effects of sugar, both combined and in isolation, on physical endurance (chapter four), cognitive performance (chapter five), subjective energy (chapter four and five) and implicit and explicit appetitive motivational processes (chapter six). All chapters utilised a balanced placebo design. *Chapter four* indicated no pharmacological effects of sugar on measures of physical endurance (leg-raise and handgrip) or subjective energy. However, sugar expectancy (regardless of beverage content) led to increased leg-raise endurance, but had no effect on handgrip

endurance, or measures of subjective energy. In *chapter five*, study 5.1 found no pharmacological effects of sugar on cognitive performance (verbal fluency, inhibitory control, memory recall) or subjective measures. Sugar expectancy did not influence any measures of cognitive performance, however there was some contribution to subjective measures in that sugar expectancy led to increased subjective energy (regardless of beverage content). Study 5.2 further explored the anticipated effects of sugar using a placebo-sugar beverage. Again, expectancy did not influence cognitive performance but did influence subjective energy in accordance with individual's expectations. *Chapter six* indicated no pharmacological effects of sugar across any explicit or implicit appetitive motivational processes. The anticipated effects of sugar did not influence AB for SSB-related cues, however, in the placebo condition, those who expected sugar reported a reduction in sugar craving. Furthermore, AB for SSB-related cues and sugar craving were positively correlated, however SSB-related outcome expectancies and AB-for SSB-related cues were not related.

Taken together, these findings suggest that despite the fact high consumers are more likely to expect certain effects from consumption (e.g. improved cognitive/physical performance, increased energy), the current findings report no pharmacological effects of sugar across any objective or subjective measures assessed in the thesis. The anticipated effects of sugar are more important influences on physical endurance and particularly self-report measures (subjective energy and sugar craving). Thus, expectancies may account for some of the positive effects of sugar found in previous research, particularly in the case of physical endurance, and increased feeling of energy. Furthermore, given the role of expectancy on craving, consuming sugar may not be necessary to control sugar cravings. Thus, in order to reduce SSB consumption and obesity, interventions should address people's beliefs about the effects of sugar and educate individuals about the contribution of expectancy to behaviour.

Chapter One:

General Introduction

1.1 Obesity and associated health issues

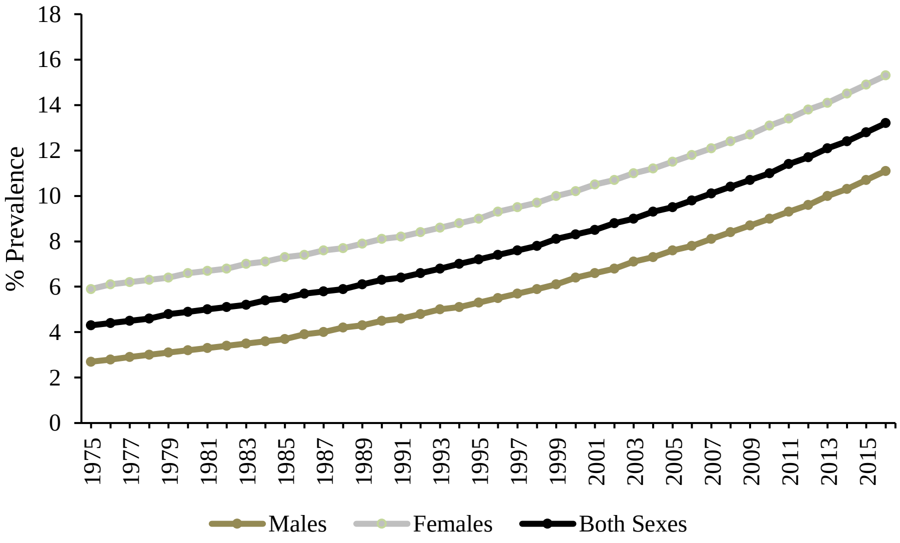
1.1.1 Obesity

Obesity is defined as a condition of abnormal or excessive fat accumulation in adipose tissue, to the extent that health may be impaired (Forster, Jeffery, Schmid & Kramer, 1988) and is one of the leading causes of preventable morbidity and mortality from type-2 diabetes, cancer, and cardiovascular disease (Gallus, Lugo, Murisic, Bosetti, Boffetta & Cecchia, 2015). The most commonly accepted classification of weight is body mass index (BMI), with a BMI 25–29.9kg/m^2 classified as overweight, ≥30 kg/m^2 as obese and ≥40 kg/m^2 as morbidly obese.

Globally, obesity has reached epidemic proportions with 1.9 billion adults (aged 18 and over) meeting the cut off for being overweight and of these 650 million classified as obese (World Health Organisation [WHO], 2018). Obesity is not just a problem in adult populations, with an estimated 42 million young children (aged under 5) classified as obese in 2013 (WHO, 2014). It imposes devastating health and financial costs to individuals and society, and despite efforts to increase awareness, obesity has risen at an alarming rate across the globe over the past few decades, with data from the global health observatory demonstrating that the prevalence has tripled since 1975 (WHO, 2017 see figure 1.1).

Obesity rates are reportedly highest in more developed countries with the Organisation for Economic Cooperation and Development (OECD) reporting that one in five adults in OECD countries (consisting of mainly high-income developed/ developing countries) were classified as obese. The highest obesity rates were in the United States (38.2%), followed by Mexico (32.4%), Australia (27.9%) and the UK (26.9%) (OECD, 2017). The trends for increasing obesity are present throughout Western Europe with a similar rise reported in the US. England has some of the worst figures and trends in obesity compared to the rest of Europe; in most European countries the trend has increased from between 10% and 40% in the last 10 years, whereas in England prevalence has more than doubled (Agha & Agha, 2017). In 1993, The Health Survey for England (HSE) reported that 13% men and 16% women were obese (HSE, 2010), however by 2017 this had risen to 27% men and 30% women classified as obese (Conolly & Davies, 2018). Similarly, in America, in 1986, 1 in 200 adults in America were morbidly obese, however, by 2009, 1 in 5 were classified as morbidly obese (Agha & Agha, 2017).

Figure 1.1- Prevalence (%) of obesity (BMI≥30) among adults (aged 18 and over), worldwide, between 1975 and 2016.



Source: WHO (2017) Global Health Observatory data (http://apps.who.int/gho/data/node.main-eu.BMIANTHROPOMETRY?lang=en).

The levels of obesity found in low and middle-income countries are also increasing, reaching levels found in higher-income countries. This is particularly true in the Middle East and North Africa with 70.6 % classified as overweight or obese and in Latin America and the Caribbean, with 50.7% classified as overweight or obese (Popkin & Slining, 2013). One explanation for increasing obesity levels across non-western countries is the global dietary changes with increased reliance on processed foods, but also reduced physical activity. The western diet is becoming more prevalent in these countries, with increased consumption of calorific sweeteners and refined carbohydrates and fats, while traditional higher quality diets rich in healthy legumes, vegetables, and grains are being consumed less (e.g. Popkin, Adair & Ng, 2012).

OECD projections show a steady global increase in obesity levels until at least 2030, with obesity levels expected to be particularly high in the United States (47%), Mexico (39%) and the United Kingdom (35%) (OECD, 2017). The financial burden imposed by obesity will increase, with greater pressure placed on healthcare systems across the world. Currently, obesity is responsible for 5% of global deaths, and is one of the top three global economic burdens generated by human beings, costing an estimated $2.3 trillion, roughly equivalent to the global impact from smoking or from armed violence, war, and terrorism combined (Dobbs et al., 2014). In the UK, in 2006/07 alone, the estimated spending for the NHS reached £5.1 billion on obesity-related health issues alone, representing 16.2% of total NHS spending (Scarborough et al., 2011). In the US, in 2008, the medical spending on obesity was estimated to amount to $147 billion (Finkelstein, Trogdon, Cohen & Dietz, 2009).

Obesity is a major contributor to the prevalence of a number of non-communicable diseases (NCDs) such as diabetes, cancer, cardiovascular disease (CVD), stroke and osteoporosis (Kumanyika, Jeffery, Morabia, Ritenbaugh & Antipatis, 2002). WHO (2014) reported that NCDs are the leading cause of mortality in the world, responsible for 38 million of the world’s 56 million deaths (68%) in 2012, and thus have huge healthcare costs. Indeed, it was recently stated by the Public Health Approaches to the Prevention of Obesity (PHAPO) working group of the International Obesity Task Force (IOTF) that "In every country in the world today, depending on its stage of epidemiologic transition, chronic non-communicable diseases are either newly appearing, rapidly rising, or already established at high levels" (Kumanyika et al., 2002, p.1). This rise in NCDs is concomitant with the global rise in obesity. Thus, with increasing rates of obesity, healthcare costs associated with obesity-related health issues will continue to increase, and thus addressing preventive factors for obesity (e.g. nutrition, physical activity) is paramount.

To demonstrate the scale of this obesity problem, the next parts of this section (1.1.2, 1.1.3 and 1.1.4) will present statistics to demonstrate the prevalence and economic impacts of a number of obesity-related non-communicable diseases (NCD's), including diabetes and cancer.

1.1.2 Diabetes

Type 2 diabetes, a metabolic disorder, is characterised by resistance to insulin that results in chronically high blood sugar in the body. Left untreated, the condition can result in severe complications, including heart disease, stroke, blindness, kidney failure, and poor blood flow to the limbs that can lead to sores and amputation, and thus is one of the major healthcare costs of obesity

In the past three decades, the prevalence of diabetes has risen substantially in countries of all income levels, mirroring the global increase in people who are overweight or obese. The WHO global report on diabetes estimated that the global prevalence of diabetes has risen from 108 million (4.7% of the adult population) in 1980, to 422 million (8.5% of the adult population) in 2014 and was responsible for 1.5 million deaths in 2012 (WHO, 2016). Over the past few decades, the prevalence of diabetes has grown faster in low- and middle-income countries than in higher income countries, with the largest number of people with diabetes estimated for the WHO South East Asia and Western Pacific regions accounting for approximately half the diabetes cases in the world (WHO, 2014). WHO (2016) reported that 40% of the increase in diabetes cases is estimated to result from population growth and ageing, and therefore, with a growing global population, diabetes will become a larger scale problem.

Diabetes presents a major health concern in the UK. The HSE reported diabetes to be the leading cause of avoidable mortality, with the prevalence more than doubling between 1994 to 2010, from 2.9% to 9.6% amongst men, and from 1.9% to 5.3% amongst women. Alarmingly, in 2005, it was estimated that diabetes was responsible for 11.6% of all deaths amongst those aged 20 to 79 (HSE, 2010). Diabetes and related health issues present a significant economic burden. A recent analysis concluded that the cost of diabetes in the UK in 2011 totalled £9.6 billion in direct costs, with around 80% of this spent on associated complications (e.g. heart-related problems, excess inpatient days and stroke) (Hex, Barlett, Wright, Taylor & Varley, 2012).

The susceptibility to diabetes is 80 times greater among obese adults than the non-obese (Agha & Agha, 2017), and therefore reducing the levels of obesity would reduce the prevalence of disease. Indeed, research suggests that type-2 diabetes can be delayed or prevented in those known to be at high risk through lifestyle interventions that promote better nutrition, weight loss, and increased physical activity (e.g. Hemmingsen et el., 2017; Asif, 2014).

1.1.3 Cancer

Data from the global cancer observatory reported 18.1 million new cases of cancer in 2018. Cancer is the leading cause of death in the UK, with an estimated 359,960 new cases and 161,849 reported deaths in 2015 (Cancer Research UK, 2018). Largely due to a growing and ageing population, the number of cancer cases is projected to rise by more than 40% to more than 514,000 new cases per year in 2035, with a greater increase in men than women (Smittenaar, Petersen, Stewart & Moitt, 2016), placing further burden on an already stretched healthcare system.

Cancer Research UK reported that 4 in 10 cancers are preventable and therefore tackling lifestyle factors to reduce incidence is crucial (Cancer Research UK, 2019). In the UK, excess weight is the second biggest cause of cancer (following smoking) due to the fact obesity effects a large proportion of the UK population (Brown et al., 2018). Indeed, many studies show associations between adiposity and increased risk of a range of cancers including cancer of the endometrium, kidney, gallbladder (in women), breast (in postmenopausal women), and colon (particularly for men) (e.g. Carroll, 1998; Bergström, Pisani, Tenet, Wolk & Adami, 2001). It is estimated that in Europe, excess body mass accounts for 5% of all cancers, 3% in men and 6% in women (Bergström et al., 2001). Using data from the Global Cancer Observatory, it was estimated that in 2012, in the United States, 3.5% of new cases of cancer in men and 9.5% of new cancer cases in women were due to overweight or obesity. The percentage of cases attributable to overweight and obesity varied for different cancers but were as high as 54% for gallbladder in women and 44% for oesophageal adenocarcinoma in men (Arnold et al., 2015). In the UK, it was estimated that 5.5% of all cancer cases (4.1% men, 9.5% in women) were attributable to obesity in 2010 (Parkin & Boyd, 2011).

The economic impact of cancer is significant and increasing with the global economic cost estimated to be approximately $1.16 trillion in 2010 (Stewart & Wild, 2014). In the UK, the cost of cancer is estimated at £15.8 billion a year. Half (£7.6bn) of the total economic cost of cancer is due to premature deaths and time off work, followed by healthcare costs (£5.6bn) and unpaid care to cancer patients by friends and family (£2.6bn) (Leal, 2012). Although there is variability across the world in the proportion of cancer cases attributable to obesity, research suggests that a substantial number of cancer cases could be prevented by reducing the prevalence of obesity.

1.1.4 Other non-communicable diseases (NCDs)

Obesity is an established key modifiable risk factor for a number of other NCDs such as cardiovascular disease (CVD) and stroke (e.g. Strazzullo et al., 2010). According to WHO, CVD is the number one cause of death globally, with an estimated 17.9 million people dying from CVD in 2016, representing 31% of global deaths (WHO, 2017a). In the UK, CVD is the second most common cause of death, causing 27% of all deaths (Townsend, Bhatnagar, Wilkins, Wickramasinghe & Rayner, 2015). The cost of CVD to the healthcare system is huge, for example, in the UK, in 2004, CVD cost the NHS £15.7 billion, representing 21% of the overall NHS expenditure (Luengo-Fernández, Leal, Gray, Petersen & Rayner, 2006).

Stroke is the second leading cause of death globally, accounting for almost seven million deaths in 2012, which represents 11.1% of total deaths (WHO, 2014a; Mozaffarian et al., 2015). In 2016, there were an estimated 13.7 million new stroke cases and more than 80 million survivors (Feigin et al., 2017). In the UK, stroke is the third most common cause of premature death (Office for national statistics [ONS], 2016) and a leading cause of disability (Newton et al., 2015), with approximately 57,000 people in the UK experiencing a stroke for the first time in 2016 (PHE, 2018). The human burden of a stroke is mirrored by the very large cost of providing healthcare to people with stroke, with stroke care accounting for approximately 3–5% of all healthcare expenditure in developed countries (Evers et al., 2004; Saka, McGuire & Wolfe, 2009). The cost of stroke care in the UK is estimated to be around £9 billion per year (Saka et al., 2009).

Taken together, research in this section demonstrates that obesity-related diseases (e.g. diabetes, cancer, CVD, etc.) are responsible for high rates of mortality and health-problems globally, placing a heavy burden on public healthcare systems and imposing significant financial costs to the individual, society, and healthcare. Reducing the prevalence of overweight and obesity would avoid a substantial number of new cases of these NCD's in the coming decades (e.g. Henry, 2011; Branca et al., 2019; Webber et al., 2012). Governments need to take action by implementing policies that reduce overweight and obesity. Maintaining healthy dietary behaviours (e.g. reducing SSB consumption, foods high in saturated fats, etc) and increasing physical exercise are crucial for tackling obesity and preventing non-communicable diseases (e.g. Lin et al., 2012; Imamura et al., 2015).

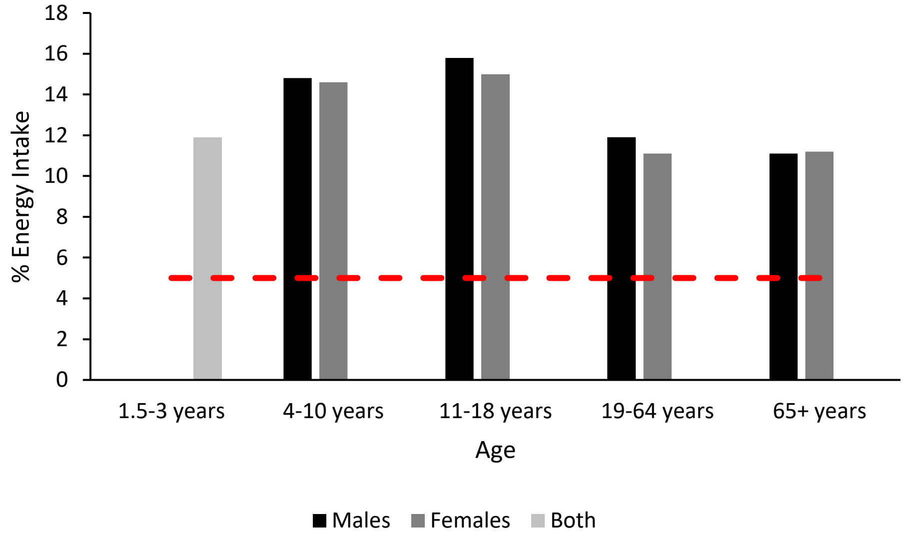
The high levels of free sugar intake is of great concern due to its association with poor dietary quality, obesity, and risk of NCDs (WHO, 2015). The next section reviews research in this area.

1.2 Sugar and obesity

1.2.1 Sugar consumption

The fundamental cause of obesity is an energy imbalance between calories consumed and calories expended. Foods and beverages high in added sugars (e.g. sucrose, glucose etc.) are highly calorific and represent a major part of the western diet, with many individuals across the world exceeding the recommended allowance for dietary sugar (e.g. Australian Bureau of Statistics, 2016; Kellie & Didier, 2011). For example, using data from the UK National Diet and Nutrition Survey, Bates et al. (2014) reported that between 2008 and 2012 estimated sugar intake exceeded the recommended daily allowance (less than 5% of total daily energy consumed) for all age groups. Furthermore, in school children and teenagers mean daily sugar intake was three times the recommended daily intake, and for adults exceeded twice the daily allowance (see figure 1.2).

Figure 1.2- Energy intake from sugar (%) compared to UK recommended maximum of 5% energy. Data from Bates et al. (2014).

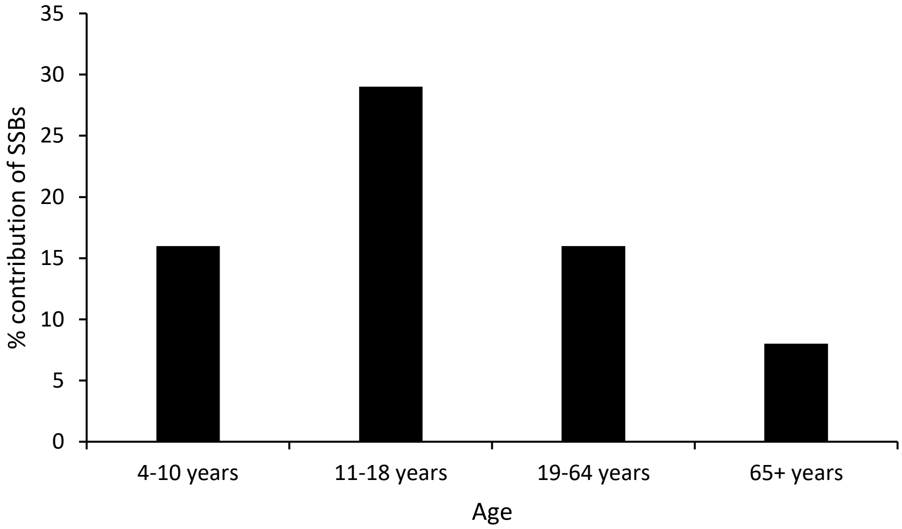


This is particularly worrying considering the abundance of research suggesting a strong link between high sugar intake, weight gain and obesity (e.g. Malik, Popkin, Bray, Despres & Hu, 2010; Morenga, Mallard & Mann, 2013), as well as other negative health problems such as type 2 diabetes, dental cavities, CVD, and even mortality (e.g. Moynihan & Kelly, 2014; Yang, Zhang & Gregg, 2014; Collins, Judd, Safford, Vaccarino & Welsh, 2019). Consequently, WHO (2015) recently set guidelines recommending the reduction of sugar intake to reduce the incidence of health-related issues in adults and children.

1.2.2 Sugar-sweetened beverages

SSBs include any beverage containing added sugars (e.g. sucrose, glucose, high fructose corn syrup) such as non-diet fruit flavoured beverages, carbonated beverages, energy and sports drinks (Han & Powell, 2013). They are highly calorific due to their high sugar content but contribute minimal nutritional value, with one 330ml can of soft drink alone containing approximately 35g of added sugar, above the NHS recommended daily allowance (Adults =30g, 7-10 years old=24g, 4-6 years old=19g). SSBs are one of the main contributors of dietary sugar intake, particularly for children and adolescents (see figure 1.3), with one in five adolescents (aged 11 to 15 year olds) reporting daily consumption of full-sugar soft drinks (Inchley, Currie, Jewell, Breda & Bernekow, 2017)

Figure 1.3- Contribution of SSBs to average daily sugar intake by age group (Data from Bates et al. (2014).



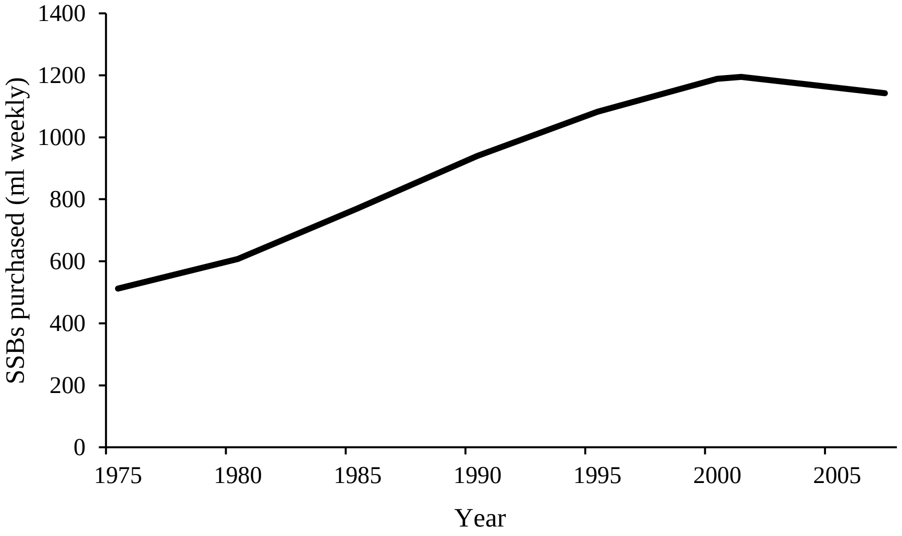
There is strong evidence for an association between SSB consumption and adverse health outcomes such as being overweight and obese, developing type-2 diabetes and heart disease (e.g. Malik, Schluze & Hu, 2006; Fung, Malik, Rexrode, Manson, Willett & Hu, 2009). Indeed, the highest consumers have up to a 26% greater risk of developing type 2 diabetes than those with the lowest SSB consumption (Malik et al., 2010). SSBs are thought to contribute to weight gain for a number of reasons. Firstly, SSBs have a high sugar content and are highly calorific. Research also suggests that

SSBs do not provide the same level of fullness that the same calories from solid food provides, therefore consumers tend not to reduce intake of other foods sufficiently to compensate for the extra calories provided by the SSBs (Pan & Hu, 2011; DiMeglio & Mattes, 2000), potentially leading to overconsumption of other high-calorie foods and beverages.

Indeed, the perceived risk of consuming SSBs is so great that a number of interventions have been introduced across several countries. For example, controls over the marketing of SSBs to children and limits on portion size, with particular attention to taxation in several countries (e.g. Hungary, France and several states in the US), as evidence suggests that taxation could reduce levels of obesity (e.g. Cabrera Esconar, Veerman, Tollman, Bertram & Hofman, 2013). Indeed, a sugar tax has recently been implemented in the UK (April 2018) on all drinks containing more than 5g of sugar per 100ml, to discourage consumers from purchasing these products.

Despite increased attention to the negative health effects and recommendations from medical experts and health organisations to reduce consumption, over the last few decades, the global consumption of SSBs has rapidly increased. Household expenditure data demonstrates that in Britain the estimated volume of SSBs purchased more than doubled from 512ml to 1142ml (per person per week) between 1975 and 2007 (see figure 1.4). Similarly, SSB intake increased gradually from 113kJ/day in 1986/87 to 209kJ/day in 2008/09 (Ng, Mhurchu, Jebb & Popkin, 2012). In America, the consumption of non-diet soft drinks reportedly increased by 135% between 1977 and 2001 (Neilson & Popkin, 2004). This increase in SSB consumption is concomitant with the increasing rates of obesity, and thus understanding factors that contribute to consumption of these beverages is one step to improving public health.

Figure 1.4 – Graph showing increasing trend in ml of SSBs purchased weekly in British households between 1975-2007 (Data from Ng et al., 2012)



1.2.3 Diet beverage consumption as an alternative

Diet beverages provide the sweet taste of SSBs, but without the calories. Research suggests that replacing foods and beverages, that provide a substantial portion of daily calories, may provide a useful strategy for modest weight reduction or weight gain prevention (Dennis, Flack & Davey, 2009). Therefore, substituting SSBs for their diet beverage counterpart may be a good strategy for weight management and control. However, there are several barriers to the use of these beverages, including the belief held by some individuals that these drinks can lead to weight gain and are associated with cancer.

1.2.3.1. Weight gain

Pre-clinical studies, as well as human imaging studies raise the concern that the consumption of artificial sweeteners can lead to the dissociation of the sensation of sweetness from caloric intake and this may disrupt the relationship between taste, appetite and consumption patterns (Drewnowski, Mennella, Johnson & Bellisle, 2012; Davidson, Martin, Clark & Swithers, 2011; Rudenga & Small, 2011). For example, Davidson et al. (2011) demonstrated that chronic exposure to artificial sweeteners in rodents reduced the effectiveness of learnt associations between sweetness and calories and lead to greater intake of a sweet high-calorie diet (see also Swithers, Martin & Davidson, 2010). Furthermore, human functional imaging studies have reported differential effects of calorific and non-calorific sweeteners on brain activation (Rudenga & Small, 2011; Green & Murphy, 2012). For example, Rudenga and Small (2011) reported that increased artificial sweetener use was associated with a reduced response to sucrose in the amygdala (a region known to signal post-ingestive effects), which may in turn influence subsequent eating behaviour and potentially weight gain.

However, a number of prospective observational studies have reported negative associations between diet beverage consumption and weight gain (e.g. Ludwig, Peterson & Gortmaker, 2001; Mozafarrian, Hao, Rimm, Willet & Hu, 2011; Schulze et al., 2004). For example, in a sample of 11 and 12 year old school children, Ludwig et al. (2001) demonstrated that each serving increase in diet beverage consumption over a 19 month study period was associated with a 56% reduction in the odds of becoming obese. However, associations between diet beverage consumption and weight gain over time are also reported. For example, Blum, Jacobsen and Donnelly (2005) examined beverage intake change (diet beverages, SSBs, etc) and BMI change in elementary school children over a two year period and found that increased diet beverages consumption was associated with an increased BMI z score at year two. Notably, increases in diet beverage consumption were significantly greater for those who gained weight and overweight subjects, compared to those who were normal weight at year two. Therefore, these results may be explained by reverse causality, since individuals at high risk of weight gain may choose to consume diet beverages in an attempt to reduce their weight gain or disease risk (Pereira, 2013). Consistent with the view of reverse causality, findings from Project EAT, surveying students between 2000 and 2005, found a positive association between frequency of diet beverage consumption and change in BMI during this period. However, following adjustments for dieting for weight control and parental weight concern, this positive association between diet beverage consumption and BMI change was no longer significant (Vanselow, Pereira, Neumark-Sztainer & Raatz, 2009). Therefore, positive associations may occur as a result of overweight individuals utilising these beverages as a strategy for weight loss. Furthermore, research generally concludes that there is no significant evidence from observational studies that low-calorie sweetened beverages are associated with weight gain (e.g. Anderson, Foreyt, Sigman-Grant & Allison, 2012).

Findings from experimental trials also suggest that diet beverages are a useful weight loss control strategy. For example, evidence suggests that, compared to a SSB group, diet beverage consumption leads to lower energy intake and greater weight loss in healthy weight adults over a 3 week period (Tordoff & Alleva, 1990), and in overweight adults over a 10 week period (Raben, Vasilaras, Møller & Astrup, 2002). The beneficial effects of artificial sweetener on weight loss have also been demonstrated over longer durations. For example, Blackburn, Kanders, Lavin, Keller and Whatley (1997) found that obese women assigned to consume artificial sweetener food/beverage products lost more weight and retained greater weight loss over a two year follow up than those consuming an artificial sweetener-free diet. Similar findings were reported by Peters et al. (2016) in overweight and obese adults over a one-year weight loss program, in comparison to a water control, and by Tate et al. (2012) who found that those in the diet beverage condition were more likely to achieve 5% weight loss at 6 months compared to an attention control. Taken together, and contrary to the belief by some individual’s that diet beverages lead to weight gain, there is no consistent evidence that this is the case. In fact, the balance of evidence suggests that diet beverages may be a useful strategy for weight management. Therefore, more education is required to individuals regarding the use of diet beverages as a useful strategy for weight management.

1.2.3.2. Cancer

A further barrier to the use of diet beverages is the belief that artificially sweetened products are associated with cancer. The link between artificial sweetener consumption and cancer is portrayed by the media, leading to negative perceptions of these beverages. Some studies on rats and mice have linked artificial sweetener consumption with the development of cancer; including bladder cancer in rats fed saccharin (Reuber, 1978), leukaemia in rats receiving high doses of aspartame

(Soffritti, Belpoggi, Esposti & Lambertini, 2005) and blood cell tumours in rats fed very high doses of sucralose (Soffritti et al., 2016). However, other rat studies report no effect of artificial sweetener exposure on development of cancer (e.g. National Toxicology Program, 2005; Mann, Yuschak, Amyes, Aughton & Finn, 2000). Notably, some of the studies finding effects on cancer utilised doses much higher than those than would be present in diet beverages, and way above the recommended daily dose for humans, and thus are not applicable to humans. Furthermore, results from human carcinogenicity studies of sweeteners do not support the existence of a consistent association between artificial sweetener consumption and cancer (e.g. Mishra, Ahmed, Froghi & Dasgupta, 2015; Lohner, Toews & Meerpohl, 2017; Marinovich, Galli, Bosetti, Gallus & Vecchia, 2013).

The use of SSBs remains drastically higher than that of diet beverages because some individuals would not consider the use of diet beverage as a low-calorie substitute. Therefore, to reduce the consumption of high calorie SSBs, it is important to understand factors that may contribute to these unhealthy beverage choices.

1.3. SSB consumption and behaviour

One reason individual may choose to consume SSBs is due to the expected behavioral effects (e.g. improved cognitive and physical performance, increased energy) they are believed to have (expected effects discussed later in section 1.4). This section will discuss research on the short-term effects of consuming sugar on cognitive performance, physical endurance, subjective energy and underlying appetitive motivational processes.

1.3.1. Cognitive performance

Sugar (mainly in the form of glucose) is the major source of energy for the brain and is essential for normal functioning of the nervous system (Sieber & Traystman, 1992). Indeed, a decline in blood glucose has been found to have a rapid impact on brain functioning, such as resulting in alterations in cortical cell functioning, changes in EEG activity, disrupted neural activity (e.g. Holmes et al., 1983; Blaabjerg & Juhl, 2016), and hypoglycaemic blood glucose levels have been associated with cognitive dysfunction (e.g. Graveling, Deary & Frier, 2013; Sommerfield, Deary, McAulay & Frier, 2003).

There is extensive research investigating the effects of glucose on executive functions and declarative memory; the former mainly located in the prefrontal regions (e.g. Funahashi & Andreau, 2013) and the latter the medial temporal regions, particularly the hippocampus (e.g. Bayley & Squire, 2003). Studies investigating the effects of acute SSB consumption on executive functions (e.g. inhibitory control, verbal fluency) have produced equivocal findings. Typically, in these studies, participants are asked to consume either a glucose-sweetened beverage or a placebo beverage (matched for sweetness), which is followed by completion of a cognitive task or battery of tasks. Studies have most consistently reported effects of glucose on the Stroop task (a measure of inhibitory control); it has been found that compared to a sugar-free placebo control (matched for sweetness), consuming a SSB can improve subsequent performance on the Stroop task (in healthy young adults; Gaillot et al., 2007; Brandt, Gibson & Rackie, 2013 and in young and old adults; Craft, Murphy & Wemstrom, 1994). Although the effects of glucose on specific inhibitory control measures (reaction time (RT) and errors) taken from the Stroop were mixed with the former study reporting reduced errors only, whereas the latter two studies found reduced RTs (with a corresponding increase in errors in the second study). Notably, in the study by Craft et al. (1994), participants also completed a verbal fluency and serial addition executive tasks which were not found to be influenced by glucose. In another study, Kennedy and Scholey (2000) reported that glucose did improve performance on a verbal fluency and serial subtraction task, although improved performance only occurred in the more demanding mental arithmetic (serial sevens) but not the less demanding serial threes task. Conversely, there is also evidence that glucose can impair cognitive performance (e.g. simple response time, mental arithmetic and Stroop performance; Ginieis, Franz, Oey & Peng, 2018). Taken together, findings regarding the effects of a SSB on executive function are mixed with findings varying within and between executive function tasks. Facilitative effects of glucose are most consistent on Stroop performance, suggesting that it may be more sensitive to the performance-enhancing effects of glucose. Furthermore, studies using some executive tasks (e.g. verbal fluency) are lacking, and thus further research is required.

Research suggests that glucose can also improve memory although this research has largely focused on verbal episodic memory. One task commonly used to assess episodic memory is word recall, in which participants are provided with a list of words and asked to recall as many as they can immediately, and sometimes following a time delay. Several studies report, that in comparison to a placebo sugar-free beverage, consuming a glucose-sweetened beverage, can enhance episodic memory recall in young healthy adults, (Stollery & Christian, 2013; Sünram-lea, Foster, Durlach & Perez, 2001; Riby, Mclaughlin & Riby, 2008). However, Stollery and Christian (2013) showed improved delayed memory recall only and Riby et al. (2008) found glucose facilitation of more difficult abstract words only, suggesting that glucose may be more sensitive to more cognitively demanding memory tasks. Notably, Scholey and Kennedy (2004) found that relative to placebo, glucose and caffeine, in combination, improved episodic memory recall, however when glucose was investigated in isolation, there was no effect on memory recall. A number of other studies have found that glucose also improves other aspects of memory including visual memory for drawings (e.g. Sunram-Lea et al., 2001) or faces (Metzger, 2000) and memory for movements (e.g. Scholey & Fowles, 2002). Riby et al. (2006) investigated the effects of a glucose-sweetened beverage on episodic (immediate/delayed word recall and paired associate) and semantic (category fluency and semantic verification) memory tasks and found that although glucose boosted episodic remembering, there was little evidence that glucose can boost semantic retrieval. They concluded that glucose acts primarily on the hippocampal region, which is known to support episodic memory. Taken together, research suggests that glucose may act as an effective tool for memory enhancement, with the most consistent findings for episodic memory.

A number of factors have been suggested to alter the effectiveness of glucose as a cognitive enhancer and may explain some of the inconsistencies in findings; these include, age, gender (e.g. Craft et al., 1994), glucoregulatory efficiency (e.g. Kaplan, Greenwood, Winocur & Wolever, 2000; Craft et al., 1994; Riby et al., 2008) and cognitive demand (e.g. Hoyland, Lawton & Dye, 2008). For example, Kaplan et al. (2000) demonstrated that in older adults poor glucoregulation was associated with poor episodic memory (immediate/delayed paragraph recall, word recall) performance, however consumption of a glucose beverage was associated with improvements in episodic memory in poor glucose regulators. In another study, Craft et al. (1994) investigated the effects of age, gender, and glucoregulatory efficiency on cognitive performance and found that glucose enhancement of recall was restricted to the male subjects, with young and old effected differently depending on glucose regulatory efficiency. Contrary to Kaplan et al. (2000) this study found that older males with good glucose regulation showed enhanced recall following glucose administration, whereas the older adults with poor regulation showed decreased recall. However, for young men this was reversed, with good glucose regulators showing decreased recall following glucose, and poorer glucoregulators showing enhanced recall performance. Notably, in this study the older adults had much poorer glucose recovery than the younger adults, with their glucose recovery indices comparable to the ‘poor’ glucoregulators in the young adult age group, which may explain differing results between the two studies.

Glucose facilitation of task performance tends to occur under circumstances of intense cognitive demand (Hoyland et al., 2008; Messier, 2004; Smith, Riby, van Eekelen & Foster, 2011). For example, tasks completed in a delayed context (delayed free recall) report glucose effects more consistently than those undertaken immediately post glucose administration (Hoyland et al., 2008). This is further demonstrated by Kennedy and Scholey (2000), who found that glucose administration improved performance in the serial sevens task (which participants rated most demanding), however no effect of glucose was found on verbal fluency or the serial threes task (rated least demanding), suggesting that glucose administration facilitate performance on tasks of higher cognitive load. This may be related to the notion that healthy young adults are operating at their ‘cognitive peak’; therefore, a cognitive enhancer would only be effective when individuals face increased cognitive demands that allow room for improvement (Foster et al., 1998). Although, some studies report no evidence of glucose effects on recall performance being influenced by task complexity (assessed by altering word difficulty; e.g. Stollery & Christian, 2013; Riby et al., 2006).

Notably, mechanisms mediating the cognitive effects of glucose are not currently clear. Several mechanisms have been proposed, for example, the action of glucose could include both central and peripheral processes. Central mechanisms include the direct metabolic contribution of sugars to brain metabolism and neurotransmitter function (Messier, 2004). Firstly, it is hypothesised that ingested glucose could improve memory through increasing access of glucose in the brain. This increased blood glucose may facilitate uptake of glucose in area of the brain where extracellular glucose levels are overly decreased (Messier, 2004). Secondly, glucose could lead to an increase in acetylcholine release and synthesis which could promote cognitive facilitation (Messier, Durkin, Mrabet & Destrade, 1990; Ragozzino, Unick & Gold, 1996; Kopf, Buchholzer, Hilgert, Löffelholz & Klein 2001). Alternatively, it is hypothesized that, since the hippocampus is densely populated with insulin receptors, a rise in insulin following glucose ingestion could promote glucose utilisation and improve memory performance (e.g. Craft et al., 1994). Other research suggests that the primary site of action of glucose may be in the periphery; changes in peripheral organs (e.g. liver) could influence brain function, possibly through activation of the vagus nerve. Glucose could act as a detection mechanism in the vagus nerve, which may then send signals to the central nervous system to influence physiological processes underlying memory function (Messier, 2004). Indeed, stimulation of the vagus nerve has been found to enhance memory in human subjects (Clark, Naritoku, Smith, Browning & Jensen, 1999).

Importantly, studies do not take into account psychological factors that may also influence cognitive performance following consumption of a sugary drink. Indeed, some studies have found improvements in cognitive performance without a change in blood glucose, suggesting that factors other than the drink content can improve cognitive performance. For example, Molden et al. (2012) had participants engage in a self-control task and then rinse with either glucose or a non-glucose solution, followed by a second inhibitory control task (Stroop task). During this period there was insufficient time for glucose to enter the blood stream and be metabolised. They found lower response times on the Stroop task for those who rinsed their mouth with the sugary solution compared to the non-sugary solution (similar results reported by; Sanders, Shirk, Burgin & Martin, 2012). This was attributed to increased motivation following the glucose rinse, thus suggesting that factors (e.g. psychological factors), other than beverage content, can also facilitate performance. One factor, widely known to influence behaviour, but minimally accounted for in this research is expectancy (merely expecting sugar has been consumed/expecting certain effects may influence cognitive performance). Currently, there are only two studies (Green, Taylor, Elliot & Rhodes., 2001; Stollery & Christian, 2013), discussed later in section 1.4.3.1, that have utilised sufficient control conditions to allow the isolation of both pharmacological and expectancy effects, and suggest the possible influence of expectancy on cognitive performance following SSB consumption.

1.3.2. Physical endurance

1.3.2.1 Objective energy

Sugar is the major source of energy for the body and is widely believed to be associated with improved physical performance. Indeed, sports and energy drinks, in which sugar is one of the main critical ingredients, are marketed as providing an energy boost and improving physical performance. Utilising aggressive marketing techniques, many SSB companies' pair SSB brands with sports. Also, SSBs are endorsed by athletes and sponsor major sporting events (Bragg, Yanamadala, Roberto, Harris & Brownell, 2013). For example, Coca-Cola has sponsored the Olympics for many years, leading consumers to build an association between these beverages and physical performance.

SSBs are consumed by athletes as a dietary aid for long lasting physical activity. Indeed, evidence suggests that during exercise of high intensity, when glucose reserves are sufficiently depleted, consuming a SSB can improve physical performance (Flora & Polenick, 2013). In comparison to a placebo-sugar beverage, consuming a sugar-sweetened beverage has been found to improve athletic endurance performance across a range of tasks, for example, increased endurance of male runners and amateur sportsmen in a treadmill exercise test (Wilber & Moffatt, 1992; Ventura, Estruch, Rodas & Segura, 1994), increased mean distance for male athletes in an arm crank exercise (Spendiff & Campbell, 2002) and delayed fatigue of experienced cyclists in a cycling exercise. Furthermore, Sünram-Lea, Owen-Lynch, Robinson, Jones and Hu (2012) demonstrated that following a stressful fire-fighting exercise, consuming a beverage with high concentrations of glucose led to a greater increase in grip strength than the placebo beverage, although the effects may have been contaminated by the small concentrations of caffeine present in the beverage. Taken together, results from these studies suggest that under intense physical conditions, where blood glucose is severely depleted, consuming a SSB can improve physical performance.

However, these beverages are also consumed by non-athletes and non-sportsman. Indeed, undergraduates represent one of the highest consumers (West et al., 2006) and may consume these beverages under circumstances when glucose resources would not be sufficiently depleted, and thus consuming a SSB would have no additional benefit on performance. Research indicates that students reportedly consume these beverages for their expected energising properties (e.g. Chang, Peng & Lan, 2017; Costa, Hayley & Miller, 2014), however, given the fact these beverages are also consumed to aid with daily routine and non-sporting related activity, glucose resources may not be sufficiently depleted for them to have a beneficial effect. Indeed, it has been suggested that for the average individual engaging in routine physical activity the use of a sugar-containing beverage is generally unnecessary adding needless calories to the diet (e.g. Committee on nutrition and the council on sports medicine and fitness, 2017). However, there is currently limited research investigating the effects of SSBs under mild physical exertion, and thus further research is required.

From a psychological standpoint, an important consideration in such research is the role of psychological factors that may contribute to improved performance. Importantly, research has demonstrated that merely rinsing the mouth out with a sugar solution (without effecting blood glucose) can influence physical endurance performance (e.g. Hawkins, Krishnan, Ringos, Garcia & Cooper, 2017).

Furthermore, it has been demonstrated that being exposed to a sports drink (without consuming it) can lead to greater persistence on physical tasks (Friedman & Elliot, 2008). This suggests that factors, other than the sugar content, could contribute to improved physical performance. Merely anticipating certain effects from consuming sugar (e.g. improved physical performance, reduced tiredness, increased energy, etc.) may lead to improved performance (Kirsch, 1997). Indeed, research suggests that ergogenic actions are nearly always accompanied by cognitive expectancies established through prior experience and/or knowledge (Corsini, 1994). Under such mild physical task conditions, where glucose resources are not sufficiently depleted, psychological factors may be particularly important in influencing physical performance and perceived energy following consumption and should be considered in research.

1.3.2.2 Subjective energy

The knowledge that sugar is a source of energy, by most people in the population, will lead to the assumption that consuming sugar will enhance energy. The fact that sugary drinks are heavily marketed as providing an energy boost has encouraged this view. In fact, any suggestion that the intake of sugar, and the associated increase in blood glucose, is associated with a ‘sugar rush’, has gained mixed support from the literature. Some studies report an initial increase in subjective energy in line with the fact sugar is associated with a perceived ‘sugar-rush’ by some individuals. For example, Blouin et al. (1991) reported that there was a reduction in self-reported tiredness following injected sugar in healthy subjects. Furthermore, Thayer (1987) found that following consumption of a sugary snack there was an initial increase in subjective energy/reduced tiredness, however this was followed by a subsequent reduction in energy and increased tiredness. Problematically, these studies measure changes overtime and lack a placebo-control condition and so it is difficult to determine whether this short-lived increase in subjective energy is due to consuming sugar or the mere expectation that sugar will provide this ‘energy boost’.

In contrast, studies assessing subjective energy alongside a placebo-control condition have found that consuming a SSB has no significant effect on subjective energy above that of the placebo sugar-free beverage (Benton & Owens, 1993; Scholey, Sunram-Lea, Greer, Elliot & Kennedy, 2009; Jones, Sunram-Lea & Wesnes, 2012; Green et al., 2001). Benton and Owen (1993) assessed ratings of energy prior to and between 15-30 minutes post-drink and found a significant increase in energy from pre to post-drink (irrespective of whether a SSB or placebo was consumed). This was replicated by Scholey et al. (2009) who found increased alertness from pre-drink to 20 minutes post-drink, and this continued to rise to 30 minutes post-drink following completion of a recognition memory task, irrespective of whether the beverage contained glucose or merely tasted sweet yet no calorific content (see also Jones et al., 2012). This suggests that the initial increase in subjective energy reported in previously mentioned studies (Blouin et al., 1990; Thayer, 1987) may actually be generated by expectations about sugar (i.e. a placebo effect) or in response to sweetness. Conversely, Green et al. (2001) reported an overall reduction in subjective energy from baseline, to 30 minutes post-drink, irrespective of beverage content. Although subjective energy was assessed following a cognitive test battery and there was no immediate post-drink measure (prior to the cognitive test battery). Thus, subjective energy is confounded by task performance and it cannot be determined if there was an increase prior to the tasks. It is possible that in these placebo control studies, participants in the placebo condition expected that they had also consumed sugar, and thus these changes in subjective energy are a result of differing expectancies held by the individuals. Problematically, these studies lack adequate control conditions to account for the potential influence of expectancy. Thus, future studies should utilise experimental designs which allow the contribution of both sugar effects and expectancies on changes in subjective energy to be assessed.

1.3.3. Appetitive motivational processes

The consumption of sugar may also influence appetitive motivational processes, such as craving and desire (wanting), which may underlie the consumption of these drinks. Currently, to the best of knowledge, no studies on SSBs exist, although other food-related research will be discussed to explore the potential influence of SSB consumption on appetitive motivational processes. Since craving is an intense desire to obtain a certain substance (in this case sugar), it would be expected that consumption of sugar would temporarily reduce sugar craving. Indeed, research suggests that consumption of chocolate can reduce self-reported chocolate craving. For example, Michener and Rosin (1993) found that compared to baseline, there were reductions in craving for chocolate immediately following consumption of milk or white chocolate, which were still evident 30 minutes later, although cocoa capsules did not significantly reduce craving. This suggests that craving was satisfied by sugar provided by the chocolate (but not cocoa capsule). Although, reduced craving may have resulted from satisfaction of an innate desire for ‘sweetness’ or purely the sensation of eating provided by the chocolate (but not cocoa capsule as this was swallowed).

In addition to self-report measures of craving, indirect measures such as sensory specific satiety, also provide insight into the potential influence of SSBs on appetitive motivational processes. These studies demonstrate that exposure to a particular sensory attribute (e.g. sweetness) can lead to reductions preference and intake of foods and beverages with the same attribute relative to another (Griffioen-Roosen Hofenkamp, Mars, Finlayson, & de Graaf, 2012). In one study, Haversmans, Jassen, Giesen, Roefs and Jansen (2009) demonstrated that participants showed less motivation (i.e. wanting) to obtain the chocolate milk than crisps (significantly lower responses for chocolate milk points than for crisp points) following consumption of chocolate milk. In line with this, Brunstrom and Mitchell (2006) reported a decrease in subjective ratings of both desire to eat and pleasantness of cakes following consumption of the cakes. This suggests that consumption of a SSB may reduce the desire to consume subsequent sweet foods and beverages (i.e. sugar craving).

SSB consumption may also influence implicit appetitive motivational processes, such as attentional bias (AB), which may also underlie motivation to consume SSBs. Indeed, Field et al. (2016) proposed that AB fluctuates in line with motivational state (e.g. craving, hunger etc). They suggested a reciprocal relationship between craving and AB, and thus it would be expected that a change in sugar craving would lead to corresponding change in AB for SSB-related cues. Indeed, there is evidence supporting the relationship between motivational state and AB, in that changes in motivational value is followed by a corresponding change in AB. For example, increased self-report craving is reportedly correlated with increased AB (e.g. Werthmann, Roefs, Nederkoorn & Jansen, 2013; Smeets, Roefs & Jansen, 2009). Furthermore, Kemps and Tiggemann (2009) demonstrated heightened attention to chocolate-related cues following a craving induction (24-hour abstinence + chocolate present during task) compared to a non-craving induction control. Similar findings were reported in a visual search paradigm with induced chocolate craving leading to increased distraction by chocolate images in chocoholics (i.e. high trait chocolate cravers) compared to controls (Smeets et al., 2009). Taken together, this suggests that SSB consumption may also result in changes in AB for SSBs, although currently no research exists utilising SSBs.

Notably, the aforementioned studies do not consider the role of expectancy. Indeed, merely expecting that sugar has been consumed could lead to changes in appetitive motivational processes. Indeed, reduced craving following milk and white chocolate, but not cocoa capsule reported above by Michener and Rosin (1993) may have occurred as a result of participants expectations about sugar, that are not associated with the cocoa capsule (e.g. sugar reduces craving). Alternatively, reduced craving may reflect satisfaction of a desire for sweetness provided by chocolate (but not cocoa), as opposed to sugar per se. If changes in motivational state are purely consequences of expectancy or satisfaction of a ‘sweetness’ craving, with no pharmacological effects of sugar, then this would suggest that, low-calorie diet beverages may be equally as effective in controlling sugar cravings. Currently, experimental designs do not utilise sufficient control conditions that allow isolation of what may be critical anticipated effects of sugar.

1.3.4. The fundamental problem with past experimental designs

The majority of the studies reported in this section utilise a standard-placebo controlled design which involves the comparison of a SSB (i.e. sugar effects + expectancy effects) with a placebo sugar-free beverage that they believe to contain sugar (i.e. expectancy effects only). This allows isolation of sugar effects and thus attributing any changes in cognitive/physical performance and subjective energy to the pharmacological effects of sugar. Problematically, in the real world the effects of sugar would involve a combination of both the pharmacological (sugar effects) and anticipated effects (expectancy effects) of sugar. From a psychological perspective, it is important to understand whether the anticipated effects of sugar contribute to changes in cognitive/physical performance and subjective energy. Given results from previous studies (e.g. Hawkins et al., 2017; Molden et al., 2012, Scholey et al., 2009) and mixed effects of sugar across measures, it is likely that the anticipated effect of sugar consumption play an important role in the gross effects of sugar. Problematically, the standard-placebo design lacks adequate control conditions to allow isolation of these anticipated effects.

The balanced placebo design been utilised widely across drug-related research (e.g. alcohol; Marlatt & Rohsenow, 1981, nicotine; Sutton, 1991), allowing isolation of the pharmacological and anticipated effects of the substance, but also of interactions which may occur between pharmacological and anticipated effects (see section 2.1 for more on balanced placebo design). When determining the pharmacological and anticipated effects of sugar utilising this design, the beverage content (sugar, sugar-free) and expected content (sugar, sugar-free) would be manipulated to create four conditions; 1) receive sugar, expect sugar, 2) receive placebo, expect sugar, 3) receive sugar, expect placebo,4) receive placebo, expect placebo. Table 1.1 depicts how the pharmacological and expectancy effects of sugar are teased apart in the balanced placebo design.

Table 1.1 – Table depicting the four conditions in a balanced placebo design. Half of the participants would consume a SSB and the other half a placebo sugar (sugar-free) beverage. Of these, half would be told that they are receiving a SSB and half told that it is sugar-free.

		Received	
		Sugar	Sugar-free (Placebo)
Told	Sugar	1 Pharmacological + Expectancy effects	2 Expectancy effects only
	Sugar-free (Placebo)	3 Pharmacological effects only	4 No pharmacological or expectancy effects

1.4 Expectancy Theory

Expectancies are the anticipation of one's own automatic reactions to various situations and behaviours (in the case of the current thesis, the anticipated consequences of consuming SSBs) (Kirsch, 1997). For example, an individual may expect to feel more alert after consuming a cup of coffee or a sugary drink, to experience less pain after taking painkillers, or more light-headed after consuming an alcoholic beverage. Social learning theory argues that such expectancies form through a process of classical conditioning (Kirsch, 1985). In this way, through verbal information, direct personal experiences, and social observation (modelling), individuals would form associations between a specific action and the following outcome, and this can lead to the development of positive and negative expectancies.

The concept of response expectancy lies behind the placebo effect (Kirsch, 1999). Indeed, expectancy theory argues that conditioning produces response expectancies (anticipated effects), and it is these expectancies that produce the placebo effect; thus, placebo effects induced by classical conditioning are mediated by expectancy (Kirsch et al., 2014; Montgomery & Kirsch, 1997). Response expectancy is supported by the fact both behavioural and subjective responses can be altered by changing people’s expectancies (see section 1.4.3). Anticipated effects represent an important consideration in the current thesis, as they have been found to influence behaviour in a wide range of fields including; pain, depression, anxiety, alcohol, sports drinks, etc. However, there is currently limited research exploring the contribution of anticipated effects to the behavioural effects of sugar. The following section will discuss the development of outcome expectancies and their influence on behaviour across a range of fields.

1.4.1 Development of outcome expectancies

Research suggests that peer/parental influence may play an important role in the development of outcome expectancies. Much of the evidence for this comes from research exploring the development of positive alcohol-related outcome expectancies. For example, Martino, Collins, Ellickson, Schell and McCaffrey (2006) found that peer and parental alcohol use was consistently related to the development of alcohol outcome expectancies in adolescents. Adolescents with greater exposure to pro-drinking peer and adult influences had more positive beliefs about alcohol (similar findings reported by Cumsille, Sayer & Graham, 2000). In line with this, children of parents who misuse alcohol hold more favourable alcohol outcome expectancies than children of parents who do not misuse alcohol (e.g. Sher, Walitzer, Wood & Brent, 1991; Brown, Tate, Vik, Haas & Aarons, 1999). Although, no research exists on expectancies in the case of SSBs, social influence variables (e.g. parental modelling; advertisements) have been found to be associated with SSB intake (e.g. van de Gaar, van Grieken, Jansen & Raat, 2017; Bere, Glomnes, te Velde & Klepp, 2007; Powell, Wada, Khan & Emery, 2017) which may be due to the development of more positive beliefs about these drinks. For example, being around other family members/peers who enjoy SSBs is likely to lead to the generation of positive expectancies (e.g. SSBs are hydrating) however, being around those who avoid consuming these drinks would lead to more negative expectancies about the consumption of these drinks

Furthermore, research has demonstrated the importance of advertisements in the development of positive outcome expectancies with studies linking exposure to portrayals of alcohol use in the mass media with the development of positive drinking expectancies in children and adolescents (Austin & Knaus, 2000; Austin, Pinkleton & Fujioka, 2000). TV advertisement which publicize unhealthy foods/drinks in a positive light would also lead to the generation of positive SSB-related outcome expectancies. For example, SSB companies often sponsor major sporting events and are endorsed by athletes (see Bragg et al., 2013). Furthermore, SSBs (particularly sports and energy drinks) are heavily marketed to reduce fatigue and improve sports performance. Through social learning individuals would associate these drinks with an active lifestyle and positive outcomes such as improved physical performance and increased energy.

1.4.2. Expectancies and participation in unhealthy behaviour.

Expected outcomes are considered when choosing a course of action (Kirsch, 1997) and have been found to be predictive of whether individuals participate in unhealthy behaviours. For example, negative expectancies (e.g. impaired cognitive performance) are suggested to reduce unhealthy behaviours, whereas positive expectancies are suggested to drive the uptake and maintenance of unhealthy behaviours. These expectancies vary across individuals and research suggests that they can explain variability in behaviours, such as, alcohol consumption (Gustafson, 1993; Leigh, 1989; McKay, Sumnall, Goudie, Field & Cole, 2011), smoking (Van der Plight & de Vries, 1998), and unhealthy diet choices (Reid, Bunting & Hammersley, 2005).

In relation to alcohol consumption, numerous studies have demonstrated that positive outcome expectancies (e.g. increased sociability, relaxation/tension reduction) are associated with increased quantity of alcohol consumption, whereas negative expectancies (e.g. hangover) are associated with reduced quantity of alcohol consumption (Fromme & D’Amico, 2000; Leigh & Stacy, 1993). Indeed, expectancies are consistently, and more strongly, associated with quantity than with frequency of drinking; this finding is robust among adolescents (Chen, Grube &

Madden, 1994; Fromme & D'Amico, 2000), college students (Mooney, Fromme, Kivlahan & Marlatt, 1987; Carey, 1995) and community samples (McMahon, Jones & O'Donnell, 1994; Lee, Greeley & Oei, 1999). Some researchers report that immediate positive expectancies are more strongly associated with drinking behaviour than long-term negative expectancies (e.g. Rohsenow, 1983; Christiansen & Goldman, 1983; Leigh & Stacy, 1993).

There is also evidence that outcome expectancies are predictive of self-reported diet. For example, Reid et al. (2005) had participants complete a food expectancy questionnaire which included both short-term (e.g. I would enjoy the taste, I feel alert) and long-term expectancies (e.g. I would gain weight). They found that chocolate/sweet consumption was related to expected positive outcomes such as feeling relaxed, rewarded, and comforted, but also more guilt about health and expected hunger. An important finding was that long-term negative expectancies were less predictive of diet, than short-term positive expectancies. For instance, in the case of sweets and chocolate, guilt about health (e.g. weight gain, dental problems) accounted for only 3% of variance in intake compared to 10% for expected short-term positive outcomes (e.g. feeling relaxed, rewarded, etc). Another study reported that subjects who expected fried breakfasts to be more relaxing also consumed them more often, despite explicit knowledge of long-term negative effects on health (Reid & Hammersley, 2001). Taken together, there is evidence that outcome expectancies can influence diet choices and lead to unhealthy food choice decisions, and that short-term positive expectancies are stronger influences of these food choices.

In case of SSB expectancies there is limited research, however, evidence does suggest that expectancies may be important influences on consumption. For example, Tuorila, Pangborn and Schutz (1990) found that the consumers of SSBs expected more positive effects from SSBs than diet beverage users or non-users (who consume neither SSB or diet). For example, SSB users believed SSBs were more thirst quenching, were less likely to cause weight gain and provided quick energy. More recently, Su (2012) found that SSB consumption was predicted by individual's outcome expectancies; positive expectancies were associated with greater consumption whereas negative expectancies were associated with lower consumption, although this study was not specific about the nature of the expectancies (e.g. if they were long-term, short-term etc). Thus, despite emphasis from health professionals that SSBs have negative health effects and are associated with weight gain in the long term, if people begin to associate these unhealthy behaviours with positive outcomes in the short-term this may override the long-term consequences and influence people’s decision to consume these drinks.

Taken together, this section highlights the importance of the anticipated consequences of our behaviour influencing the decision to participate in these unhealthy behaviours. Currently, there is limited research exploring the role of expectancies in relation to SSB consumption, but it is possible that they may serve as one mechanism underlying the consumption of these beverages.

1.4.3. The influence of expectancies on behaviour

According to response expectancy theory, individuals respond in accordance with what they expect to happen (Kirsch, 1985). Expectancies have been found to influence behaviour across a wide range of fields including in the case of placebo analgesia, placebo alcohol, placebo caffeine, and placebo antidepressants, etc. Research investigating the influence of expectancy on behavior across a range of fields will be discussed in this section (1.4.3). In the subsections that follow (1.4.3.1, 1.4.3.2, 1.4.3.3, 1.4.3.4), research investigating response expectancy on behaviours specifically related to the current thesis (e.g. cognitive performance, physical endurance, and subjective measures, appetitive motivational processes) will be discussed.

Placebo effects have become a critical issue for the development of novel therapeutics and treatment of patients in clinical settings. They complicate efforts to detect efficacy of new treatments in the drug development industry (e.g. painkillers, antidepressants). In many cases, placebo responses appear to be mediated by expectancy (see Wager et al., 2004). Placebo analgesia is one of the most robust and best studied placebo effects (Hoffman, Harrington & Fields, 2005). The deceptive administration of a placebo treatment can lead subjects to believe that the treatment is effective (Kirsch & Weixel, 1988; Kirsch, 1999). In this situation, the expectation of analgesia leads to a significant placebo analgesic effect (Pollo et al., 2001; Amanzio & Benedetti, 1999). This was demonstrated by Pollo et al. (2001) who treated patients with buprenorphine for three consecutive days, alongside a basal intravenous infusion of saline solution. Verbal instructions about the basal solution were changed in three different groups of patients; the first group were told nothing about the analgesic effects (control group), the second group that it was either a potent painkiller or placebo (double-blind administration), and the third group were told that the basal solution was a potent painkiller (deceptive administration). Results indicated that the there was a reduction in requests for buprenorphine in the double-blind compared to control group, however there was a larger reduction in requests for buprenorphine for those in the deceptive administration group, thus demonstrating that increased expectation of receiving analgesia led to a greater reduction in pain.

Furthermore, research suggests that verbal instructions about the effects of the painkiller can alter analgesic effects. For example, Benedetti et al. (2003) timed how long participants could squeeze a hand grip (measure of pain tolerance) after receiving a saline solution. On day one, no information about the analgesic effects were given. However, on day two, one group was told that the saline solution was a powerful painkiller, and the other group that it was a drug that would increase pain. In line with their expectations, there was a reduction in pain tolerance in those told that they were receiving a drug that would increase pain, and increased pain tolerance in those told they were receiving a powerful painkiller, thus suggesting that analgesic responses were mediated by expectancies. Verbally induced expectations can be reinforced through manipulations in which a placebo treatment is paired with reduced pain intensities so that subjects come to experience analgesia which thereby enhances their expectations of future pain relief. This procedure typically evokes much stronger and more stable placebo analgesic effects compared to verbally induced effects (Collaca & Benedetti, 2006; Klinger, Soost, Flor & Worm, 2007), demonstrating how direct experience of analgesic effects can further reinforce these expectancies and strengthen their effects on behaviour. Expectations of analgesia can also be acquired through social learning. For example, Colloca and Benedetti (2009) showed that substantial placebo analgesic responses were present after observing a benefit in another person undergoing an analgesic treatment. Indeed, placebo analgesic effects following the observation of a beneficial effect in another person were similar in magnitude to those induced by directly experiencing the benefit through a conditioning procedure.

Expectancies have also been found to be important in the therapeutic effects of antidepressants. A meta-analysis of conventional double-blind studies (involving comparison of antidepressant drug versus placebo) indicated that 25% of the response to antidepressants is due to the passing of time, 50% due to expectancy, and only 25% due to the pharmacological effects of the drug (Kirsch & Sapirstein, 1998). This was replicated by Kirsch, Moore, Scoboria and Nicholls (2002) using data from the Food and Drug Administration. They found that 42% of trials showed a benefit of drug over placebo, however the placebo response represented 82% of this response to anti-depressants, demonstrating that merely expecting that the drug had been consumed accounted for a large portion of the therapeutic effect.

The importance of expectancy in the efficacy of antidepressant medication has been experimentally demonstrated by Rutherford et al. (2017). They manipulated expectancy through instructions provided to participants about the probability of receiving active treatment versus placebo. One group was told that they were allocated to open trial antidepressant (100% chance of receiving active drug) and another that they were randomised to a placebo-controlled antidepressant (50% chance of receiving active treatment). Participant expectation regarding the efficacy of their treatment was assessed post randomization (i.e. beliefs about whether depressive symptoms will reduce). They found that those randomised to the open trial antidepressant had greater improvement in depressive symptoms than those assigned to the placebo-controlled antidepressant, however this was mediated by patient expectancy. Importantly, despite receiving identical antidepressant treatment, depressed subjects who knew they were receiving citalopram improved on average six points more on the Hamilton Rating Scale for Depression than subjects receiving citalopram who were aware they had a chance of receiving placebo, demonstrating the powerful influence of expectancy-based placebo effects on depressive symptoms.

1.4.3.1. Expectancies and cognitive performance

Placebo effects and expectancy have been found to influence cognitive performance following administration of a range of substances (e.g. alcohol, caffeine, ‘cognitive enhancing’ pills, etc.). In the case of alcohol, it is well established that alcohol consumption can impair cognitive function (Fillmore, 2007), however research suggests that this response to alcohol may be mediated by expectation of alcohol and expected impairment. Indeed, there are individual differences in response to alcohol (some individuals have a larger degree of impairment than others) and research suggests that this variability may occur due to different expectations held amongst individuals. For example, Fillmore and Vogel-Sprott (1995) asked participants to rate the level of cognitive impairment they expected from a moderate dose of alcohol. They then completed a motor skills task following a moderate dose of alcohol in one session and a placebo beverage (in which they expected alcohol) in another session. Results indicated that participants who expected greater impairment displayed poorer performance following both alcohol and placebo. A similar expectancy-performance relationship was reported by Fillmore et al. (1998) in an information processing task following alcohol and placebo alcohol, and by Christiansen, Jennings and Rose (2010) in an inhibitory control task following placebo-alcohol. However, in both studies, no expectancy-performance relationship was found in a control group (whom neither expected alcohol nor received alcohol). The importance of placebo expectancy effects was further demonstrated by Gilbertsen, Prathers and Nixon (2010) who found that placebo effectiveness (believing alcohol was consumed) influenced cognitive performance in moderate drinkers. Specifically, those who received placebo but reported that they received alcohol demonstrated impaired reaction times on an attentional processing task similar to those receiving alcohol. Although, some studies have reported that the anticipated effects of alcohol have no effect on verbal fluency (controlled oral word association task; Christiansen, Rose, Cole & Field, 2013) or performance in a battery of neuropsychological tasks (Petersen, Rothfleisch, Zelazo & Pihl, 1990), suggesting that some tasks may be more sensitive to the anticipated effects of alcohol. Taken together, the balance of research suggests that expectancies regarding alcohol’s effects play an important role in the behavioural response to alcohol.

Caffeine-related expectancies have also been found to be an important influence on cognitive performance following caffeine (Shabir, Hooton, Tallis & Higgins, 2018). Two studies directly manipulated caffeine performance expectancies and found that performance was consistent with expected effects of caffeine. In the first study, Fillmore and Vogel-Sprott (1992) assigned participants to one of four conditions. Three groups received a placebo caffeine beverage (believed to contain caffeine) with different information about the effects of caffeine; one group was told that caffeine would impair performance, another that it would improve performance and the other received no information about the effects of caffeine. A control group received no drink or information. They found that those expecting enhanced performance displayed greater improvement under placebo caffeine, however those expecting impairment displayed poorer performance following placebo caffeine in a pursuit rotor task. Although, placebo-caffeine had no effect on performance in those who received no information about the beverage (all compared to control). Consistent findings were reported by Fillmore and Vogel-Sprott (1994) who found that, in comparison to placebo, caffeine improved psychomotor performance, but both groups performance was predicted by their expectations. Those who expected most improvement, improved the most in the psychomotor task, suggesting that individual differences in cognitive performance following caffeine consumption may be due to individuals' expectations. In contrast, another study suggested that expectancies may sometimes result in compensatory responses. Harrell and Juliano (2009) provided participants with either a caffeine or placebo-caffeine beverage, and they were told that it would either impair or improve performance. They found improved performance on a sustained attention and finger tapping task following caffeine, relative to placebo. In the placebo condition, participants who expected impairment performed better in the sustained attention task than those who expected improvement, however, performance in the finger tapping task was not influenced by expectancy suggesting that some tasks may be more sensitive to expectancy effects. Taken together, findings suggest that expectancies can influence performance following caffeine, and thus are an important factor to consider when attempting to isolate the pharmacological effects of caffeine.

The importance of anticipated effects in influencing cognitive performance has been further demonstrated across a number of other studies. Kvavilashvili and Ellis (1997) investigated the effects a sugar pill which participants were told would improve performance or impair performance on a delayed recall task. They found that those anticipating impaired performance remembered fewer words and had lower accuracy scores on the delayed recall task compared to the control group (received no pill), however recall performance of those expecting improved performance did not differ from the control. In contrast, Parker, Garry, Einstein and McDaniel (2011) found that participants anticipating a ‘memory enhancing’ drug performed better on a prospective memory task than those who anticipated a placebo, demonstrating that the anticipated effects can influence performance even with substances which participants would have no previous experience. In another study, Cropsey et al. (2017) utilised a balanced placebo design to isolate the pharmacological and anticipated effects of mixed amphetamine salts on a battery of cognitive tasks (including measures of verbal fluency, inhibitory control, sustained attention, etc.) in college students. They found that amphetamine administration led to improvement on only 2 of 31 cognitive measures. However, expecting they had consumed amphetamine (regardless of what was administered) led to the most robust improvements on cognitive outcomes, but expecting placebo led to worse performance across a range of tasks. This demonstrates the importance of beliefs in influencing cognitive performance. Merely expecting a certain substance to improved/impair performance can alter cognitive performance, and thus the combined influence of pharmacological and expectancy effects should be accounted for in research exploring the effects of substances on cognition.

In the case of the current thesis, of particular importance is the contribution of sugar-related expectancies to cognitive performance following consumption of a SSB. It is commonly believed that SSBs provide energy, and thus may be used by some individuals as an aid to improve cognitive performance. Indeed, expectancies about the effects of SSBs on cognitive performance may mediate the pharmacological effects of sugar on cognitive tasks. As previously reviewed (section 1.3.1), the effects of a sugary beverage on cognitive performance have produced mixed findings, and one reason for this may be due to differing expectancies held by individuals.

Limited research in this area accounts for the role of expectancy effects, and currently there are only two studies that have utilised a balanced placebo design to manipulate the pharmacological and anticipated effects of sugar, to examine the contribution of each (Green et al., 2001; Stollery & Christian, 2013). In the former study, glucose produced faster access to words in an immediate recognition task. Glucose also improved performance in a sustained attention (Bakan) task but only in those who received the drink congruent message (told received glucose). However, there was no effect of drink or expectancy on immediate free recall or a finger tapping task. In the latter study, glucose improved performance on a delayed recall task, but not on immediate recall, category verification or a spatial location task. Some effects of message were reported; in the category verification task those ‘told glucose’ responded more slowly than those ‘told diet’ and in the spatial location task those receiving a glucose beverage with a glucose congruent message (told glucose) showed a slower decline in accuracy as memory load increased.
However, Stollery & Christian (2013) acknowledged that beliefs participants form about the drink content (whether it contains glucose or not) may not always coincide with the message given and in turn expectancy effects may derive from these beliefs. They also found that believing glucose had been consumed (regardless of the beverage content) independently improved episodic memory (although immediate recall was unaffected) and impaired semantic memory. In addition, in the spatial recognition task, those who consumed a glucose beverage were faster at recognising a valid location, but not rejecting an invalid location, however, this was only true for those who believed they had received placebo. Thus, believing they had received glucose seemed to mask this effect. One explanation for this is that those whose expected glucose put less effort into the task or those who expected placebo increased effort (for compensatory responses see Fillmore & Vogel-Sprott, 1996; Fillmore et al., 1994; Fillmore & Blackburn, 2002). Taken together, although research in this area is limited (see Bellisle, 2001), results suggest the potential importance of sugar and expectancies on cognitive performance, although there is a

need for further research utilising fully balanced placebo designs across different cognitive domains and tasks.

1.4.3.2. The influence of expectancies on physical performance.

During sports related activities, both athletes and non-athletes use performance-enhancing substances in an attempt to improve performance, however there is controversy over how much of this beneficial effect can be attributable to the pharmacological effects. It is suggested that any ergogenic actions are nearly always accompanied by cognitive expectancies established through prior knowledge and/or experience (Corsini, 1994). For example, through experience with certain substances (e.g. steroids, caffeine, sugar) individuals may form expectations that these substances can improve physical performance or increase energy. These expectancies alone can impact on behaviour, and thus it is important to explore the role of both pharmacological and expectancy contributions of any sports aid. Indeed, expectancies have been found to play an important role in the success of treatments in sports related activity (e.g. Kalasountas, Reid & Fitzpatrick, 2007; Maganaris, Collins & Sharp, 2000; Ariel & Saville, 1972).

In the area of strength training, improved performance has been demonstrated following placebo steroids in which participants are provided with false information about a known ergogenic aid. For example, Kalasountas et al. (2007) provided college students with a placebo pill (believed to improve maximal force production) and found that compared to a control group, placebo increased force production on a leg and bench press exercise. However, disclosure of true nature of the placebo led to a reduction in force production to levels approximating the control group. Similar findings were reported by Maganaris et al. (2000) in professional power lifters (knowledgeable about the effects of anabolic steroids) on a number of tasks (bench press, squat and deadlift). In the first session, participants were administered a placebo-steroid and informed it was a powerful anabolic steroid, however during the second session the true nature of the drug was disclosed to half of the participants. They found that expecting an anabolic steroid led to improved performance relative to baseline across all three tasks, however when the true nature of the placebo was revealed performance did not differ from baseline. In line with these results, Ariel and Saville (1972) demonstrated that administration of placebo-steroid resulted in greater strength gain than during the pre-placebo period, demonstrating the power of expectancies in influencing strength performance.

The contribution of expectancy to physical performance has been further demonstrated across a number of studies in students and athletes. For example, investigating the effects of placebo caffeine on motor performance in college students, Kirsch and Weixel (1988) demonstrated that performance was dependent on beliefs about the efficacy of caffeine. Individuals who expected caffeine to impede performance showed a subsequent drop in performance, however those expecting enhancement showed an improvement. Using a more intense physical task, Pollo, Carlino and Benedetti (2008) explored the effect of placebo caffeine on quadriceps muscle endurance in students and found that placebo caffeine led to an increase in leg extensions that was not accompanied by a decrease in muscle fatigue. The importance of positive and negative expectancies has also been demonstrated using intense physical measures in athletes. For example, Beedie, Coleman and Foad (2007) provided one group with positive information and another group with negative information about the effects of a pill on running performance. They found that during baseline trials there was a progressive decrease in sprint speed in both groups, however, across successive experimental trials, the negative-belief group showed a continued reduction in speed, but the positive-belief group showed increased sprint speed following placebo administration. Taken together, these studies demonstrate the importance of both positive and negative expectancies across a range of physical and endurance tasks.

Of particular importance is the contribution of the pharmacological and expectancy effects of a substance, both combined and in isolation to physical performance. This is best obtained through use of the balanced placebo design (Marlatt & Rohsenow, 1980) which involves manipulation of the actual content and expected content of the substance to create four conditions. To the best of knowledge, currently there are only three studies in this area that have utilised this design and explored potential interactions that may exist between pharmacological and anticipated effects

(McClung & Collins, 2007; Clark, Hopkins, Hawley & Burke, 2000; Foad, Beedie & Coleman, 2008). McClung and Collins (2007) explored the pharmacological and anticipated effects of sodium bicarbonate on 1000m time trial performance. Results indicated that although receiving the drug (and expecting drug) produced the fastest time, those who expected the drug (but received no drug; the isolated psychological effect) produced a significantly better average performance than the purely pharmacological impact of the bicarbonate (those who expected placebo but received drug). Indeed, consuming the substance without expectancy (pure pharmacological effects) did not influence performance, demonstrating how individual's beliefs about the effects of the substance can influence the effectiveness of the sports aid. In another study, Clark et al. (2000) explored the pharmacological and anticipated effects of a carbohydrate supplement on 40km cycling performance. They found a 4% enhancement in mean power relative to baseline for those told they were consuming a carbohydrate compared to a 0.5% increase in mean power for those told they were consuming a placebo beverage (regardless of the content they consumed), however the effects of carbohydrate were negligible. However, contrary to previous reported studies, Foad et al. (2008) found that expecting caffeine added no substantial benefit to cycling performance following caffeine. Notably, caffeine exerted the greatest effect on performance when participants expected no caffeine. One possible explanation for this is that participants put more effort into the task when they believed no caffeine was consumed. Furthermore, belief exerted a greater influence on performance in the absence of caffeine. Taken together, this indicates that the pharmacological effects of several substances on physical performance are influenced by individuals' expectancies, and thus suggests the importance of isolating both the pharmacological and anticipated effects in such research.

The majority of research exploring expectations and placebos in sport performance has used athletes, however due to the widespread use of sports aids it is important to explore potential placebo-induced changes in non-athletes as well. Particularly, in the case of the current thesis, expectancies may play an important role in influencing performance following consumption of an SSB which are used by both athletes and non-athletes (e.g. college students). Indeed, SSBs contain high quantities of sugar which is widely recognised as providing fuel for the body, and thus associated with increased energy. Furthermore, SSBs (particularly sports and energy drinks) are heavily marketed as providing an energy boost and improving physical performance. Indeed, Costa et al. (2014) found that individuals aged between 12 to 15 years, reported consuming energy drinks for their stimulant effects and believed these beverages to provide a quick fix to their problem of tiredness. Similarly, O'Dea (2003) reported that, in 11 to 18 year olds, energy and sports drink were consumed for their energizing properties, to provide a 'buzz' and also alongside sports as stimulants and ergogenic aids. Sports drinks were also perceived to improve sports performance and to provide energy. It is possible that individuals' expectations could influence physical performance following consumption of a SSB. Problematically, current studies, reviewed in section 1.3.2, do not consider the anticipated effects of sugar, and thus any changes in performance are attributed to the pharmacological effects of sugar. Therefore, it is important for further research to utilise balanced placebo designs to allow isolation of both pharmacological and anticipated effects.

1.4.2.3. The influence of expectancies on subjective measures.

There is a large body of research to suggest that individuals' beliefs about the effects of consuming certain substances can influence their responses on self-report rating scales (e.g. pain, arousal). Indeed, according to expectancy theory individual's respond in accordance with what they expect to happen (e.g. Kirsch, 1985), and thus if individual's consume substances that they associate with altered subjective effects (e.g. decreased pain, increased alertness), they would respond in accordance. As a result, expectancies are an important consideration in research and may mediate the effects of certain substances on subjective measures. The current section will review research investigating the effects of expectancies across a range of subjective measures.

There is evidence to suggest that expectations are a key factor influencing the effects of analgesic drugs on the subjective experience of pain. For example, Bingel et al. (2011) demonstrated that individual's beliefs about whether they received the painkiller (remifentanil) altered subsequent pain ratings. Remifentanil was administered under three consecutive conditions during constant heat pain; no expectancy (received drug but were not aware), positive expectancy (expected drug) and negative expectancy (expected no drug; told infusion had stopped). They found that positive expectancy doubled the benefit of the opioid, however negative expectancy (expecting no drug) abolished its analgesic effect, demonstrating that merely expecting the drug can alter the efficacy of the drug given. These changes in reported analgesia with different expectancies are accompanied by significant changes of activation in core regions of the pain and opioid-sensitive brain networks, such as the thalamus, the MCC, and the primary somatosensory cortex, demonstrating that self-reported changes in pain were not due to reporting bias. Problematically, this study did not utilise a placebo control condition so could not explore potential interactions between drug effects and expectancy. Utilising a balanced placebo design, Atlas et al. (2012) found that both remifentanil and expectancy can reduce heat pain ratings, however there was no interaction between the two. In contrast, Schenk, Sprenger, Geuter and Buchel (2014) reported that another painkiller (lidocaine) reduced pain ratings (capsaicin pre-treated skin), and that this reduction was greater in those who expected lidocaine than those who expected no treatment. This demonstrates that under some circumstances expectancies may interact with the effects of the drug to further increase the analgesic effect, although differences in results between the two study may reflect the different treatment administered.

Expectancies have also been found to be important influences on self-report responses following nicotine. For example, Kelemen and Kajghobadi (2007) used a balanced placebo design to explore both pharmacological and expectancy effects of nicotine across a number of subjective measures. They reported that although pharmacological effects played a stronger role across the majority of self-report measures (including craving, nausea, dizziness etc), merely expecting nicotine produced changes in ratings of increased wakefulness, calming, concentration, cigarette satisfaction and hunger reduction, although there were no significant interactions between nicotine and expectancy. In another study, Juliano and Brandon (2002) investigated the effects of nicotine and expectancy on subjective effects of smoking, following a three-hour abstinence. After anxious mood induction, they found that nicotine administration produced a greater reduction in self-reported anxiety compared to a de-nicotinized cigarette. However, merely expecting nicotine also reduced anxiety, but only in those who held the belief that nicotine reduces anxiety, suggesting that nicotine expectancy effects were moderated by the expected effects of nicotine on anxiety. Furthermore, placebo nicotine produced comparable reductions in urge to smoke as did nicotine, but only in those who expected they had consumed nicotine (see also Gottlieb et al., 1987 for the importance of expectancies on reported symptoms of withdrawal). Taken together, these findings suggest that in some cases, nicotine related outcome expectancies can influence the subjective effects of smoking (regardless of whether nicotine or placebo is administered).

Placebo-caffeine has been found to influence the subjective effects of caffeine. This was demonstrated by Mills, Boakes and Colagiuri (2016) who reported that, in abstinent coffee drinkers, placebo caffeine led to a greater reduction in self-reported craving, fatigue, lack of alertness and flu-like symptoms in those who expected caffeine than those who expected decaffeinated coffee. Similar findings were reported by Kirsch and Weixel (1988) in abstinent coffee drinkers. Those who believe they have consumed caffeine reported feeling more alert and tense following placebo coffee, compared to a no-beverage control condition and this expectancy effect was greatest in those who believed they had consumed a moderate dose, than a low or high dose. Similar findings have also been reported in non-abstinent coffee drinkers (e.g. Schneider et al., 2006). Addressing potential interactions that may exist between coffee and expectancy, Mikalsen, Bertelsen and Flaten (2001) utilised a modified balanced placebo design and reported that caffeine increased self-reported contentedness (relative to baseline) but only when participants were told that the drink contained caffeine, and therefore research should address potential interactions that may exist between substance effect and expectancies held by the individual.

Taken together, studies provide evidence for the influence of expectancy effects on subjective measures, in that participants tend to respond in accordance with their expectations. In studies that fail to account for expectancies, it is possible that changes in subjective effects, that have been attributed to the pharmacological effects of the substance are, in part, due to expectancies. Thus, research should account for expectancies when exploring the pharmacological effects of a substance.

Addressing the current thesis, it is believed by some people in the population that the consumption of sugar is associated with a ‘sugar rush’ (e.g. increased energy, reduced tiredness, etc). These beliefs may influence subjective measures following consumption of a SSB. Although limited research exists, studies reported in section 1.3.2.2 show that SSBs have produced mixed effects on subjective energy (report increased energy, reduced energy and no effect) and expectancies may be one factor contributing to this. Thus, to explore this, studies are required that utilise an experimental design (balanced placebo) that allows isolation of both the pharmacological and anticipated effects of sugar, as well as interactions that may exist between the two.

1.4.2.4 The influence of expectancies on appetitive motivational processes

Expectancy effects have been found to influence explicit appetitive motivational processes (e.g. craving, desire), which may underlie unhealthy food/beverage consumption behaviours, although this is currently understudied. The current section will review research with several substances (e.g. alcohol, nicotine, caffeine) to demonstrate the importance of accounting for expectancy effects when exploring underlying appetitive motivational processes.

A priming dose of alcohol has been found influence a number of appetitive motivational processes of alcohol seeking, including both subjective (e.g. craving, desire) and objective (e.g. AB, approach responses) measures (e.g. Schoenmakers, Wiers & Field, 2008; Fernie, Christiansen, Cole, Rose & Field, 2012; Rose & Grunsell, 2008; Christiansen et al., 2013), with these effects attributed to the pharmacological effects of alcohol. However, a meta-analysis by Hull and Bond (1986) reported that increased desire for alcohol was a result of the anticipated rather than pharmacological effects of alcohol. Indeed, using a balanced placebo design Marlatt, Demming and Reid (1973) demonstrated that expectancy was a significant determinant of how much participants drank following a priming dose of alcohol rather than the actual drink they consumed. Those told that they were consuming alcohol (regardless of the drink content) subsequently consumed more alcohol, thus suggesting that the importance of the anticipated effects of alcohol on appetitive motivational processes following alcohol consumption. In line with this, a number of studies have demonstrated increased craving and ad lib consumption, but also automatic approach responses following both priming doses of alcohol and placebo-alcohol (e.g. Christiansen et al.,2016; Christiansen et al., 2013; Christiansen, Townsend, Knibb & Field, 2017). Thus, in the real world the influence of alcohol on appetitive motivational processes is a combination of both the pharmacological and anticipated effects.

There is also evidence from nicotine studies that expectancies influence explicit motivational processes (e.g. craving and desire). This has been demonstrated across a number of studies using the balanced placebo design. For example, Juliano and Brandon (2002) demonstrated that placebo-nicotine reduced craving and urge to smoke in those who expected nicotine but not those who expected de-nicotinized cigarettes, however expectancy had no effect on craving in those who consumed nicotine. In a further study, Schlagintweit, Good and Barett (2014) found that nicotine expectancy (regardless of whether nicotine was actually consumed) was effective in reducing withdrawal-related craving. Nicotine administration was also observed to reduce self-reported intentions to smoke; however, this was dependent on the expectation that nicotine had been administered. In contrast, Perkins et al. (2004) reported no anticipated effects of nicotine on cravings, although, they found high levels of disbelief in their deceptive conditions, and thus participants expectations may not be in line with instructions given. Expectancies have also been demonstrated to influence the desire to consume caffeine. For example, Mills et al. (2016) found that placebo caffeine led to a greater reduction in craving in abstinent drinkers who expected caffeinated coffee, but not those who expected decaffeinated, although limited research exists in this area. Taken together, this suggesting that the importance of non-pharmacological factors on craving and related measures have been demonstrated across a range of substances. In the real world, the effects of substances on appetitive motivational processes would be combination of both pharmacological and anticipated effects.

To the best of knowledge, no research investigates the influence of substance-related expectancy effects on AB. However, considering placebo-alcohol increases other implicit motivational processes (e.g. automatic approach responses; Christiansen et al., 2013), as well as craving which is reportedly closely related to AB (e.g. Field et al., 2016; Werthmann et al., 2013; Smeets et al., 2009), anticipated effects may also influence AB. In the case of the current thesis, there is currently no research which explores the influence of SSBs on appetitive motivational processes that may underlie consumption of these drinks, and thus this warrants further research. Notably, considering research presented in this section suggests the potential importance of expectancies on appetitive motivational processes across several substances, an experimental design that allows the isolation of both pharmacological and anticipated effects of sugar should be utilised.

1.5. Summary and aims of the thesis

To summarize, the preceding literature highlights a number of points. Firstly, within the framework of expectancy theory, through direct experience, observing other social models, and marketing techniques, individuals would come to expect certain effects from SSB consumption (e.g. improved cognitive/physical performance, hydration, increased energy, etc.) (Kirsch, 1985). There is evidence to suggest that these expectancies are considered when choosing a course of action and can influence a variety of behaviour's including, smoking, alcohol consumption, and diet choices, etc. Currently, limited research explores this idea with SSBs, although there is some evidence to suggest that consumers of these drinks come to expect certain outcomes from consuming SSBs (e.g.Tuorila et al., 1990; Su, 2012). Understanding the role of expectancies on SSB consumption may provide further understanding about the mechanisms underlying unhealthy food and beverage consumption, and aid with the development of strategies to reduce the consumption of these calorific beverages contributing to the obesity epidemic.

The preceding discussion also outlines the influence of SSBs on a variety of behaviours (e.g. cognition, physical endurance, subjective energy and underlying appetite motivational processes), although findings across these domains are mixed, and thus no firm conclusions about sugars effects can be made. Problematically, most previous studies utilise the standard-placebo design which isolates the pharmacological effects of sugar but does not account for the role of SSB-related expectancies. Indeed, in the real world the effects of sugar on behaviour would be a combination of both the pharmacological and anticipated effects of sugar. According to expectancy theory, expectancies can influence subjective and behavioural responses and there is a large body of evidence across a wide range of fields to support this (section 1.4). Therefore, expectancies may be responsible for some of the effects attributed to sugar which could explain the mixed findings. Thus, studies require adequate control conditions, through use of the balanced placebo design, which allows isolation of both pharmacological and anticipated effects.

The first aim of the thesis was to explore the influence of people’s beliefs about the short term effects of SSBs (anticipated effects) on SSB consumption (chapter three). Following on from findings in this study, the aim of the subsequent chapters of the thesis was to investigate whether the pharmacological effects of sugar are influenced by anticipated effects of sugar, but also to explore the anticipated effects of sugar in isolation. Studies in these sections examine the influence of pharmacological and anticipated effects of sugar across a range of behaviours including, physical endurance, cognitive performance and appetitive motivational processes. These aims are important for several reasons. Firstly, they will better our understanding of the contribution of expectancies to SSB consumption, which may inform future interventions to reduce SSB consumption. In regard to the second aim, isolating the influence of expectancy, will further understanding of the effects of sugar across several aspects of behaviours.

Chapter Three: This study involved the development of a scale to measure SSB-related outcome expectancies (focussed around expected changes in cognitive/physical performance, hydration, craving and mood). We examined the psychometric properties of the scale and the relationship between subscales and SSB consumption. To better understand the influence of differing beliefs on SSB consumption, we also compared subscale scores in high consumers (at risk of associated health issues, e.g. diabetes) and non-consumers.

The studies in the subsequent chapters utilised the balanced placebo design to investigate the influence of SSBs, whilst isolating the role of expectancies on several aspects of behaviour.

Chapter Four: This study investigated the pharmacological and anticipated effects of sugar, both combined and in isolation, on performance in physical endurance tasks (handgrip, leg-raise) and measures of subjective energy.

Chapter Five: This chapter includes two studies. Study 5.1 utilised the balanced placebo design to investigate the pharmacological and anticipated effects of sugar, both combined and in isolation, on cognitive performance and self-reported measures of energy in a natural environment. Cognitive performance was assessed across a range of tasks including the Controlled Oral word Association Task (COWAT; a measure of verbal fluency), the Stroop Task (a measure of inhibitory control) and memory recall (immediate and delayed word recall), while subjective energy was assessed with several self-report scales. Study 5.2 expanded on study 5.1 to further examine the role of expectancy on cognitive performance and subjective energy. Expectancy was manipulated using specific message manipulations with only a placebo-sugar beverage. The same cognitive tasks (apart from no memory recall in study 5.2 due to time constraints) and subjective measures were used across the two studies.

Chapter Six: This study investigated the pharmacological and anticipated effects of sugar, both combined and in isolation, on explicit and implicit automatic appetitive motivational processes (craving and attentional bias -AB) that may underlie SSB consumption.

Chapter Two:
General Methods

The balanced placebo design is used consistently throughout the studies in this thesis (apart from Chapter three), and thus an overview is provided in this section. The drink preparation procedure used in chapters four, five, and six, as well as the SSB consumption measure that is consistently used throughout studies, are also outlined. Other tasks and self-report measures differ across studies, and therefore are described in the methods section relevant to each study.

2.1. Balanced placebo design

The balanced placebo design (formulated by Ross et al., 1962) refers to a methodology that allows investigation of pharmacological and anticipated effects of a substance, but also interactions between the two. This design was chosen based on the fact it has been used widely across a range of fields including alcohol (e.g. Marlatt et al., 1973), nicotine (e.g. Sutton, 1991) and sports (McClung & Collins, 2007) research, some of which has been discussed in section 1.4. In addition, most previous research investigating the effects of SSBs on behaviour (section 1.3) has focused on the pharmacological effects of sugar through use of the standard placebo controlled design (in which a SSB is compared with a placebo-control beverage), and does not accounted for the role of expectancies. In subsequent studies, the beverage administered (SSB or sugar-free) and expected content (expect SSB or expect sugar-free) are manipulated to create four groups (table 1.1). These are; 1) receive SSB (expect SSB), 2) receive SSB (expect sugar-free), 3) receive sugar-free (expect SSB) and 4) receive sugar-free (expect sugar-free).

2.2 Drink Preparation

In chapters four and five, the beverages used were all non-carbonated and prepared prior to the studies. The SSB beverage (calorie content 201kcal) consisted of 300 ml water, 30 ml of sugar-free squash and 50g of glucose powder (similar content to many SSBs on the market, for example, 380ml of Lucozade orange and 500ml of pepsi/coca cola/ 7 up, etc). The placebo-sugar (diet) beverages contained 0.04g sucralose in place of the sugar. Both drinks were matched for sweetness, based on a prior taste test. Non-branded beverages, that were prepared specifically for the studies in this thesis, were used to eliminate effects of brand knowledge, but also to allow for the expectancy manipulation. Participants were asked to consume all of the beverage to ensure that the same sugar content was consumed across participants.

In chapter six, a popular beverage, familiar to participants, was used as it was important for participants to be able to distinguish which images in the attentional bias task were the full-sugar and sugar-free (diet) versions. Sprite was selected, as the full-sugar and diet versions were found to be most indistinguishable in taste in a pilot taste test (see Appendix A), which was necessary for the expectancy manipulation. The Sprite was also placed into a plain plastic cup with a lid and straw, to allow expected beverage content to be manipulation. Participants were required to consume either 330ml of full-sugar or sugar-free sprite depending on the beverage condition that they were allocated to.

2.2.1 Drinks Pilot

To determine the quantity of sucralose to utilise in the placebo-sugar beverage in chapters four and five, a variety of placebo-sugar beverages (300ml water, 30ml sugar-free orange squash) were prepared in which different quantities of sucralose was added (ranging from 0.02 to 0.06g). A number of subjects around the department (*N*=30) were asked to taste the placebo sugar (although subjects did not know the beverages contained no sugar) beverages and indicate which was the same as the reference drink (containing 50g of glucose beverage). 0.04g of sucralose was chosen for the placebo-sugar beverage as participants reported not being able to taste the difference between the two beverages. Sugar-free orange cordial was added as in previous studies, to further ensure the beverages were indistinguishable in taste (e.g. Scholey et al., 2001). This method was chosen as within the time constraints of the study, it allowed quick but effective matching of beverages. Across the two chapters, the drinks matching procedure was successful as no participants reported being deceived by the expectancy manipulation (i.e. could not tell that the placebo-sugar free beverages were in fact sugar free and vice versa).

Prior to the final study (in chapter six), a pilot taste test was carried out to determine which full-sugar and sugar-free equivalent on the market (including Coke, Pepsi, Sprite, etc) were most indistinguishable in taste. Participants (*N*=32) were asked to taste the pairs of beverages and indicate whether it was the full-sugar or diet version. Appendix A presents chi square results including percentage of participants who guessed full-sugar and diet. Although there were a number of full sugar and diet pairs which appeared to taste alike, Sprite was chosen, as both the full sugar and diet version of the drink were highly indistinguishable This method was chosen it allowed determination of whether subjects guesses were due to chance (i.e. could not tell whether it was full-sugar or sugar-free). Scores of 50% indicated that participants guesses were at chance of guessing the correct beverage, and thus closest to 50% indicated that participants were least able to identify if the beverage was full-sugar or diet (see table A1).

2.3. SSB Consumption

To measure SSB consumption participants were asked to complete a beverage frequency questionnaire. They recorded the quantity in popular serving size (e.g. carbonated beverages in cans and squash in glasses) and how often (daily or weekly) they consume a number of SSBs. Non-SSBs were also included in the questionnaire to disguise the fact SSB consumption was being assessed. SSBs included non-diet fruit-flavoured drinks (e.g. squash/bottled juice), non-diet carbonated drinks, and non-diet energy and sports drinks, however, milk-based products were excluded (Han & Powell, 2013; BMA, 2015). Total SSB consumption was calculated by adding together the total quantity (ml) of (non-diet) carbonated beverages, fruit flavoured beverages, energy drinks, and sports drinks that participants consumed daily (see Appendix B).

Chapter Three:
Do beliefs about the short-term effects of Sugar-Sweetened Beverage consumption influence the consumption?

3.1 Abstract

Obesity is a major global epidemic with the consumption of sugar-sweetened beverages (SSBs) argued to be a major contributor. Therefore, it is important to understand driving factors that may influence the consumption of SSBs. Few studies have explored the contribution of outcome expectancies to SSB consumption. The current study involved the development of the SSB outcome expectancies scale (SOES) to assess the relationship between short-term expectancies and SSB consumption and provides initial validation of the scale. In study 3.1, the SOES was completed by a sample of 301 participants. In study 3.2, a new sample of 300 participants completed the SOES. In both studies, the SOES was completed again two weeks later for test re-test reliability. Participants also completed a beverage frequency questionnaire to determine daily SSB consumption (ml). The results of exploratory (study 3.1) and confirmatory factor analysis (study 3.1 and 3.2) indicated that the scale consisted of three subscales; positive cognitive and physical effects, craving for sugar, and hydration. Each subscale had high internal consistency (α*'s*≥.88) and test re-test reliability (*r*'s≥.66). In study 3.1, all subscales were positively correlated with SSB consumption (ml/day), with similar findings reported in study 3.2 apart from there was no significant correlation between the craving subscale and SSB consumption. In both studies, high consumers had higher scores on the positive cognitive and physical effects and hydration subscale than non-consumers, however there was no significant group differences on the craving subscale. The SOES provides a reliable tool for assessing short-term expectancies associated with SSB consumption. Findings provide initial evidence for the role of expectancies in SSB consumption, although further research is required to offer further insight into the role of expectancies.

3.2 Introduction

As outlined in section 1.1, the consumption of SSBs is a major contributor to weight gain and obesity, and other obesity-related health problems such as type 2 diabetes (e.g. de Ruyter, Olthof, Seidell & Katan, 2012; Malik et al., 2006; Imamura et al., 2015). Thus, reducing the consumption of SSBs is of particular interest to public health services but also an important strategy for obesity prevention and control (Hu, 2013). Despite awareness of the negative health effects associated with consumption of SSBs and the other 'low-calorie sugar-free' alternatives available, rates of SSB consumption remain variable in the population with many individuals still consuming excessive amounts of these beverages (e.g. Bates et al., 2014). Therefore, to aid in the development of interventions to improve public health, it is important to understand factors that influence the decision to consume these beverages.

Many factors have been suggested to influence food and beverage choices including health lifestyle, cost, convenience, mood, familiarity, and sensory appeal (Neumark-Sztainer, Story, Perry & Casey, 1999). The influence of some of these factors on food/beverage choice can be explained by outcome expectancies. Expected outcomes are considered when choosing a course of action, and thus may be an important influence on food and beverage choice behaviour (e.g. Kirsch, 1985;1997). For example, people who expect negative health effects (e.g. weight gain) from consuming certain foods and beverages will probably avoid consumption, whereas individuals who expect positive effects (e.g. improved mood) from consumption are more likely to choose to consume these products (e.g. Gutjat et al., 2015). Rogers, Edwards, Green and Yas (1992) used outcome expectancies as an explanation for coffee consumption. They suggested that coffee is associated with increased alertness and concentration which may influence people to consume coffee in the morning, however, in the evening when individuals are wanting to sleep this may become a negative outcome expectancy leading to avoidance of this beverage. Thus, outcome expectancies should be one potential factor to consider when understanding food and beverage decisions.

There is considerable evidence demonstrating the development of outcome expectancies through experience with different foods and drinks and their influence on dietary intake. For example, individuals develop expectancies regarding the satiating and thirst-quenching effects from the sensory properties of foods and beverages (McCrickerd, Lensing & Yeomans, 2015; Hogenkamp, Stafleu, Mars, Brunstrom & de Graaf, 2001). Specifically, McCrickerd et al. (2015) found that products anticipated to be creamier were expected to be more filling and hunger suppressing than those expected to be less creamy. They also found that beverages expected to be salty and thick were expected to be the least hydrating. Outcome expectancies have also been found to be predictive of vegetable consumption. Reid et al. (2005) found that people who ate more fruit expected fewer negative effects (e.g. indigestion) from fruit consumption, however the strongest correlation was between fruit consumption and expecting positive effects such as being happy, alert and energetic. Similarly, Domel et al. (1995) found that expected social (e.g. my friends will like me more) and physical and health benefits (e.g. I will have more energy to run, play and think) were positively correlated with fruit and vegetable consumption. Taken together, these studies highlight the potentially important role outcome expectancies have in dietary decisions.

Outcome expectancies have been found to be predictive of participation in unhealthy behaviours, with negative expectancies reducing unhealthy behaviour and positive expectancies driving the uptake and maintenance of unhealthy behaviours; including drinking alcohol (Gustafson, 1993; Leigh, 1989; Jones, Corbin & Fromme, 2001), smoking (Van der Plight & de Vries, 1998) and unhealthy diet choices. In relation to the latter, Reid et al. (2005) found chocolate consumption was related to expected positive outcomes such as feeling relaxed, rewarded, and comforted. An important finding was that long-term negative expectancies were less predictive of diet than short-term positive psychological expectancies; for instance, in the case of chocolate and sweet intake, guilt about health (e.g. weight gain, ruin teeth) accounted for only 3% of variance in intake compared to 10% for expected short-term positive outcomes (e.g. feeling relaxed, rewarded, etc.). Another study found that subjects who expected fried breakfasts to be more relaxing also consumed them more often, despite explicit knowledge of long-term negative effects on health (Reid & Hammersley, 2001).

Similarly, alcohol research reports positive (more immediate) outcomes to be more predictive of drinking behavior than negative (more delayed) outcomes (e.g. Leigh & Stacy, 1993).

Although limited research exists, some evidence suggests that expectancies are related to SSB consumption. For example, Tuorila et al. (1990) found that SSB consumers believed full-sugar beverages were more thirst quenching, provided more energy and were less likely to cause weight gain than diet beverage consumers or non-users (consumed neither SSB or diet), suggesting they expect more positive effects from these drinks. More recently, Su (2012) found that SSB consumption was related to individual’s outcome expectancies. Positive expectancies were associated with greater consumption whereas negative expectancies were associated with lower consumption, although they were not explicit about the nature of the expectancies. Thus, despite emphasis from health professions that SSBs have negative health effects and are associated with weight gain in the long-term, if people associate SSBs with positive outcomes in the short-term this may override the long-term consequences and influence people’s decision to consume these drinks.

Currently, there is limited research investigating outcome expectancies in relation to unhealthy drinking behaviour and no questionnaire which allows the assessment of individual’s beliefs regarding the effects of SSB consumption. The aim of this chapter was to develop a SSB outcome expectancies scale (SOES) and to determine whether individual’s beliefs regarding the short-term effects of SSBs are related to SSB consumption. The focus was on short-term outcome expectancies as these are stronger predictors of diet (e.g. Reid et al, 2005). In study 3.1, participants were asked to complete the initial SOES with questions assessing the expected effects of SSBs on cognition, physical endurance, hydration, mood, and craving to determine the factor structure of the scale. Participants were also asked to complete a beverage frequency questionnaire (BFQ) to determine the relationship between outcome expectancies and SSB consumption. In study 3.2, the SOES and BFQ was administered to a second sample to confirm the factor structure and further explore the relationship between subscales and SSB consumption. It was hypothesised that expectancy subscale scores would be associated with SSB consumption levels and that high consumers of SSB would have more positive outcome expectancies than non-consumers of these drinks.

3.3 Study 3.1

3.3.1 Methods

Participants

301 participants (54 males, 247 females) aged between 18 and 64 years old (*M*=23.89 *SD*=9.68) completed the study. The sample size was based upon recommendations that at least 300 participants are required for factor analysis (Field, 2013). Participants consumed a mean of 255.56 (±385.27) ml of SSBs per day. A sub-sample of 166 participants completed the scale again two weeks later to assess test-retest reliability.

Participants were recruited via the EPR scheme, a system whereby first year students sign up for studies in receipt of course credits. The study was also advertised on social networking sites (e.g. Facebook, Twitter). Inclusion criteria included being aged 18 and above and a fluent English speaker. Participants were not eligible if they had a diagnosis of diabetes. There was an optional prize draw as an incentive for completion.

Measures

Initial SSB Outcome Expectancies Scale (SOES). A pool of potential items assessing the positive and negative outcome expectancies regarding the short-term effects of SSB consumption were collated following a literature search. We carried out several literature searches (using the university of Liverpool search engine with searches across a vast range of electronic databases). Search terms included those related to sugar (e.g. sugar, sweetness, glucose, etc) and a term related to preceding effects (e.g. short-term effects, behavioural effects, behaviour, cognition, physical performance, subjective effects, etc). Cross literature reviews and journal papers identified cognitive performance, physical performance and aspects of affect were consistently reported to be influenced by sugar, and thus we generated potential items focussed around these areas. The items were validated and further added to by academics in the appetite and obesity group during a focus group discussion. Although there was agreement regarding the importance of including cognitive, physical and mood effects, it was also agreed that items surrounding sugar craving and the hydrating effects of SSBs, should also be included in the initial questionnaire. The initial scale consisted of 66 items (see Appendix C) focussed around short-term changes in mood, cognition, physical endurance, craving and hydration. Examples include: After consuming a SSB;" I feel hydrated"; "I am more alert"; "I crave more sugary foods and drinks". Participants responded to items on a 6-point Likert scale ranging from no chance of happening (1) to certain to happen (6).

SSB consumption. See chapter two (general methods)

Procedure

Participants were sent a link to the online questionnaires. After giving consent, they completed the SOES and BFQ. Participants were then given the option to provide their email to complete the second wave questionnaire. Two weeks later, these participants were sent a link to complete the SOES again. Upon completion of the study, participants were provided with a debrief sheet and thanked for their participation.

3.3.2 Statistical Analysis

Data Preparation and Pre-analysis Checks

Prior to analysis, participant responses to each item on the SOES were assigned a value from 1 to 6 (1=no chance, 2=very unlikely, 3=unlikely, 4=likely, 5=very likely, 6=certain to happen). A higher score indicated a greater expectation that the statement would happen following SSB consumption. Negatively worded items were reverse scored so that scoring was consistent. Kaiser-Meyer-Olkin (KMO) statistic was used to assess sampling adequacy (>0.5 deemed acceptable; Kaiser, 1974) and Bartlett's test of sphericity to assess whether correlations between items were sufficiently large for principle component analysis (PCA) ($p<.05$ are indicative of sufficient inter-item correlations).

Exploratory Factor Analysis

The factor structure of the SOES was examined using PCA with oblique (oblimin) rotation as the factors were hypothesised to be separable, but related constructs (Brown, 2009). A parallel analysis (using the Monte-Carlo simulation method; Glorfeld, 1995), a scree plot (Cattell, 1966) and eigenvalues (>1 for factor to be retained; Guttman, 1954, Kaiser, 1960) were used to identify the initial factor solution. Items were removed if they had a factor loading of less than .50 on a single factor or a factor loading of greater than .35 on a second factor. Further items were removed following reliability analysis (Cronbach's alpha) and if items on a single factor were highly correlated or had the same conceptual meaning to other items in the scale.

Confirmatory Factor Analysis

Using AMOS (Arbuckle, 2013), the factor solution was tested via confirmatory factor analysis (CFA) on data from the subsample of participants who completed wave two of the study ($n=166$). Items were loaded onto their respective factors, and factors were free to correlate with each other. Model fit was assessed by examining Normed chi-squared statistic (χ^2/DF), Bollen-Stine bootstrap, Standardised Root Mean Residual (SRMR), Root Mean Square Error of Approximation (RMSEA) and the Comparative Fit Index (CFI). The following cut-off values were used to assess the goodness of fit of the specified model; Normed X^2 between 1 and 3 (Carmines & McIver, 1981), Bollen-stine bootstrap $p>0.05$, SRMR <.08, CFI > .90 (Hu & Bentler, 1999) and RMSEA <.1 (MacCallum, Browne & Sugawara 1996).

Internal Consistency and Descriptives

Cronbach's alpha was used to assess the internal consistency of each subscale identified by factor analysis, with values greater than 0.70 deemed acceptable. SOES subscale scores were calculated by computing the mean score for each subscale (i.e. scores from 1 to 6). Independent samples t-tests were used to determine whether scores differed between males and females and Pearson's correlation to determine if scores on each subscale were associated with age.

Test-Retest Reliability

Test-retest reliability was assessed using Pearson's correlation to examine the relationship between subscale scores at wave one (i.e. initial time of testing) and scores at wave two (i.e. two weeks later). Pearson's correlation coefficients of 0.6 and greater are indicative of good test re-test reliability (Cicchetti, 1994).

Relationship between SOES Subscales and SSB consumption

Pearson's correlations were computed to determine the relationship between subscale scores and SSB consumption. Independent samples t-tests were also conducted to compare high consumers (i.e. top tertile) and non-consumers (i.e. bottom tertile) of SSBs on SOES subscale scores.

3.3.3 Results

Pre-analysis Checks

Values for skewness and kurtosis were within the acceptable range of +2 and -2, therefore, no transformations were necessary (Field, 2013). Kaiser-Meyer-Olkin statistic was above the acceptable level of 0.5 (KMO=.92) and Bartlett's test of sphericity was significant $\chi^2(2145) = 15897.59$, $p<.001$), and thus factor analysis was conducted on the data.

Exploratory Factor Analysis

Following removal of items (using the procedures outlined above), a clear four-factor solution was derived from the remaining 43 items with eigenvalues of 11.69, 9.98, 2.60 and 2.24 explaining 27.19%, 23.21%, 6.05% and 5.21% of the variance, respectively.

Factor one consisted of 19 items referring to the ‘positive cognitive and physical effects’ of SSB consumption (e.g. “I have more energy to complete daily activities”, “I can think quicker”) (*M*=3.17, *SD*=.73).
Factor two consisted of 15 items referring to the ‘negative cognitive and physical effects’ of SSB consumption (e.g. “It is detrimental to my performance on mental tasks”, “I am more tired”) (*M*=2.90, *SD*=.73).
Factor three consisted of 5 items assessing ‘craving for sugar’ following SSB consumption (e.g. “I have a stronger urge to consume more sugary drinks”) (*M*=3.34, *SD*=1.00).
Factor Four (referred to as ‘hydration’) consisted of 4 items assessing individuals’ beliefs about the hydrating effects of a SSB (e.g. “I feel hydrated”, “I feel less thirsty”) (*M*= 3.37, *SD*=.91).

Notably, researchers have exercised caution over separate factors resulting from both positively and negatively worded items appearing in the same scale (in this case the positive/negative cognitive and physical effects subscales). There is some consensus that negatively worded items tend to be linked together in a quantitatively, and perhaps qualitatively different manner than positively worded items which may be attributable to respondent carelessness resulting in two separate factors (e.g. Merritt, 2012). This may have adverse effects on factor analysis outcomes (e.g. Roszkowski & Soven, 2010) and will be explored further in confirmatory factor analysis.

Confirmatory Factor Analysis

To verify the factor structure of the SOES, CFA was carried out. Model fit indices for each model tested are presented in table 3.1.

Table 3.1- Model fit indices for CFA models

	χ^2/DF	Bollen-Stine Bootstrap (*p*-value)	CFI	RMSEA	SRMR
Model 1: four factor solution	2.19	.002	.80	.085	.080
Model 2: covariance pathways	2.09	.006	.82	.081	.078
Model 3: three factor solution	1.94	.068	.90	.075	.064
Model 4: two low loading items removed	1.86	.106	.92	.072	.060

Model one (initial four-factor solution): Only one item ("I feel calmer") had a standardised regression weight less than .5; the highest value was .87 and the lowest .37. Although all the items demonstrated significant standardised regression scores on their corresponding factor, the estimate for the overall fit of the model suggested a poor model fit.

Model two: Covariance pathways between error terms, as identified by examination of large modification indices in model one, were added to the model. Two model fit indices (Bollen-Stine, CFI) still failed to meet the cut-off criterion for a 'good fit'.

Model three: Addressing the potential issues with separate factors resulting from both positively and negative worded items, the negative cognitive and physical effects factor was removed from the model and the new three-factor solution was tested. Results indicated a substantial improvement in the model with all model fit indices suggesting a good model fit. However, compared to the other items, two items had a particularly lower regression coefficient weights (.35 and .55). All other items loaded significantly with the corresponding factor with factor loadings above .60 (highest .88).

Model four: The two low loading items (“I have more strength”, “I feel calmer”) were removed from the model and model four was tested. All model fit indices exceeded the cut of criteria, indicating a good fit of the model to the data. All items in the model were found to load highly significantly onto their corresponding factor (p<.001). Thus, all subsequent analyses were based on this model.

The final three factor solution (figure 3.1) consisted of 26 items explaining 65.06 % of the variance in data; Factor 1 (positive cognitive and physical effects) explained 41.73%, factor 2 (craving for sugar) 14.98% and factor 3 (hydration) 8.35% of the variance.

Table 3.2 shows that correlations between the craving factor and the positive cognitive and physical effects/hydration factors were small. However, the positive cognitive and physical effects and hydration factor were moderately correlated.

Internal Consistency and Descriptive Statistics

All subscales were found to have high internal reliability; Positive cognitive and physical effects (17 items, α=.96), Hydration (4 items, α=.88) and Craving (5 items, α=.91). Mean scores on the SOES scale are presented in table 3.3 for the whole sample. Independent samples t-tests revealed no significant gender differences on the hydration or positive cognitive and physical effects SOES (ps≥.113), however females (3.43 ± .97) scored significantly higher than males (2.95 ± 1.04) on the craving SOES (t (299) = 3.21, p=.001, d=.48). Pearson’s correlation also revealed no significant relationship between age and scores on any of the SOES subscales (ps≥.204).

Test-retest reliability

Pearson's correlation revealed good test-retest reliability, *r*=.76, .66, .72 (*p*s<.001) for the hydration, craving and positive cognitive and physical effect subscales, respectively.

Relationship between SOES Subscales and SSB consumption

The relationship between SOES subscales and SSB consumption was analysed on data for the whole of the sample. Table 3.3 shows mean scores on the three expectancy factors and mean daily SSB consumption (ml).

Correlations

Table 3.2 shows correlations between SOES subscales (hydration, craving, physical and cognitive effects) and SSB consumption (ml/day). Results indicated a small but significant correlation between the hydration, craving and the positive physical and cognitive effects SOES factors and quantity of SSBs consumed per day. The more individual's expected SSBs to be hydrating, have positive cognitive and physical effect and increase craving for sugar, the greater the quantity of these beverages that they consumed.

Table 3.2- Correlations between SOES factors and SSB consumption for study 3.1 (and study 3.2)

	SSB consumption (ml/day)	Hydration SOES factor	Craving SOES factor	Physical and cognitive effects SOES factor
Hydration SOES	.25** (.16)*	--	--	--
Craving SOES	.12* (-.04)	-.11* (-.08)	--	--
Physical/ cognitive effects SOES	.17** (.23)**	.36** (.23)**	.24** (.26)**	--

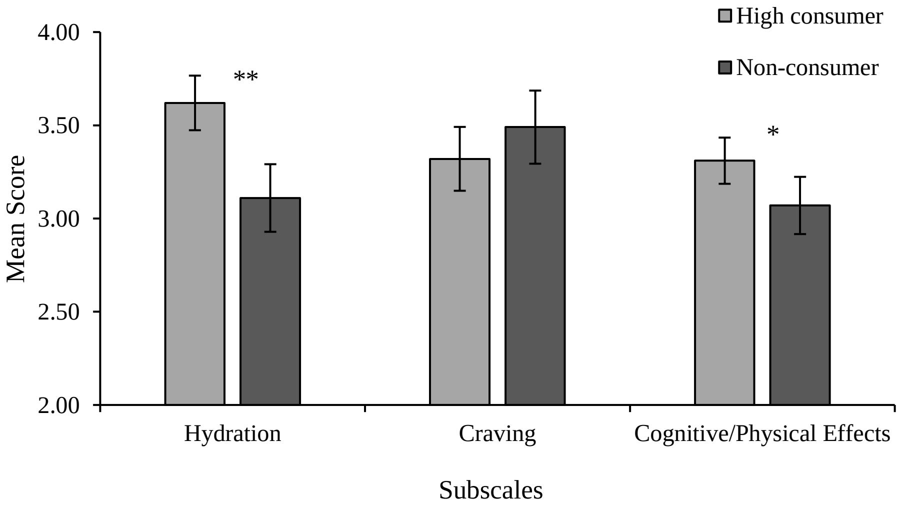
** Correlation is significant at the .001 level.

* Correlation is significant at the .05 level.

High Consumers vs Non-Consumers

To better understand whether the expected effects of SSBs influence the consumption of these drinks, subscale scores in two extreme groups (high and non-consumers) were compared on each subscale (hydration, craving and positive cognitive and physical effects) (figure 3.2). SSB consumer groups were identified by taking the top tertile (high consumers; *M*=665.10ml, *SD*=41.02) and bottom tertile (non-consumers; *M*=0ml, *SD*=0). Independent samples t-tests indicated no significant difference in 'craving' scores between high and non-consumers of SSBs (*t* (206) = 1.30, *p*=.194, *d*=0.18). However, results indicated there were significantly higher 'hydration' scores in high (3.62 ± .75) than non-consumers (3.11 ± .94; *t* (206) =4.30, *p*<.001, *d*=.60). There were also higher scores on the 'positive cognitive and physical effect' subscale in high (3.31 ± .62) than non-consumers (3.07 ± .77; *t* (206) = 2.45, *p*=.015, *d*=.34). This suggests that high consumers of SSBs believed that these beverages were more likely to be hydrating and have more positive cognitive and physical effects than non-consumers.

Figure 3.2- Subscale means (and 95% confidence interval) for high and non-consumers separately.



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

3.4 Study 3.2

In study 3.2, another sample of participants were recruited. There were differences between the two samples in age (study 3.1 mean= 23.89 years old, study 3.2 mean= 31.51 years old) and SSB consumption (study 3.1 mean = 255.56 ml/day, study 3.2 mean= 119.01 ml/day). The aim of study 3.2 was to further verify the factor structure of the scale and explore the relationship between SOES subscales and SSB consumption in a new sample of participants.

3.4.1 Methods

Participants

300 participants (245 female, 55 male) aged between 18 and 72 (*M*=31.51, *SD*=12.14) completed the study. Mean SSB consumption for this group was 119.01 (±264.68) ml per day. A subsample of 39 participants (determined using power analysis; r=.50, a=.05, power=.80) completed the questionnaire for a second time two weeks later for test-retest reliability. Inclusion criteria and recruitment techniques were the same as study 3.1.

Measures

SSB Outcome Expectancies Scale (SOES). In study 3.1, following factor analysis outcomes, 40 items were removed from the SOES scale, leaving a remaining 26 items loading onto the three expectancy factors (positive cognitive and physical effects, hydration and craving for sugar). This 26 item scale was used in the current study (study 3.2). Participants responded on a 6-point Likert scale how likely each item was to happen to them when they consume a SSB from no chance (1) to certain to happen (6) (Appendix D).

SSB consumption. See chapter two, general methods.

Procedure

Participants completed the SOES and BFQ on Qualtrics. A subsample of participants provided their email (*n*=39) to complete the questionnaire again approximately two weeks later (for re-test reliability). Following completion, participants had the option to enter a prize draw for a monetary voucher.

3.4.2 Statistical Analysis

For criteria used during statistical analysis, refer to statistical analysis section in study 3.1.

3.4.3 Results

Confirmatory Factor Analysis

17 items were free to load onto the positive cognitive and physical effects factor, five onto the craving factor and four onto the hydration factor. Confirmatory factor analysis indicated an acceptable model fit [χ^2 /df =2.98, RMSEA = .081, CFI =.919, SRMR =.044, Bollen-Stine bootstrap *p*>.05]. Standardised factor loadings indicated that all items appropriately reflected their underlying latent variable (*p*<.001). Table 3.2 shows that correlations between all factors (positive cognitive and physical effects, hydration and craving) were small.

Internal Consistency and Descriptive Statistics

For mean scores for the SOES subscales refer to table 3.3. T-tests revealed significant gender differences for each subscale (all small to moderate effect sizes); males scored higher than females on the expected hydration subscale (3.64 ± 1.05 vs 3.32 ± .92; (298) = 2.25, *p*=.025; *d*=0.32) but lower on the expected craving subscale (3.16±1.09 vs 3.55; *t*(298)=2.5, *p*=.011; *d*=0.38) and there was a trend towards males scoring higher than females on the expected positive cognitive and physical effects subscale (3.33 ±.74 vs 3.12 ±.70 *t*(298)=1.92, *p*=.056, *d*=0.28). Age did not significantly correlate with scores on the expected positive cognitive and physical effects subscale (*r*=-.08, *p*=.180) or expected hydration (*r*=.001, *p*=.993), however there was a small but significant negative correlation with expected craving (*r*=-.16, *p*=.005). Cronbach's alpha revealed high internal reliability for the positive cognitive and physical effects (*α*=.96), hydration (*α*=.88) and craving (*α*=.93) subscales.

Test-retest reliability

The intraclass correlation coefficient revealed good test re-test reliability for each of the subscales; positive cognitive and physical effects (*r*=.75), hydration (*r*=.67) and craving (*r*=.69, *p*s<.001).

Relationship between SOES Subscales and SSB Consumption

See table 3.3 for mean scores on the three subscales and mean daily SSB consumption for this sample.

Correlations

Table 3.2 shows correlations between SOES subscales (cognitive and physical effects, hydration, craving) and SSB consumption (ml/day). Pearson's correlation revealed small to medium significant correlations between daily SSB consumption and scores on the positive cognitive and physical effect and hydration subscales but not on the craving subscale. The more individual's expected SSBs to have positive cognitive and physical effects and be hydrating, the greater the quantity of these beverages they consumed.

High vs. Non-consumer

An independent samples t-test was used to compare high consumers (*M*=310.73, ml/day, *SD*=362.14) with non-consumers (*M*=0.00ml/day, *SD*=0.00) on scores for each subscale of the SOES. Results indicated significantly higher scores for high consumers (3.35±.71) than non-consumers (3.05 ± .71) on the positive cognitive and physical effects subscale (*t* (268) = 3.37, *p*=.001, *d*=.42). There were also significantly higher scores on the hydration subscale for high consumers (3.55 ± .95; *t* (268) = 2.87, *p*=.005, *d*=.35) than non-consumers (3.22 ± .94), however no significant group difference on the craving subscale (*t* (268) = 1.64, *p*=.102, *d*=.20).

Table 3.3- Means (±*SD*) for each subscale and SSB consumption for each participant sample.

	Study 3.1 ***N*=301**	**Study 3.2** ***N*=300**	***t***
Hydration SOES	3.37 (±.91)	3.38 (±.95)	ns
Craving SOES	3.34 (±1.00)	3.48 (±1.05)	ns
Positive cognitive/physical effects SOES	3.19 (±.74)	3.16 (±.95)	ns
SSB Consumption (ml/day)	255.56 (±385.27)	119.01 (±264.68)	5.07**

** *p*<.001

3.5 Discussion

The current study aimed to develop and validate a psychometric scale assessing individuals' beliefs about the short-term effects of SSB consumption and to assess the relationship between the subscales and SSB consumption. It was hypothesized that expectancy subscale scores would be associated with SSB consumption levels and that high consumers of SSBs would have more positive beliefs about the short-term effects of SSB consumption than non-consumers.

Following exploratory and confirmatory factor analysis, a three-factor solution was deemed a best fit of the data. This comprised of a factor consisting of 17 items assessing the expected positive cognitive and physical effects of SSB consumption, a factor consisting of five items assessing expected craving for sugar and a final factor consisting of four items assessing expected hydration. In study 3.1, all SOES subscales (hydration, craving and positive cognitive and physical effects) were found to be significantly positively correlated with SSB consumption (ml/day). The more individuals expected SSBs to be hydrating, improve cognitive and physical performance and to increase craving, the greater the quantity of these beverages they consumed per day (ml/day). Similar findings were reported in study 3.2, however there was no significant correlation between expected craving and SSB consumption (ml/day). Furthermore, in both studies, high consumers scored significantly higher than non-consumers on the positive cognitive and physical effects and hydration subscales, however there were no group differences on the craving subscale.

Scale Construction

The current study involved the development of a new scale assessing the short-term outcome expectancies for SSB consumption, an area where limited research currently exists. Thus, the initial stages of research involved a comprehensive literature review to determine the potential short-term effects of SSB consumption. From this, a number of items were constructed reflecting factors influenced by SSB consumption (e.g. cognitive and physical performance, mood, thirst, and sugar craving). To further refine the scale, a focus group was then carried out with researchers in the area of appetite and obesity and additional items agreed to be salient were added.

In study 3.1, the initial factor analysis of items tapping into various outcomes of SSB consumption revealed a four-factor solution representing the expected positive cognitive and physical effects, negative cognitive and physical effects, hydration and craving. Negative and positive outcomes represented the largest expectancy factors, similar to previous research involving alcohol, smoking and food expectancy scale construction (e.g. Leigh & Stacy, 1993; Jones et al., 2001; Hine, Honan, Marks & Brettschneider, 2007; Reid et al., 2005). Although factors demonstrated good discriminant validity, research suggests potential caveats associated with two separate factors resulting from positively and negatively worded items (Roszkowski & Soven, 2010). Furthermore, this PCA scale construction technique retained some items with low factor loadings.

Confirmatory factor analysis conducted on data from a subsample of participants in study 3.1 indicated that the four-factor solution provided a poor fit to the data. Addressing potential issues with factors resulting from positively and negatively worded items, and due to research suggesting a stronger relationship between positive expectancies and behaviour in both alcohol and food research (e.g. Reid et al., 2005; Leigh & Stacy, 1993) the negative factor was removed. In addition, some low loading items were removed, and the new three factor structure tested. The final three factor model provided a good fit to the data and the factor structure was confirmed utilising a new sample in study 3.2. All items loaded significantly onto each factor and all factors had good discriminant validity. Cronbach's alpha values for both samples ranged from .88 to .96 reflecting excellent internal consistency for individual subscales. Both studies indicated small to medium positive correlations between factors. Thus, if an individual scored highly on one subscale, they also scored highly on the others which may reflect a general positive attitude towards SSBs across all subscales.

Outcome Expectancies and SSB Consumption

In line with predictions, study 3.1 found that all expectancy subscale scores were positively correlated with SSB consumption. Specifically, the more individual's expected SSBs to have positive cognitive and physical effects, to be hydrating and to increase craving, the greater the quantity they consumed. Similar findings were reported in study 3.2, apart from there was no significant correlation between the craving subscale score and SSB consumption. This may be due to sample differences, for example, the first sample consumed a mean of 255.56 ml/day, more than twice the amount of the second sample (119.01ml/day) and there was also smaller variation in consumption in the second sample (study 3.1 *SD*=385.27, study 3.2 *SD*=264.68). Therefore, there may be differences in expectancies held by the two samples.

These findings suggest that individual's expectancies may be one factor driving the decision to consume SSBs and are in line with previous research suggesting expectancies influence the decision to participate in unhealthy behaviours such as drinking alcohol (Gustafson, 1993; Leigh, 1989) and smoking (Van der Plight & de Vries, 1998), but also unhealthy diet such as chocolate, fried breakfast and SSB consumption (e.g. Reid et al., 2005; Reid & Hammersley, 2001; Su, 2012). The current study focussed on short-term expectancies and is supportive of research also demonstrating the importance of short-term expectancies in alcohol consumption (e.g. Leigh & Stacy, 1993) but also dietary choices such as chocolate, fried breakfast and vegetable consumption (Reid et al., 2005; Reid & Hammersley, 2001; Domel et al., 1995). Thus, people's beliefs about the short-term positive effects of food/beverage consumption can influence unhealthy diet choices and may override acknowledged long-term negative consequences (e.g. weight gain).

Notably, the current scale does not assess the contribution of long-term negative expectancies on SSB consumption behaviour. Although previous research suggests that short-term positive expectancies are more important influences on behaviour than long-term negative expectancies (e.g. Reid et al., 2005; Leigh & Stacy, 1993), there are some studies suggesting that negative expectancies can contribute to participation in unhealthy behaviours (e.g. Jones et al., 2001; Su, 2012; Reid et al., 2005). Furthermore, there is limited research on the role of expectancies on SSB consumption behaviour. Therefore, the contribution of both short and long-term expectancies should be explored further in future research to better understand the role of expectancies in SSB consumption behaviour. Furthermore, caution is required over the interpretation of causality in cross-sectional research. The demonstrated relationships between the SOES subscales and SSB consumption do not enable the conclusion that SSB expectancies cause SSB consumption behaviours. Further experimental and longitudinal research using the SOES is needed to adequately assess causality.

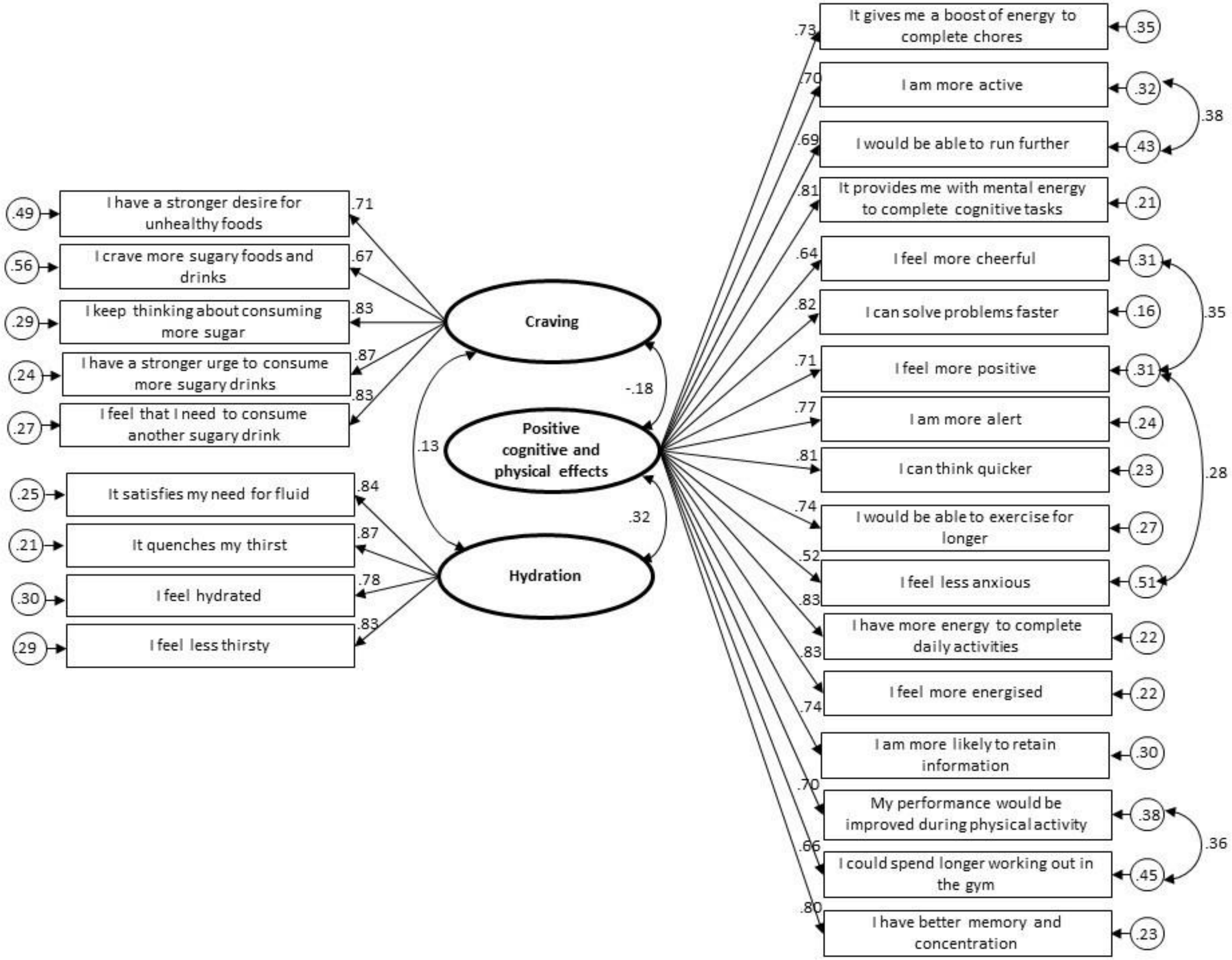
To get a better understanding of the role of expectancies on SSB consumption, the current study also explored differing beliefs in two extreme consumer groups, non-consumers and high consumers; the latter at greater risk of developing obesity as well as type-2 diabetes (e.g. Malik, et al., 2006; Imamura et al., 2015; Malik et al., 2010). In line with predictions, results demonstrated that high consumers expected more positive effects from consumption than non-consumers. In both studies, high consumers were more likely to expect SSBs to have positive cognitive and physical effects and increase hydration than non-consumers, however there were no group differences in expected craving. This is also in line with findings from previous research reporting consumers of full-sugar carbonated beverages to expect more positive effects from consumption of full-sugar beverages than diet consumers (Tuorila et al., 1990) and provides further evidence to suggest that expectancies are an important factor to consider to understand SSB consumption.

There are some limitations related to the current research. Firstly, the current scale assesses expectancies related to SSBs in general, with a range of beverages falling under the SSB category. It is possible that individuals have expectancies which are more strongly related to some of these beverages than others. For example, it would be expected that improved physical performance would be more strongly associated with sports and energy drinks than other fruit-flavoured drinks. Therefore, if expectancies were tailored to drink type, they may be more strongly related to consumption patterns. Furthermore, there are limitations around using self-report for dietary assessments. People tend to hold back from reporting unhealthy food consumption due to reasons such as embarrassment (see Macdiarmid & Blundell, 1997), and therefore it is possible that participants consumed higher levels of SSBs than are recorded in the current study. Finally, other expectancies not included in the scale may be important for SSB consumption. For example, SSB consumption could be influenced by individual's feelings of guilt following consumption. Social expectancies, which have been found to influence alcohol and vegetable consumption (e.g. Rohsenow, 1983; Domel et al., 1995) may also be important for SSB consumption (e.g. they may be consumed in a fun environment or to enhance family/friend interactions), and therefore should be explored in future research.

Notably, potential caveats surround the literature review and focus group approach used to determine items to include in the initial scale. Firstly, the literature review was carried out by myself which poses potential biases with the search and some important papers (due to search term constraints) may have been missed. It is also possible that consumers experience some short-term effects not currently present in the literature. Furthermore, the focus group aspect of item generation consisted of academics in the appetite and obesity group who have an interest in food and beverage research. Problematically, this population may suggest items of interest to their own research and what they want to include. It is possible that some important short-term effects of SSBs were not captured in the focus group and thus the scale may miss some important items relevant to high consumers, limiting the generalisability of questionnaire items to different consumer groups. Future research could address these potential issues by utilising a range of academics with differing background to come up with search terms/ carry out the literature search. Furthermore, focus groups could be conducted with wide array of consumer groups, to ensure all probable short-term effects are accounted for. Indeed, it is possible that the effects of sugar are experienced differently across consumer groups.

In conclusion, the current study offers new insight into the role of expectancies as a driving factor for SSB consumption. A new, psychometrically sound scale was constructed consisting of three subscales; positive cognitive and physical effects, hydration and craving. The study also provides new insight into the role of expectancies on SSB consumption. Expectancy subscales were found to be correlated with SSB consumption (ml/day) and high consumers were found to score higher on expectancy subscales than non-consumers. This suggests that higher consumers expect more positive effects from consumption. Therefore, expectancies may be one factor to consider in order to reduce the consumption of these beverages and obesity, although more research in this area is required.

Figure 3.1- Factor model of SOES with standardised factor loadings (i.e. values corresponding to one-way arrows), error terms (circled values), and covariances (values corresponding to two-way arrows).



Chapter Four:

The anticipated effects of sugar on physical endurance and subjective energy

4.1 Abstract

Research suggests that consuming a SSB improves physical performance, however it is unknown the extent to which sugar-related expectancy effects contribute to this. Currently, studies lack adequate control conditions that allow isolation of the anticipated effects of sugar. The current study utilised a balanced placebo design to investigate the contribution of both the pharmacological and anticipated effects of sugar to physical endurance on a handgrip and leg raise task. Participants (*N*=64) were allocated to either the SSB or placebo-sugar (sugar-free) condition; in one session they were informed that the beverage contained sugar and in the other session they were informed that the beverage was sugar-free. Measures of physical persistence were assessed pre- and post-drink, and subjective sense of energy was assessed pre-drink and at two time points post-drink. Results indicated no effect of sugar consumption on persistence in both physical tasks or on self-reported measures of energy. However, sugar expectancy led to a significant increase in persistence from pre to post-drink on the leg-raise task, but not on the handgrip, or subjective measures of energy. Taken together, results suggest no beneficial effect of consuming a full-sugar beverage on short-term physical energy or subjective sense of energy. However, the anticipated effects of sugar did influence physical persistence without a concomitant change in subjective sense of energy, although further research is required to determine how consistent sugar-related expectancy effects are across a range of physical tasks.

4.2 Introduction

The previous chapter demonstrated that the expected physical effects incorporated the largest SSB expectancy factor (expected cognitive and physical effects) and that SSB consumers are more likely to expect physical improvement from consumption. Indeed, glucose is the main source of fuel for the body and under intense physical conditions when glucose reserves are sufficiently depleted, research suggests that consumption of a SSB (in the form of glucose) can increase endurance on a range of physical tasks (Flora & Polenick, 2013). For example, compared to a placebo (sugar-free) beverage, consuming a glucose-containing beverage has been found to increase mean distance in an arm crank exercise, increase running endurance, and delay fatigue during a cycling exercise (Ventura et al., 1994; Spendiff & Campbell, 2002; Coyle et al., 1983). Furthermore, compared to placebo, consuming a high glucose drink increased grip strength following a fire-fighting exercise, although effects may have been contaminated by low levels of caffeine that were also present in the beverage (Sünram-Lea et al., 2012). Taken together, studies suggest that consuming a beverage sweetened with sugar can increase persistence and improve performance on a range of intense physical tasks.

Problematically, these studies utilise a standard placebo design which involves the comparison of a SSB with a placebo sugar-free beverage. Such comparisons allow isolation of sugar effects, thus attributing changes in physical performance/increased persistence to the pharmacological effects of sugar. However, in the real world the effects of sugar would be a combination of both the pharmacological and anticipated effects. From a psychological standpoint, an important consideration is whether the anticipated effects of a SSB contribute to a change in physical performance. The expectation that sugar will improve physical performance, that was found in chapter three, may contribute, at least in part, to improved performance.

Indeed, many SSB brands are endorsed by sports organizations and athletes (e.g. Bragg et al., 2013) and sponsor major sporting events, such as Coca-Cola sponsoring the Olympic Games (see figure 4.1). Furthermore, sports and energy drinks (e.g. Lucozade), in which sugar is one of the critical ingredients, are heavily marketed as providing an energy boost and producing greater endurance performance. Through conditioning, individuals would associate these beverages with an active lifestyle and expect increased energy and improved physical performance from consumption (e.g. Kirsch, 1997). Indeed, chapter three found that consumers of SSBs expect SSBs to aid with physical performance and increase energy, but also to be hydrating (see also Tuorila et al., 1990). In addition, energy drinks and sports drinks are reportedly consumed for their stimulant effects, to fix problems of tiredness and to improve sports performance in 12 to 15 year olds (Costa et al., 2014) and 11 to 18 year olds (O'Dea, 2003). These findings suggest that some individuals anticipate SSBs to have positive physical outcomes.

Figure 4.1- Example of an advertisement depicting Coca-Cola being consumed by an athlete.

Although most previous research has investigated the effects of glucose under intense physical activity, in the real-world individuals would consume these drinks under a variety of conditions, sometimes where glucose resources would not be sufficiently depleted, and perhaps when consuming additional sugar would have limited effects on performance. Under such conditions, psychological factors may be particularly important in influencing physical performance.

There is substantial evidence for the influence of anticipated effects of a range of substances on physical performance (see chapter one, section 1.4.3.2). To briefly summarise, improved strength has been demonstrated following placebo steroids (Kalasountas et al., 2007; Ariel & Saville, 1972). Furthermore, Hurst, Board and Roberts (2013) found that relative to baseline performance, receiving a placebo sport drink (informed to improve 5km endurance performance) had a beneficial effect on 5km running performance, suggesting the contribution of expectancies to successful physical performance. Another study by Kirsch and Weixel (1988) found that consuming placebo-caffeine impaired motor performance in those who expected caffeine to impair performance, however improved performance in those who expected caffeine to improve performance.

Isolation of both the pharmacological and anticipated effects of a substance is best obtained through use of the balanced placebo design (Marlatt & Rohsenow, 1980; Kirsch & Weixel, 1988), however, to date, limited studies that explore the effectiveness of substances on physical performance have utilised this design or explore potential interactions that may exist between pharmacological and anticipated effects. Clark et al. (2000) utilised a modified version of this design to determine the pharmacological and anticipated effects of a carbohydrate supplement on 40km cycling performance. They found a 4% enhancement in mean power relative to baseline for those told they were consuming a carbohydrate compared to a 0.5% increase in mean power for those told they were consuming a placebo beverage (regardless of the content they consumed), however the effects of carbohydrate were negligible. In another study, McClung and Collins (2007) demonstrated that the anticipated effects of a sodium bicarbonate pill produced a significantly larger improvement in time trial running performance than purely the pharmacological impact of the pill. This demonstrates the need to explore the contribution of both the pharmacological and anticipated effects of a substance to improved physical performance.

Previous studies (barring those mentioned above) lack adequate control conditions to isolate the contribution of both pharmacological and anticipated effects of supplements on physical performance. Specifically, no studies investigating the effects of sugar on endurance utilise sufficient control conditions to explore what may be critical anticipated effects of sugar. This study aimed to investigate both the pharmacological and anticipated effects of sugar, both combined and in isolation, on physical endurance and measures of subjective energy. A handgrip and leg raise task were utilised as participants would need to expend effort whilst experiencing discomfort (conditions representative of an endurance situation). These tasks were also suitable for a laboratory-based setting and have been used to measure changes in physical persistence in previous studies (e.g. Friedman & Elliot, 2008; Muraven, Tice & Baumeister, 1998; Bray, Martin Ginis, Hicks & Woodgate, 2008). Participants consumed either a SSB or sugar-free beverage; on one session they were told the beverage contained sugar, and on the other they were told the beverage was sugar-free. Endurance performance was assessed pre- and post-drink to control for individual differences in task performance (assessed pre- and post-manipulation in previous research; e.g. Friedman & Elliot, 2008). Measures of subjective energy were also assessed pre-drink and at two time points post-drink.

It was hypothesized that both the anticipated and the pharmacological effects of sugar would improve physical endurance performance and increase subjective energy. Thus, it was expected that when the anticipated and pharmacological effects of sugar were both present this would produce the largest effect. For example, the group that received a glucose drink and were told that the drink contained glucose would have the largest improvement in physical endurance performance and largest increase in subjective energy, however the group that received a placebo drink and were told that they had received placebo would have the smallest improvement in physical endurance performance and the smallest increase in subjective energy.

4.3 Methods

Participants

64 participants (17 males and 51 females) aged between 29 and 42 years old (*M*=27.77, *SD*=8.49) participated in the study. The sample size resulted from power calculation in which 54 participants were recommended (power = 80%, α=.05, f=.25) - we over-recruited to account for potential dropouts. A medium effect size was chosen as a middle ground based on the fact there were no comparable studies using mild endurance tasks to base effect sizes on and recruiting more participants (to detect a small effect size) was not practical based on limited funding. Participants were eligible if they were aged 18 and above, fluent in English, and had a healthy

BMI in the range 18.5-29.9. Those with a diagnosis of diabetes, who trained hand grip or leg strength regularly or had consumed alcohol the night before the study were not eligible to participate. Participants were provided with course credit or financial reimbursement following completion.

Design

This study utilised a mixed-factorial design consisting of one between-subjects factor drink-type (SSB, sugar-free) and a within-subjects factor message (told SSB, told sugar-free). Participants were randomly allocated to consume either a SSB or a sugar-free beverage; on one session they were provided with the SSB message and on the other session they were provided with the sugar-free message (order of which was counterbalanced).

Measures of physical endurance and subjective energy were measured at different time points throughout the study. Performance on endurance tasks was measured twice; pre- and post-beverage consumption. Self-report measures of subjective energy were assessed at three time points; pre-drink (time 1), immediately post-drink (time 2), and after the final endurance tasks (time 3).

Measures

SSB-related Expectancies. The Sugar Outcome Expectancies Scale (SOES; developed in chapter three) consists of 26 items assessing the short-term expected effects of SSB consumption. The subscales include; (1) cognitive and physical effects, (2) hydration and (3) craving for sugar. This study focussed on the expected cognitive and physical effects subscale. Items include ‘after consuming a SSB’; ‘I am more active’, ‘I feel more energised’ etc. Participants were asked to rate on a 6-point Likert scale how likely each item is to occur to them after consuming a SSB, ranging from no chance of happening (1) to certain to happen (6).

Subjective Energy. The Short-form Profile of Mood States Scale (SF-POMS; Shacham, 1983) was used to assess changes in subjective energy using the vigour (6 items) and fatigue (5 items) subscales of the SF-POMS. Participants were asked to rate how they felt on a 5-point Likert scale with a higher score indicating a higher level of this measure.

SSB Consumption. See chapter two, general methods.

Endurance Tasks:

Handgrip Task (e.g. Muraven et al., 1998). Whilst sitting, participants were asked to squeeze a handgrip in their dominant hand with their arm held at a 90-degree angle. Participants were timed for how long they could squeeze the handles together (in seconds). A small sponge was placed between the handles; when the sponge fell out timing stopped (see figure 4.2 for demonstration).

Leg raise Task (e.g. Friedman & Elliot, 2008). Whilst sitting, participants were asked to raise their dominant leg horizontally (parallel to the floor). Participants were timed how long they could keep their leg raised without it dropping. The timer was stopped once participants could no longer keep their leg parallel to the floor (see figure 4.2 for demonstration).

Figure 4.2- Demonstrations of handgrip (left) and leg-raise task (right).

Drink Preparation

The SSB and placebo-sugar beverage were prepared prior to the study and participants were asked to consume all of the beverage. See chapter two for drink preparation procedure.

Procedure

Study sessions were conducted between 9am and 12pm. Prior to the session, it was highlighted to participants that they must refrain from eating or drinking anything other than water for two hours before the study. Upon arrival, participants provided informed consent and following this all participants were provided with demonstrations of the handgrip and leg raise task (using dominant arm and leg). Participants completed a practise of the hand and leg raise tasks to ensure they were completed correctly. They were then asked to provide basic demographics (e.g. age, sex) and to complete the BFQ, SOES and baseline SF-POMS.

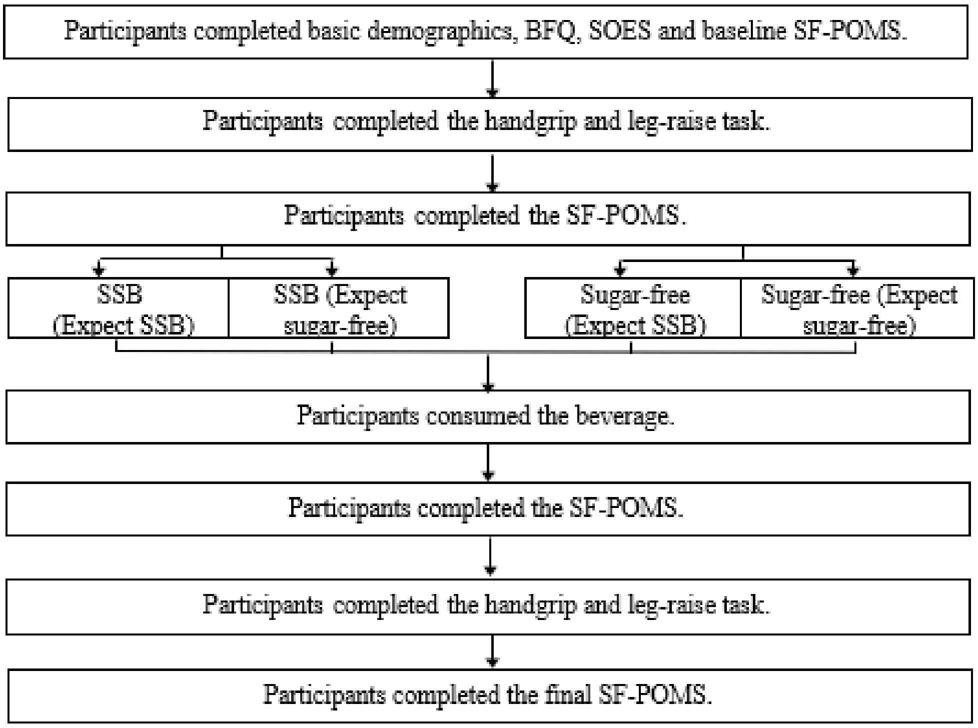
During both experimental sessions, participants were asked to record breakfast consumption prior to the study. Participants then completed the hand grip task and leg raise task (order counterbalanced). Following this, participants were asked to complete the SF-POMS. Participants then provided with either the SSB or diet beverage. Before consuming the beverage, participants were provided with the message manipulation.

In one session participants were read the ‘told SSB’ message:
“This is a SSB containing glucose and therefore we would expect it to provide you with energy and improve your performance on the tasks”.

In the other session participants were read the ‘told sugar-free' message:
“This is a sugar-free, diet beverage containing the artificial sweetener sucralose. It contains no calories and therefore we would not expect it to provide you with energy or improve your performance on the tasks”.

Participants were then given five minutes to consume the drink followed by a 20 minute sugar absorption period. After the absorption period, by which time blood glucose levels should have risen for those provided with the glucose beverage (Spendiff & Campbell, 2002), participants were asked to complete the SF-POMS again followed by the same two endurance tasks. Following these tasks, participants were asked to complete the final SF-POMS and to estimate how many calories they thought were in the beverage. Height and weight were measured at the end of the second session.

Figure 4.3- Schematic overview of experimental procedure



4.4 Results

Multifactorial analysis of variance (ANOVA) was conducted on measures of endurance as well as subjective measures. All analyses had drink (sugar+, sugar-) as the between-subjects factor and message (expect+, expect-) and time as within-subjects factors. A Bonferroni correction was applied during *post hoc* testing. For the related measures, when sphericity was violated (based on magnitude of ε, wherein values >.75) the Huynh-Feldt correction was reported.

Sample Statistics

A summary of sample statistics are presented in Table 4.1. Independent samples t-tests revealed no significant difference between the two groups for age (*t* (62) = .96, *p*=.343), height (*t*(62)=.43, *p*=.669), weight (*t*(62)=.83, *p*=.412), BMI (*t*(62)=.69, *p*=.492), cognitive and physical effects SOES (*t*(62)=.88, *p*=.381) and SSB consumption (*t*(61)=.36, *p*=.721).

Table 4.1- Sample characteristics (means ±*SD*) separated by between-subjects factor (drink condition)

	Sugar + *n*=32	**Sugar -** *n*=32
Age	26.75 (± 7.87)	28.78 (± 9.08)
Height	1.70 (± .10)	1.69 (± .10)
Weight	69.86 (± 12.61)	67.40 (± 11.16)
BMI	23.95 (± 2.65)	23.46 (± 2.93)
Cognitive and physical effect SOES	3.51 (± .59)	3.38 (± .66)
Daily SSB consumption	213.26 (± 280.69)	250.23 (± 509.74)

Manipulation Check

A 2 x 2 ANOVA was conducted on calorie estimations, with message (Expect+, Expect-) as a within subject’s factor and drink (sugar+, sugar-) as a between subject’s factor. Results indicated no main effect of drink on calorie estimates (*F* (1, 61) = 0.66, *p*=.419, n_p^2=.01), however there was a very large main effect of message (*F* (1, 61) = 39.24, *p*<.001, n_p^2=.39). In the Expect + session participants reported higher calorie estimates (195.81 ± 156.39) compared to in the Expect- session (102.46 ± 145.76), suggesting that participants believed the message manipulation. There was no significant interaction between message and drink (*p*=.540).

Endurance performance

To determine the influence of SSB consumption and expectancy effects on endurance performance, persistence on the handgrip and leg raise task (in secs) was assessed both pre- and post-drink for all conditions. Table 4.2 shows descriptive statistics for task performance for all combinations of conditions.

Table 4.2- Means (±*SD*) for endurance time (secs) on hand grip and leg raise task both pre and post-drink in each of the four experimental conditions.

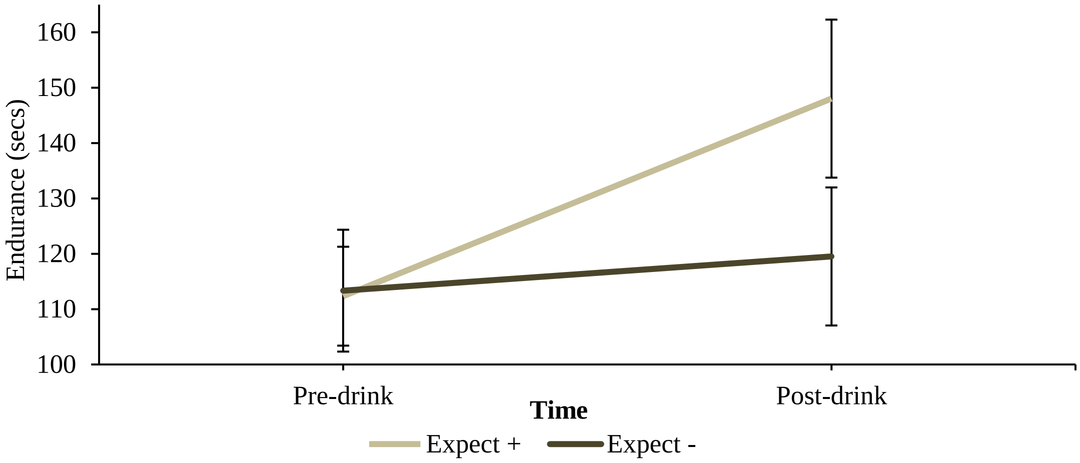
	Sugar +		**Sugar -**	
	Expect + *n*=28	**Expect -** *n*=28	**Expect +** *n*=29	**Expect -** *n*=29
Handgrip				
Pre-Drink	82.29 (±68.77)	76.25 (±67.34)	98.55 (±68.52)	98.76 (±59.56)
Post-Drink	90.61 (±62.42)	79.82 (±75.92)	112.41 (±64.70)	107.83 (±60.27)
Leg raise				
Pre-Drink	92.25 (±51.77)	108.96 (±99.33)	131.72 (±75.61)	117.55 (±65.26)
Post-Drink	119.79 (±64.33)	108.39 (±105.64)	175.28 (±132.93)	130.24 (±81.94)

A 2x2x2 analysis of variance (ANOVA) was conducted on handgrip and leg-raise performance, with drink (SSB, sugar-free) as the between-subject factor and with message (expect SSB, expect sugar-free) and time (pre, post-drink) as within-subjects factors. Seven outliers were identified (> 3 *SD*s above the mean) for endurance performance and excluded from the analysis.

Handgrip: Results indicated no main effect of drink or message (*p*s≥.146), however there was a main effect of time (*F* (1, 55) = 4.51, *p*=.038, n_p^2=.08) with significantly longer handgrip times at post-drink (101.70 ± 63.97) as opposed to pre-drink (90.56 ± 68.52). The predicted two interactions between message and time (*F* (1, 55) = .32, *p*=.575, n_p^2<.01) and between drink and time (*F* (1, 55) =.45, *p*=.504, n_p^2<.01), and predicted three-way interaction between message, drink and time (*F* (1, 55) =0.00, *p*=.998, n_p^2<.01) were non-significant.

Leg-Raise: There was no main effect of drink or message (*p*s≥.088), however there was a main effect of time (*F* (1, 55) =6.69, *p*=.012, n_p^2=.11) with significantly longer leg raise times post-drink (172.03 ± 160.48) as opposed to pre-drink (136.37 ± 94.92). The predicted interaction between drink and time was non-significant (*F* (1, 55) = .83, *p*=.367, n_p^2=.02), however, the interaction between message and time was highly significant (*F* (1, 55) = 8.91, *p*=.004, n_p^2=.14; see figure 4.4). Post hoc tests revealed a significant increase in leg raise times from pre-drink to post-drink following the Expect+ message (*p*=.002), but not the Expect- message (*p*=.421). However, the predicted three-way interaction between drink, message and time was non-significant (*p*=.890).

Figure 4.4- Graph showing mean endurance times (±*SE*) for the leg raise task at pre and post-drink time points



Subjective Measures

To determine the effect of a SSB and sugar expectancy on subjective sense of energy, analysis was performed on self-reported vigour and fatigue at immediately pre-drink (time 1) and at two time points post-drink; immediately post-drink (time 2) and following the endurance tasks (time 3) under all experimental conditions. Table 4.3 shows descriptive statistics for self-reported vigour and fatigue at pre- and post-drink time points under all conditions.

Table 4.3- Means (±*SD*) for self-reported fatigue and vigour pre and post-drink, under all combinations of conditions.

	Sugar+		**Sugar-**	
	Expect+ ***n*=31**	**Expect-** ***n*=31**	**Expect+** ***n*=32**	**Expect-** ***n*=32**
Vigour				
Pre-Drink (Time 1)	1.62 (±.66)	1.40 (±.75)	1.84 (±.91)	1.66 (±.80)
Post-Drink (Time 2)	1.63 (±.54)	1.56 (±.68)	1.93 (±.86)	1.69 (±.73)
Post-Drink (Time 3)	1.69 (±.61)	1.67 (±.63)	1.90 (±.86)	1.78 (±.75)
Fatigue				
Pre-Drink (Time 1)	.96 (±.73)	1.02 (±.71)	1.00 (±.68)	1.20 (±.92)
Post-Drink (Time 2)	.61 (±.61)	.94 (±.66)	.71 (±.79)	.86 (±.75)
Post-Drink (Time 3)	.67 (±.59)	.93 (±.74)	.77 (±.69)	.97 (±.75)

Data was analysed using a 2x2x3 ANOVA with drink (sugar+, sugar-) as a between-subjects factor and with message (expect+, expect-) and time (time 1, time 2, time 3) as within-subjects factors. Two participants had missing data points for the POMS subscales, and thus were excluded from the analysis.

Vigour: Results indicated that for vigour ratings there was a main effect of time (F (1.83, 105.40) =3.48, p=.038, n_p^2=.06; since Mauchly's test of Sphericity was violated Huynh-Feldt correction was reported ($\chi^2(2) = 9.0$, p=.011). Post hoc analysis indicated an increase in vigour from pre-drink (1.65 ± .67) to post-drink time point 3 (1.76 ± .63; p=.044), but not from pre-drink to immediately post-drink (1.70 ± .63; p=.830). However, there was no main effect of drink or message (ps≥.134). The predicted two-way interactions between drink and time and between message and time were non-significant (ps≥.425). The predicted three-way interaction between drink, message and time was also non-significant (p=.720).

Fatigue: Results indicated a main effect of time (F (1.80, 108.00) = 15.84, p<.001, n_p^2=.21); Huynh-Feldt correction was reported as Mauchly's test of Sphericity was violated (χ^2 (2) = 10.39, p=.006). Post hoc analysis revealed a significant reduction in fatigue from pre- to post-drink time points (ps≤.002), but no significant difference between post-drink time points (p=.494). Results also indicated a main effect of message (F (1, 120) = 6.24, p=.015, n_p^2=.09) with significantly higher fatigue in those who expected the sugar-free beverage (0.99 ± 0.69) than those who expected the SSB (0.79 ± 0.61). However, there was no significant main effect of drink (p=.668) and predicted interactions between message and time and between drink and time were non-significant (ps≥.332). There was also no three-way interaction between drink, message, and time (p=.153).

4.5 Supplementary Analysis

Breakfast Consumption Analysis

Breakfast consumption prior to each session may be an important consideration for analysis. To determine the potential influence of breakfast consumption on physical endurance performance and subjective energy, an additional factor was created. Participants were coded according to whether they consumed breakfast prior to both sessions, none of the sessions or prior to only one of the sessions. Individuals breakfast consumption patterns prior to the two experimental sessions are first presented below to determine if participants were consistent across the two sessions.

Breakfast Consumption Patterns

Table 4.4 demonstrates whether each individual consumed breakfast prior to each experimental session (by within-subjects factor message).

A chi-square was performed to determine whether breakfast consumption was consistent across the two sessions for each participant. Results indicated that breakfast consumption prior to each session was consistent for each participant $\chi^2(1)$ =38.81, p<.001, V=.78. As can be seen from table 4.4, 94.4% of individuals who consumed breakfast prior to the ‘expect+’ session also consumed sugar prior to the ‘expect-’ session. In addition, 82.1% who consumed no breakfast prior to the ‘expect+’ session also consumed no breakfast prior to the ‘expect-’ session suggesting that individuals were largely consistent across the two experimental sessions. Thus, inconsistencies in breakfast consumption did not appear to be a factor contributing to any differences in physical performance across the two sessions.

Table 4.4- Breakfast consumption prior to each experimental session.

			'Expect +' session		Total
			Consumed Breakfast	Consumed no Breakfast	
'Expect -' session	Consumed breakfast	N	34	5	39
		%	94.4%	17.9%	60.9%
	Consumed no breakfast	N	2	23	25
		%	5.6%	82.1%	39.1%
Total		N	36	28	64
		%	100%	100%	100%

ANOVA was then performed on physical endurance and self-report data (as in previous analysis), with breakfast consumption (prior to both sessions, prior to neither session) as an additional factor. Seven participants were inconsistent across sessions (consumed breakfast only on one session) and were therefore excluded from the analysis. Endurance performance outliers identified in previous analysis were also excluded.

Physical Endurance performance

A drink x message x time ANOVA was conducted (as previously) with breakfast (consumed breakfast, consumed no breakfast) as an additional between-subjects factor.

Leg-raise: The message x time interaction was marginally non-significant (F (1, 48) = 3.97, p=.052, n_p^2=.08, although sample analysed was smaller which could explain reduced significance (especially given the medium effect size reported). There was a significant increase in leg-raise endurance for those following the expect+ message (p=.011) but not following the expect- message (p=.087). The interaction between drink and time remained non-significant F (1,48) =.49, p=.486, n_p^2=.01 and there were also no significant three-way interactions between drink, breakfast and time F (1, 48) =.39, p=537, n_p^2 =.01 or message, breakfast and time F

(1,48) = .96, *p*=.333, n_p^2=.02, suggesting that breakfast consumption did not significantly influence these measures.

Handgrip: Results indicated an interaction between message and time (*F* (1, 48) =4.56, *p*=.038, n_p^2=.09, which was driven by a borderline significant interaction between breakfast, message and time *F* (1, 48) = 4.00, *p*=.051, n_p^2=.08. Follow up analyses revealed no significant message by time interaction for those who consumed breakfast prior to both sessions *F* (1, 30) = .01, *p*=.930, n_p^2<.001, however there was a significant message by time interaction for those who consumed no breakfast prior to both sessions *F* (1, 20) = 5.81, *p*=.026, n_p^2=.23. *Post hoc* analysis revealed no significant difference between expect+ and expect- at pre-drink (*p*=.825), however at post-drink there were significantly higher handgrip times following the expect+ message compared to the expect- message (*p*=.036).

Subjective Measures

A drink x message x time ANOVA was conducted with the addition of a between subject's factor breakfast (consumed breakfast, consumed no breakfast).

Following the addition of the breakfast factor to the ANOVA, results for fatigue and vigour ratings were consistent with those reported previously. Interactions between message and time (*p*s>.398) and drink and time (*p*s>.889) remained non-significant. In addition, there were no three-way interactions between drink, time and breakfast (*p*s≥.230), or message, time and breakfast (*p*s≥ .164).

Notably, independent samples t-test revealed that vigour ratings were significantly higher at baseline for those who consumed breakfast (1.77 ±.66) compared to those who consumed no breakfast (1.31 ±.65; *t* (54) = 2.56, *p*=.013, *d*=.70), however there was no significant difference for fatigue ratings (*p*=.356).

4.6 Discussion

The aim of this chapter was to investigate the contribution of pharmacological and anticipated effects of sugar, both combined and in isolation, to physical endurance and subjective energy. It was hypothesized that consuming a SSB would increase persistence on the physical tasks and subjective sense of energy. However, contrary to this, results indicated no effect of acute SSB consumption on endurance performance or subjective energy. It was also hypothesized that expecting sugar (regardless of the content) would improve physical endurance performance and increase subjective energy. Results indicated that expecting sugar improved endurance performance on the leg-raise task, however, not on the handgrip task and did not influence subjective sense of energy. Contrary to predictions, there was no combined effect of sugar and expectancy on physical performance or subjective measures, providing mixed support for the hypotheses.

Although previous research suggests that individuals expect SSB consumption to provide energy and improve physical performance (revealed in chapter three, also Costa et al., 2014; O’Dea, 2003), the current study found no evidence for improved physical performance on the handgrip and leg raise task or increased energy following consumption of a SSB. This is contrary to the proposed hypothesis and also contrasts with previous studies that have found SSB consumption to increase persistence across a range of endurance tasks, such as running endurance, arm crank and cycling endurance exercises (e.g. Ventura et al., 1994; Spendiff & Campbell, 2002).

One explanation for the discrepancy in findings may be due to the difference in tasks used to assess physical performance. The current study used tasks that required mild physical exertion, requiring use of only the hand/leg muscles and in this situation glucose availability would not have been a limiting factor. This is in contrast with the more intense physical exercises used in previous studies, where glucose reserves would have been depleted. Thus, in the real world, individuals should consider the situation in which they consume these beverages; in some cases, these beverages may be consumed under physical conditions where sugar consumption would have no additional benefit. Furthermore, it is possible that in previous studies some participants were able to detect the difference between the SSB and placebo, and thus expectancy effects may account for some of the positive effects that were attributed to sugar. Despite this, findings from the current study question the use of a SSB to provide a quick energy boost and to increase short-term physical energy. Although, conclusions about the effect of a SSB under intense physical exertion are unequivocal, low-calorie diet beverages are not only a ‘healthier’ option but with the addition of ingredients such as caffeine (consistently found to reduce fatigue and improve physical performance on a range of tasks; e.g. Forbes, Candow, Little, Magnus & Chilibeck, 2007; Smith, 2002), may be more (or at least just as) beneficial for physical endurance performance than consuming a high-calorie SSB, particularly under less intense task conditions when glucose levels are not depleted.

An important consideration in the current study was the contribution of sugar expectancy to physical endurance. In line with the hypothesis that expecting sugar would lead to improved physical endurance performance, results from the current study indicated improved performance on the leg-raise task in those who expected that they had consumed sugar (regardless of the beverage content). This finding is consistent with previous research that has found expectancies to be important across a range of substances on physical performance (Kalasountas et al., 2007; Hurst et al., 2013; Kirsch & Weixel, 1966). For example, Hurst et al. (2013) found improved running endurance following consumption of a placebo sports drink, and Kirsch and Weixel (1966) found improved motor performance following consumption of placebo caffeine (in those led to believe that it would improve performance). The current findings provide further insight into the importance of expectancy effects on physical performance and suggest that positive effects from sugar (at least in part) may be derived from individual’s expectations. Problematically, expectancy effects did not influence performance on the handgrip task, questioning the consistency of these sugar-related expectancies across a range of physical tasks. Although not explicitly tested, many participants reported that the leg-raise task was more strenuous than the handgrip task. Thus, participants may have put more effort/expected greater improvement in leg-raise performance from consuming sugar, although further research is required to disentangle the contribution of expectancy across a range of tasks.

Notably, when breakfast consumption prior to the session was accounted for, analysis revealed that for those who consumed no breakfast, there was greater persistence in the handgrip task post-drink when participants expected sugar compared to when they expected no sugar. However, sugar expectancy had no effect for those who consumed breakfast. Indeed, consuming breakfast increases the energy levels of the body and research suggests that breakfast omission has negative effects on how we perform physically and mentally throughout the entire day (e.g. Wyon, Abrahamsson, Jartelius & Fletcher, 1997; Scholey, Harper & Kennedy, 2001). Thus, in the current study those who consumed breakfast would have higher blood glucose starting the session and feel more invigorated. Indeed, results indicated higher vigour ratings at baseline for those who consumed breakfast prior to the session compared to those who did not consume breakfast. Thus, these individuals may be closer to their optimum physical performance, compared to those who did not consume breakfast. Surprisingly, consuming the sugar beverage did not improve performance in this group, suggesting that people’s expectations may be more important in guiding their behaviour. These results indicate that larger expectancy effects on physical endurance may be evident when energy levels are low (i.e. after a period of fasting), although future research is required to explore this idea.

Contrary to predictions, expectancy effects did not influence subjective ratings of energy, which is in contrast with response expectancy theory which argues that individual’s respond in accordance with what they expect to happen (e.g. Kirsch, 1997). Notably, in the current study daily consumption of SSBs varied across participants. However, as revealed in chapter three, individuals who consume high quantities of these beverages (those ‘at-risk’ of health issues) are more likely to expect these positive effects. Although participants were provided with a message informing them of the positive physical effects of these beverages, this may be in contrast with beliefs they have already formed and therefore participants may have been resilient to the effects of new information. In addition, the beverage was presented in a plain, non-branded cup. Individual’s may form expectations related to certain brands or specific categories of SSBs. For example, sports and energy drinks are directly marketed as specifically boosting energy and to improve physical performance, and thus these beverages may have stronger sugar-related expectancies associated with them.

In summary, present study findings suggest that acute sugar consumption had no effect on short-term physical energy (assessed using hand grip and leg-raise task) or subjective ratings of energy. Any effects found were due to individual's expectancies; expecting sugar led to an increase in endurance times for the leg-raise task. In addition, expectancy effects enhanced performance on the handgrip task if participants had not consumed breakfast prior to the study. However, expectancy effects did not influence subjective ratings of energy. Together, these findings suggest that consuming an SSB is not beneficial for short-term physical activity, and that individual's expectancies are more important in influencing physical persistence. Although there is need for more research in this area, it may be more beneficial to consume a low-calorie, healthier option with the addition of other 'performance enhancing' ingredients such as caffeine.

Chapter Five:

The effects of sugar and expectancies on cognitive performance and subjective energy

5.1 Abstract

Studies investigating the effects of sugar on cognition have produced equivocal findings. One reason for this may be the influence of the anticipated effects of sugar. Problematically, most previous studies use the standard-placebo controlled design (SSB vs placebo sugar) which lacks adequate control conditions to isolate the anticipated effects. Using a balanced placebo design, study 5.1 explored both the pharmacological and anticipated effects of sugar on cognitive performance (verbal fluency, inhibitory control and memory recall) and measures of subjective energy. Participants were allocated to one of four conditions in which the beverage content (sugar, sugar-free) and expected content (sugar, sugar-free) was manipulated (*N*=307). Study 5.2 expanded on findings from study 5.1, manipulating the anticipated effects of sugar using a placebo-sugar beverage only. Participants received one of four messages in which information about the cognitive and subjective effects of SSBs was manipulated (*N*=294). Study 5.1 indicated no effects of sugar on cognitive performance or subjective energy. Both studies indicated no anticipated effects of sugar on performance in any cognitive tasks, however, the anticipated effects of sugar influenced subjective measures. Study 5.1 revealed a significant reduction in self-reported fatigue and tiredness for those who expected a SSB, but not those who expected sugar-free. There was also a significant reduction in self-reported vigour for those who expected sugar-free but not those who expected a SSB. Study 5.2 found a significant reduction in fatigue and increase in vigour for those who expected increased energy but no significant change in those who expected no effect. There was also a greater reduction in tiredness for those who expected increased energy compared to those who expected no effect. Results suggest no beneficial effect of acute sugar consumption on cognitive performance or subjective energy, however, there is some contribution of expectancy concerning the positive effects of consuming sugar on self-report measures.

5.2 Introduction

Some of the highest rates of SSB consumption have been reported in undergraduate students, with 65% reportedly consuming these beverages on a daily basis (West et al., 2006). One reason for the high rates of consumption in this population may be the expected positive effects (‘outcome expectancies’) associated with consuming these drinks (e.g. Su, 2012). Indeed, some individuals expect SSBs to provide ‘a quick burst of energy’ (Tuorila et al., 1990; Ruiz et al., 2012) and to improve cognitive performance and concentration whilst studying (Malinauskas, Aeby, Overton, Carpenter-Aeby & Barber-Heidal, 2007; Attila & Cakir, 2010; Bulut, Beyhun TopbaŞ & Çan, 2014). This was highlighted in chapter three with expected cognitive effects incorporating the largest subscale of the SOES and high consumers more likely to expect these positive cognitive effects. These findings suggest that SSBs are sometimes utilised as an aid in cognitively demanding student environments.

Studies investigating the effect of sugar on executive function (e.g. inhibitory control, verbal fluency) have produced equivocal findings. Typically, in these studies, participants consume either a sugar sweetened beverage (in the form of glucose) or a placebo sugar beverage. Studies have most consistently reported effects of glucose on Stroop performance (Brandt et al., 2013; Craft et al., 1994; Gaillot et al. 2007), although the results are inconsistent across Stroop measures. The former two studies found improved reaction times (with a corresponding increase in errors in the second study), whereas the latter study found reduced errors (suggesting that significant findings can be attributable, at least in part, to the analytical flexibility offered by the Stroop). Notably, Craft et al. (1994) also utilised a serial addition and verbal fluency task but failed to find effects of sugar. In another study by Kennedy and Scholey (2000) glucose improved performance on a verbal fluency and serial subtraction task, although only in the more demanding mental arithmetic (serial sevens), but not the less demanding serial threes task. Conversely, there is also evidence for impaired cognitive performance (e.g. simple response time, mental arithmetic and Stroop performance) following glucose (Ginieis et al., 2018).

Research also suggests that compared to a placebo control, a glucose-sweetened beverage can improve memory recall in young healthy adults (e.g. Stollery & Christian, 2013; S*ü*nram-lea et al., 2001; Riby et al., 2008) with the former showing improved delayed recall only and latter glucose facilitation of more difficult (abstract) words only. Notably, Scholey and Kennedy (2004) found that glucose and caffeine, in combination, improved episodic memory performance however, when glucose was investigated in isolation there was no effect on free recall. Taken together, the effects of sugar on executive function are mixed with results varying within and between tasks. Studies utilising some executive tasks (e.g. verbal fluency) are lacking and require more research. Furthermore, glucose appears to be more sensitive to verbal episodic memory although some studies fail to find this.

One reason for these equivocal findings may be due to the lack of sufficient control conditions. Indeed, most current studies investigating the effects of SSBs on cognitive performance utilise a standard-placebo design (SSB vs placebo-sugar) which does not allow for isolation of anticipated effects. In the real world, the effects of consuming a SSB on cognition would involve the combined effects of sugar and expectancies. As a result, mixed findings in previous studies, may occur due to the influence of individual’s anticipated effects.

There is a considerable evidence base which suggests that the anticipated effects of a substance, in the absence of the substance can influence cognitive performance (see chapter one, section 1.4.3.1). To briefly summarise, placebo alcohol has been found to impair cognitive performance (e.g. Christiansen et al., 2016; Fillmore & Vogel-Sprott, 1995; Gilbertson, Prather & Nixon, 2010), with the former two studies showing impaired performance correlated with expectation of alcohol-induced cognitive decline. In addition, studies report that placebo caffeine improves attention and cognitive performance in sleep-deprived (Sun, Zhang, He, Liu & Miao, 2007; Anderson & Horne, 2008) and enhances alertness and also motor performance in students who expect these effects (Kirsch & Weixel, 1988). Notably, individuals do not need cumulative experience with a substance for expectancies to impact performance. Specifically, Kvavilashvili and Ellis (1999) found a placebo pill impaired memory performance in those told the pill would impair memory, however the placebo pill did not influence memory performance in those who expected improvement, possibly due to reduced effort on the task. Taken together, these studies demonstrate that outcome expectancies influence cognitive performance across several domains.

To adequately explore both the pharmacological and anticipated effects of a substance a balanced placebo design is necessary. Currently, only two studies have used the balanced placebo design to isolate the pharmacological and anticipated effects of sugar on cognition (Green et al., 2001; Stollery & Christian, 2013). The former study found that glucose produced faster access to words in an immediate recognition task. Glucose also improved performance in a sustained attention (Bakan) task but only in those who received the drink congruent message (told received glucose). There was no effect of drink or expectancy on immediate free recall or a finger tapping task. The latter study found that glucose improved performance on a delayed recall task, but not on immediate recall, category verification or a spatial location task. There were some message effects; in the category verification task, there was a borderline significant effect of message (although medium effect size) with the ‘told glucose’ group responding more slowly than those ‘told diet’. Furthermore, in the spatial location task, those receiving a glucose beverage with a glucose congruent message showed a slower decline in accuracy as memory load increased (than those who expected placebo).

Critically, Stollery and Christian (2013) acknowledged that beliefs participants form about the drink content (whether it contains glucose or not) may not always coincide with the message given and in turn expectancy effects may derive from these beliefs. They found that believing glucose was consumed (regardless of the beverage content) independently improved episodic memory (although immediate recall was unaffected) and impaired semantic memory. In the spatial recognition task, those who consumed a glucose beverage were faster at recognising a valid location, but not rejecting an invalid location, however, this was only true for those who believed they had received placebo. Thus, believing they had received glucose seemed to ‘mask’ this effect. One explanation for this is that expecting glucose led to reduced effort on the task. There was also an increase in arousal from pre- to post-drink for those believing that they had consumed a glucose drink, but not those believing they had consumed a placebo drink. Although research in this area is limited (see Bellisle, 2001), results suggest the potential importance of sugar and expectancies on cognitive performance, warranting the need for research utilising fully balanced placebo designs across different cognitive domains and tasks.

The aim of this chapter was to determine the influence of a SSB and expectancy effects on cognitive performance and subjective energy. Previous studies looking at the effect of a SSB on cognitive performance have produced mixed results; this could be due to lack of an adequate control (i.e. balanced placebo design not used) as well as the effects of sugar being task-specific. Thus, using a balanced placebo design the aim of study 5.1 was to determine the influence of a SSB and anticipated effects of sugar on a range of cognitive tasks. As in chapter four, self-report measures of subjective energy were included to explore the pharmacological and anticipated effects of sugar on subjective energy in a different context. Study 5.2 aimed to expand on findings from study 5.1 by further exploring the role of anticipated effects on cognitive performance and subjective energy by manipulating individual's beliefs about the cognitive and subjective effects of sugar using a placebo-sugar beverage only.

5.3 Study 5.1

In study 5.1 participants were allocated to one of four conditions in a balanced placebo design. Two groups consumed a sugar beverage with one of these groups told that the beverage contained sugar (Sugar+/ Expect+) and the other told that the beverage was sugar-free (Sugar+/Expect-). The other two groups consumed a placebo sugar drink with one group told that the beverage contained sugar (Sugar-/Expect+) and the other that it was sugar-free (Sugar-/Expect-). Cognitive performance, as well as subjective measures of energy and boredom were assessed at pre- and post-drink time points. It was predicted that; 1) consuming a SSB would enhance cognitive performance and increase subjective energy; 2) expecting to consume a SSB (regardless of drink contents) would enhance cognitive performance and increase subjective energy following drink consumption; 3) the largest effect would be found in those who consumed a SSB and expected a SSB, i.e. a combined pharmacological and expectancy effect.

5.3.1 Methods

Participants

307 first year psychology undergraduates (261 females) aged between 18 and 21 (*M*=18.00, *SD*=1.57) participated during their seminar. This sample size was deemed sufficient from a power calculation to detect a small to medium effect with 80% power (Cohen's f=0.15, α=.05). Small to medium effect size was chosen based on effect sizes of interactions involving message, drink and time in the previous chapter. Participants were required to speak fluent English and were not eligible to participate if they had a diagnosis of diabetes or a strong dislike for sweet beverages. The study was approved by the University of Liverpool ethics committee and all participants provided informed consent.

Measures

SSB consumption – See chapter two general methods.

SSB expectancies – See chapter four methods section for description of SOES. This study focused on the cognitive/physical effects subscale.

Subjective measures – The profile of mood states-short form (SF-POMS; Shacham, 1983) measures six dimensions of mood. This study focussed on the fatigue (6 items) and vigour (5 items) dimensions of the scale. Participants were required to self-report how they felt from 0 (not at all) to 4 (extremely), for each adjective. Two additional 25-point Likert scales measuring subjective tiredness and boredom were included.

Cognitive Tasks

Stroop Task (Stroop, 1935) - This task was used as a measure of executive function, specifically inhibitory control. Participants were presented with the words ‘blue’, ‘green’, ‘yellow’ and ‘red’ printed in a mismatched colour (60 words, 15 of each colour). E.g. the word ‘red’ printed in green ink or the word ‘blue’ printed in yellow ink. Participants were required to name the colour of the ink, whilst ignoring the word itself. This task was completed in pair. Time taken to complete the task (secs) was recorded by the other person in the pair . There were two variations of the task; one provided at pre-drink and the other at post-drink (order counter-balanced across groups).

Controlled Oral Word Association Task (COWAT; Benton, 1967) – This was used as a measure of verbal fluency, which taps into various components of executive function, such as response inhibition, cognitive flexibility, strategy utilization and suppression of interference. Participants were provided with the three letters ‘PLW’ and ‘FAS’ (see Christiansen et al., 2013); with one set provided pre-drink and the other post-drink (counter-balanced across groups). These combinations of letters have been found to produce a similar number of words in previous studies (Ross et al., 2007). They had one minute (per letter) to write down as many words as they could beginning with that letter, excluding proper nouns and the same word with a different suffix. The dependent variable was the total number of words produced across the three letters.

Memory Recall (word list taken from Walker & Hulme, 1999) - Participants were shown a list of 20 words (10 abstract and 10 concrete) at a rate of two seconds per word. The list consisted of one syllable words between three and six letters long and were matched for frequency of occurrence in the English language (Kucera & Francis, 1967). Participants were given three minutes to write down as many words as they could remember immediately (immediate recall) and 35 minutes after word presentation (delayed recall). The dependent variables were the number of abstract and concrete words remembered.

Drink preparation

Beverages were prepared prior to the study. See chapter two general methods for description of SSB and placebo-sugar beverage.

Design

This study utilised a between-subjects design. Participants were allocated to one of four conditions defined by two independent factors; drink (Sugar+, Sugar-) and message (Expect+, Expect-) by class so that all students in the same class completed the same experimental condition. Subjects in the first condition (Sugar+/Expect+) received a SSB and were told the beverage contained sugar. Another condition (sugar+/Expect-) received an SSB and were told the beverage was sugar-free. The third condition (Sugar-/Expect+) received a placebo sugar drink and told the beverage contained sugar and the subjects in the final condition (Sugar-/Expect-) received a placebo sugar drink and told the beverage was sugar-free.

Verbal fluency and Stroop performance was assessed at two time points; pre-drink and post drink. Word list recall was assessed twice at post-drink time points; immediately post-drink (immediate recall) and 35 minutes post-drink (delayed recall). Finally, self-report measures were taken at three time points; pre-drink, immediately post-drink and 35 minutes post-drink.

Seminar Approach

All testing took place during student seminars. Seminars were in both the morning and afternoon; classes were allocated to one of the four experimental conditions so that each condition consisted of similar number of participants who took part in a morning or afternoon session. Participants completed all tasks alone apart from the Stroop task which they were instructed to complete the Stroop task in pairs (so that the other person could time them). The two variants of the COWAT and Stroop (one completed pre-drink and one completed post-drink) were matched for difficulty level. The order of completion was counterbalanced across classes to control for any potential effects of task difficulty.

Procedure

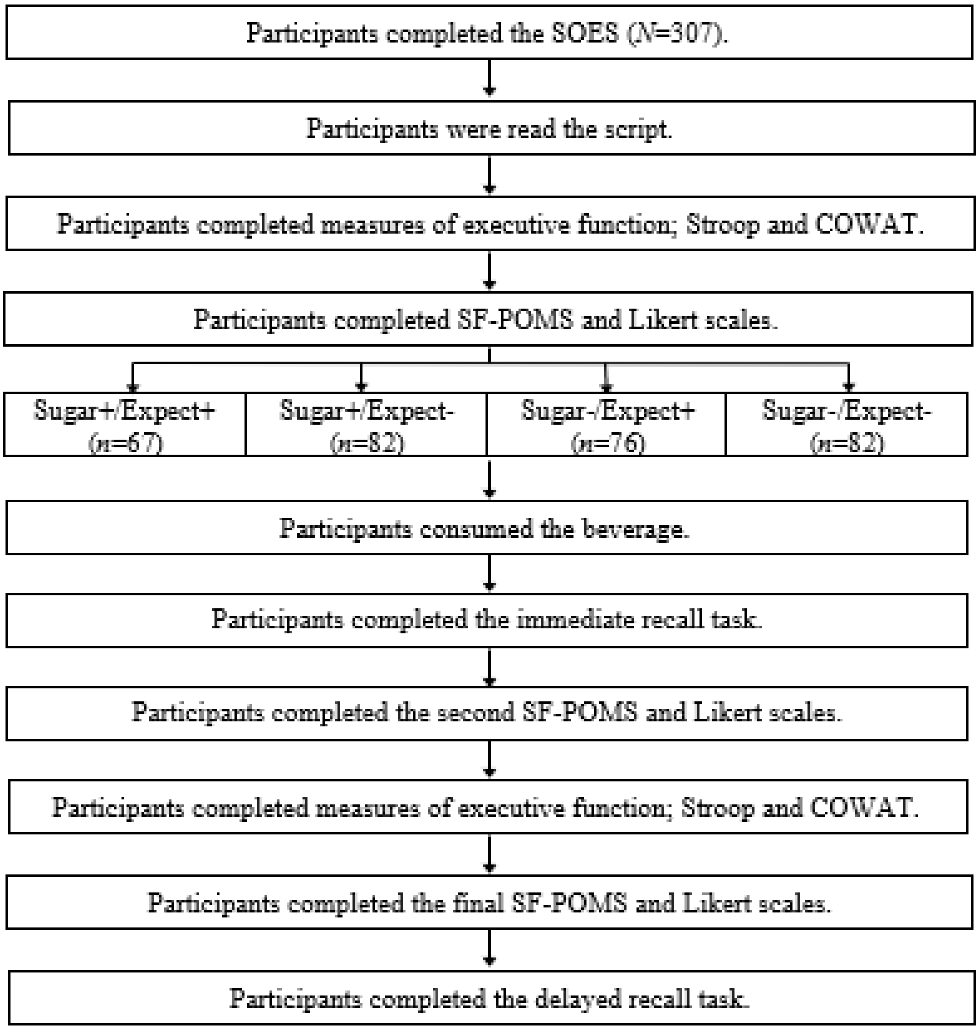
Beverages were prepared prior to the session and questionnaire/task booklets ready on student's desks for the start of the class. First, participants were asked to provide informed consent before completing basic demographics (e.g. age, gender, height, weight), followed by completion of the SOES. They were then read the following script: "Sugar consumption is suggested to effect several aspects of behaviour including cognitive performance. Research has found that consumption of a sugar-sweetened beverage can improve executive function, including self-control and verbal fluency, as well as performance on memory tasks. During this session, you may be asked to consume a sugar-sweetened beverage". Participants then completed the Stroop (in pairs) and COWAT, followed by SF-POMS and likert scales.

Prior to consuming the beverage, participants were read a message informing them of the contents of the drink. The 'Expect+' groups were provided with the message: *"The drink provided on your desk is a sugar-sweetened beverage. It contains glucose and therefore we would expect it to provide you with energy and improve your performance on the cognitive tasks. If for any reason, you cannot consume sugar, feel free to withdraw now. You have five minutes to consume the drink. This will be followed by a ten-minute absorption period to allow the sugar to enter the blood stream".*

Those in the 'Expect-' groups were read the message:
"The drink provided on your desk is a sugar-free beverage, sweetened with the artificial sweetener sucralose. It is low calorie and therefore we would not expect it to provide you with energy or improve your performance on the cognitive tasks. You have five minutes to consume the drink".

Following this, participants had five minutes to consume the drink. Then there was a ten minute absorption (by which time blood glucose levels should have increased, Meikle, Riby & Stollery, 2004; Stollery & Christian, 2013) during which participants were asked to complete the BFQ. Participants then completed the immediate recall task, SF-POMS and Likert scales followed by the second Stroop (in pairs) and COWAT. Next, participants completed the final SF-POMS and Likert scales, followed by the delayed free recall task (35 mins post word presentation). Finally, participants estimated how many calories they thought was in the beverage.

Figure 5.1- Schematic overview of experimental procedure



5.3.2 Results

The basic design for analysis of task performance and self-report measures in section one and two of the analyses was a two-factor independent Analysis of Variance

(ANOVA); Drink (Sugar+, Sugar-) x Message (Expect+, Expect-). Other within subjects factors are identified at the start of each analysis. For all analyses, a Bonferroni correction was applied during post hoc testing. For related measures, when sphericity was violated, Huynh-Feldt correction was reported where appropriate (based on magnitude of ε, wherein values >.75).

Data is presented in two sections;
Section one analysis: conducted on the whole data set (*N*=307) to determine the influence of sugar and sugar expectancy on cognitive performance and measures of subjective energy.
Section two analysis: focusses on those who 'believed' the message manipulation (considered important by Stollery & Christian, 2013). Beliefs about the contents of the drink may differ from the actual message given, for example, the Expect+ group may be able to detect that the drink is in fact a diet drink and expectancies may derive from these beliefs. Estimated drink calories were used as an indicator of whether participants believed the message. In the 'expect+' condition, those who reported that the drink contained more than 100 calories were classified as those who believed the 'told glucose' message. In the 'expect-' condition, those who reported that the drink contained less than 50 calories were classified as believing the 'told diet' message. 152 participants were excluded from the analysis (final *n*=155).

Sample Characteristics

A summary of sample characteristics for each group can be seen in Table 5.1. There was no significant difference between groups in age (F (3, 303) =0.61, p= .609, η_p^2=.01), daily SSB consumption (17 missing values; F (3, 286) =0.52, p=.670, η_p^2=.01) or BMI (F (3, 259) =.89, p=.449, η_p^2=.01). However, there were group differences in expected cognitive and physical effects at baseline (F (3, 303) =3.55, p=.015, η_p^2=.03). Post hoc comparisons revealed that group 2 and 3 were more likely to expect positive cognitive and physical effects from SSBs than group 1 (*p*s<.050). Pearson's correlation revealed that apart from a marginal correlation between scores on the expected cognitive/physical effects SOES and Time 3 vigour ratings (although small effect size; r=.11, p=.047) there was no significant correlation between scores on the expected cognitive\physical effects SOES and any of the cognitive performance or self-report outcome measures (*p*s≥.089).

Table 5.1- Means (±*SD*) for age, SSB consumption, BMI and SOES for each group

	Sugar+		**Sugar-**	
	Expect+ ***n*=67**	**Expect-** ***n*=82**	**Expect+** ***n*=76**	**Expect-** ***n*=82**
Age	19.08 (±1.35)	19.01 (±1.67)	19.11 (±2.17)	18.80 (±.78)
BMI	22.89 (±4.84)	23.18 (±13.42)	22.51 (±4.84)	21.05 (±3.64)
SSB Consumption	276.11 (±366.18)	354.30 (±366.93)	360.64 (±547.12)	341.71 (±435.59)
SOES Cognitive/ Physical Effects	3.11 (±.64)	3.40 (±.59)	3.38 (±.51)	3.26 (±.60)

Section One: Analysis on Full Sample

In this section, analysis of task performance and self-report measures is performed on the full sample (*N*=307). Since the sample consists of unequal males and females and there are a small number of males in each group, the influence of gender cannot be explored in ANOVA. Results of ANOVA for ‘female only’ data is highly consistent with that of the whole sample, and thus males were retained for this analysis. To see analysis on females only subsample refer to Appendix E.

Cognitive Performance

To determine the influence of SSB consumption and expectancy effects on cognitive performance measures, verbal fluency (COWAT) and Stroop performance was assessed pre- and post-drink. Memory recall was assessed immediately post-drink and following a 35 minute delay. Table 5.2 shows descriptive statistics for task performance for all combinations of conditions.

Table 5.2- Means (±*SD*) of cognitive performance measures for each of the four experimental conditions.

	Sugar+		**Sugar-**	
	Expect+ ***n*=67**	**Expect-** ***n*=82**	**Expect+** ***n*=76**	**Expect-** ***n*=82**
COWAT				
Pre-Drink	35.06 (±6.64)	35.14 (±8.01)	35.33 (±8.61)	34.71 (±8.40)
Post-Drink	40.00 (±6.20)	39.62 (±8.23)	40.49 (±9.26)	38.74(±7.92)
Stroop Time				
Pre-drink	53.70 (±10.35)	53.57 (±9.58)	52.63 (±13.87)	55.24 (±14.37)
Post-Drink	47.64 (±8.45)	48.36 (±9.14)	46.03 (±7.60)	46.72 (±9.78)
Recall (Concrete)				
Immediate	5.13 (±1.63)	4.44 (±1.62)	5.18 (±1.77)	5.20 (±1.74)
Delayed	4.09 (±1.72)	3.58 (±1.55)	4.12 (±1.94)	4.30 (±1.78)
Recall (Abstract)				
Immediate	4.19 (±1.70)	4.32 (±1.11)	4.44 (±1.58)	4.35 (±1.62)
Delayed	3.29 (±1.79)	3.15 (±1.57)	3.29 (±1.48)	3.29 (±1.68)

COWAT: Number of words produced was analysed using a 2x2x2 mixed ANOVA with time (pre-drink, post-drink) as the related factor. Results indicated a main effect of time (*F* (1, 303) =187.37, *p*<.001, η_p^2=.38); significantly more words were produced post-drink (*M*=35.11, *SD*=7.94) as opposed to pre-drink (*M*=39.72, *SD*=8.01). There were no significant main effects of drink or message, and the predicted two-way interactions between drink and time, and message time, and three-way interaction between drink, message and time were non-significant (*p*s>.050).

Stroop Task: Time taken to complete the task (secs) was analysed using a 3-factor mixed ANOVA design with time (pre-drink, post-drink) as the related samples factor. Seven extreme outliers were excluded from the analysis (more than 3 *SD*s above or below the mean).

Results indicated a significant main effect of time (*F* (1, 296) = 263.99, *p*<.001, η_p^2=.47) with significantly lower Stroop times post drink (*M*=47.18, *SD*=8.84) as opposed to pre-drink (*M*=53.89, *SD*=12.26) There were no other significant main effects of drink or message and the predicted two-way interactions between drink and time and message and time were non-significant ($ps \geq .087$). The predicted three-way interaction between drink, message and time was also non-significant ($p=.066$).

Free Recall: Number of words remembered was analysed using a four-way ANOVA with word type (abstract, concrete) and delay (immediately post-drink, 35 minutes post-drink) as related samples factors. There was a main effect of word-type (F (1, 303) =37.07, $p<.001$, $\eta_p^2=.11$) with significantly more concrete words (M=4.50, SD=3.79) recalled than abstract words (M=3.79, SD=1.53). There was also a main effect of delay (F (1, 303) =442.91, $p<.001$, $\eta_p^2=.59$) with more words remembered immediately post-drink (M=4.66, SD= 1.21) than 35 minutes post-drink (M=3.64, SD=1.36). There were no main effects of drink or message ($ps \geq .087$). The predicted two-way interactions between message and time, and drink and time ($ps \geq .694$), and three-way interaction between drink, message and time ($p=.381$) were non-significant.

Self-Report Measures

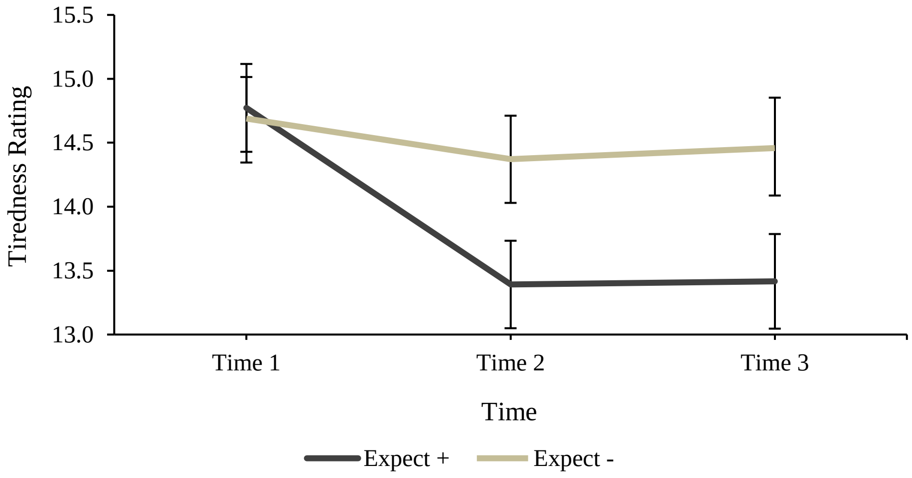
For all self-report measures a three-way ANOVA was conducted with time (pre-drink (time 1), immediately post-drink (time 2), 35 minutes post-drink (time 3)) as the within subjects factor. Table 5.3 shows descriptive statistics for subjective measures for all combinations of conditions.

Table 5.3- Means (±*SD*) of self-report measures for each of the four experimental conditions.

	Sugar+		**Sugar-**	
	Expect+	**Expect-**	**Expect+**	**Expect-**
	***n*=67**	***n*=82**	***n*=76**	***n*=82**
Tiredness VAS				
Time 1	14.77 (±3.92)	14.41 (±4.47)	14.78 (3.89)	14.97 (±4.34)
Time 2	13.56 (±4.31)	14.38 (±4.25)	13.24 (3.85)	14.36 (±4.54)
Time 3	13.40 (±4.83)	14.70 (±4.58)	13.43 (6.67)	14.21 (±4.91)
Boredom VAS				
Time 1	11.11 (±3.98)	11.46 (±5.33)	10.61 (±4.57)	11.43 (±4.87)
Time 2	11.19 (±4.50)	13.08 (±5.17)	11.80 (±5.06)	11.87 (±4.99)
Time 3	12.20 (±5.59)	13.39 (±5.49)	12.88 (±5.68)	12.64 (±5.76)
Vigour SF-POMS				
Time 1	.95 (±.64)	1.06 (±.70)	1.04 (±.67)	1.01 (±.66)
Time 2	.92 (±.70)	.96 (±.70)	1.06 (±.66)	.95 (±.58)
Time 3	.88 (±.67)	.85 (±.62)	1.11 (±.83)	.88 (±.58)
Fatigue SF-POMS				
Time 1	1.26 (±.84)	1.53(±.91)	1.52 (±.90)	1.49 (±.98)
Time 2	1.16 (±.80)	1.51 (±.89)	1.36 (±.84)	1.38 (±.90)
Time 3	1.12 (±.83)	1.62 (±.85)	1.37 (±.97)	1.37 (±.90)

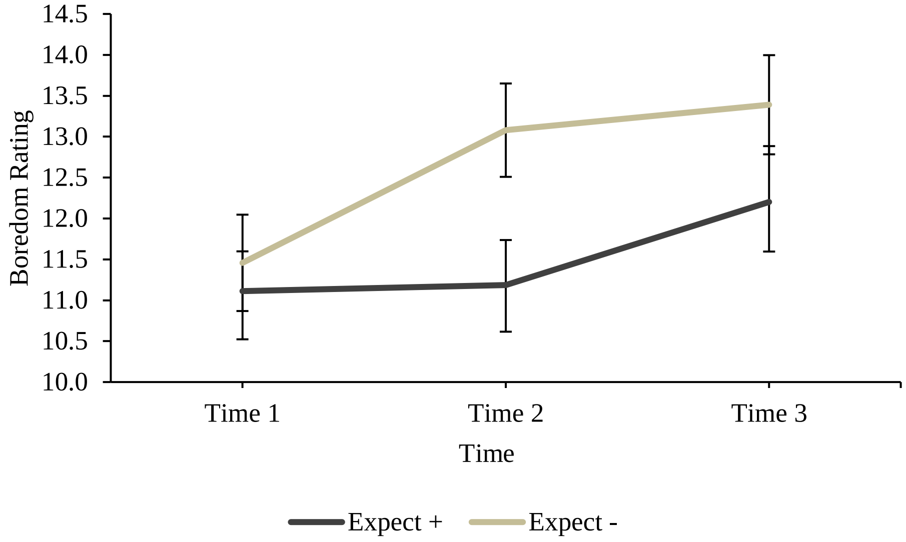
Tiredness: There was a main effect of time (F (1.79, 541.93) = 11.56, p<.001, η_p^2=.04). Post hoc comparisons revealed a significant reduction in tiredness from pre- to both post-drink time points (ps≤.002), however, no significant change in tiredness between post-drink time points (p=1.00). No other significant main effects were revealed. Critically, there was a significant interaction between time and message (F (1.79, 541.93) =5.12, p=.008, η_p^2=.02; see figure 5.2). Post-hoc analysis revealed a reduction in tiredness from pre-drink to both post-drink time points (ps<.001) following the expect+ message (p<.001), but not the expect- message (ps≥.631). There were no other significant interactions (ps≥.354).

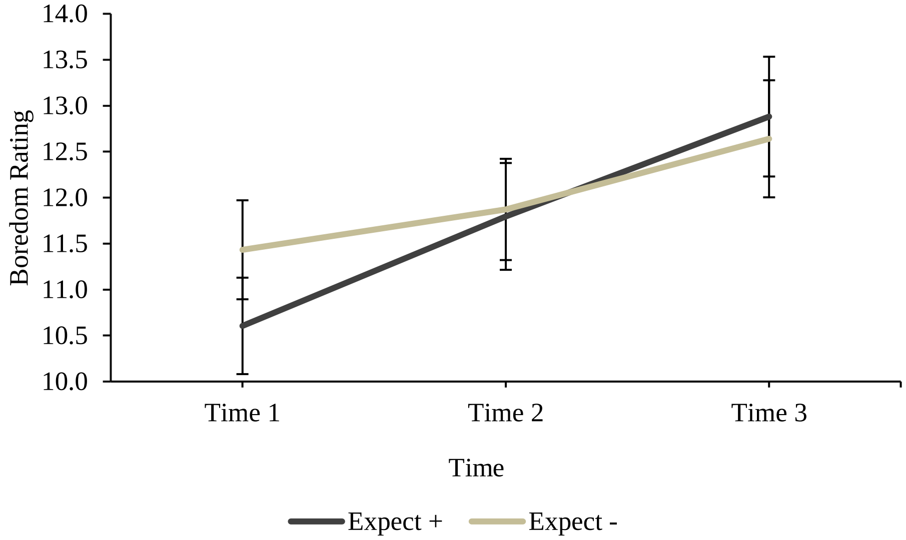
Figure 5.2- Graph showing mean tiredness ratings (±*SE*) for those provided with the 'expect+' and 'expect-' message at pre-drink and post-drink time points.



Boredom: Results indicate a significant main effect of time (*F* (1.81, 549.60) =22.06, *p*<.001, η_p^2=.07) with a significant increase in boredom from pre-drink to both post-drink time points (*p*s<.001) and between post-drink time points (*p*=.002). Results also revealed a significant message x drink x time interaction (*F* (1.81, 549.60) =3.16, *p*=.048, η_p^2=.01; see figure 5.3), although the effect size is very small, and thus should be treated with caution. Post hoc analysis indicated that the message x time interaction was non-significant in the sugar- group (*p*=.291), however, there was a trend towards significance in the sugar+ group (*F* (1.74, 258.28), *p*=.085, η_p^2=.02). Since the effect size increases in the two-way interaction, the non-significance may have occurred due to a reduction in statistical power. Post-hoc tests on the sugar+ condition revealed an increase in boredom from pre- to both post drink time points (*p*=.001) for those who received the expect- message but not for those who received the expect+ message (*p*s>.050).

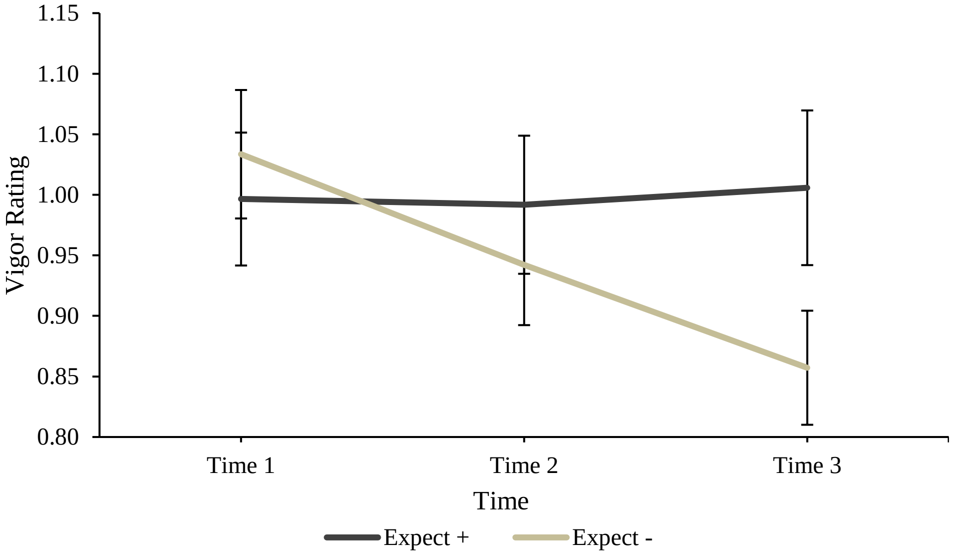
Figure 5.3- Graph showing mean boredom ratings (±*SE*) for the Sugar + (top) and Sugar - (bottom) conditions. Results are shown for those provided with the expect- and expect+ message at pre-drink (time 1) and both post-drink time points (time 2 and 3).





Vigour SF-POMS: There was a main effect of time (*F* (1.96, 592.42) = 5.22, *p*=.006, η_p^2=.02). Although there was no significant change in vigour from pre to immediately post-drink (*p*=.176), there was a significant reduction in vigour from pre-drink to 40 minutes post drink (*p*=.010). This was qualified by an interaction between time and message (*F* (1.96, 592.42) = 5.81, *p*=.003, η_p^2=.02; depicted in figure 5.4). Post hoc analysis revealed a reduction in vigour from pre-drink to both post-drink time points (*p*s≤.029) and between post-drink time points (*p*=.038) for those who received the expect- message, but no significant change for those who received the expect+ message (*p*s=1.00).

Figure 5.4- Graphs showing mean vigour ratings (±*SE*) for those provided with the expect+ and expect- messages at pre-drink (time 1) and both post-drink (time 2 and time 3) time points.



Fatigue SF-POMS: Results indicated a main effect of time (*F* (1.84, 558.81) = 6.23, *p*=.003, η_p^2=.02) with a significant reduction in fatigue from pre-drink to immediately post drink (*p*=.001), however there was no significant change in fatigue at post-drink time points (*p*=1.00). There were no significant main effects or interactions involving drink or message (*p*s≥.063).

Section Two: Subsample Analysis ('Believed' message)

Cognitive Performance

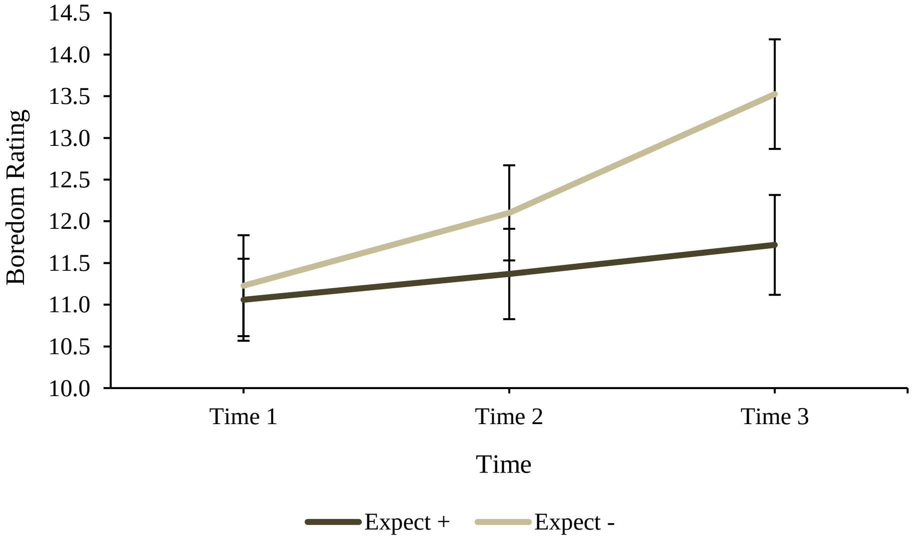
Analysis on this subsample (those who 'believed' the message) revealed no additional main effects of message or interactions involving message for COWAT, Stroop or word recall performance. Overall, results are entirely consistent to section one with no additional statistically significant results found, therefore, analyses on cognitive performance for this subsample are not reported here.

Self-Report Measures

The influence of message on self-report measures in this subsample are largely consistent to the analysis on the full sample, although there was a small increase in effect sizes for message x time interactions. There were additional significant message x time interactions for boredom and fatigue ratings which are reported below (see Appendix F for analysis on other subjective measures).

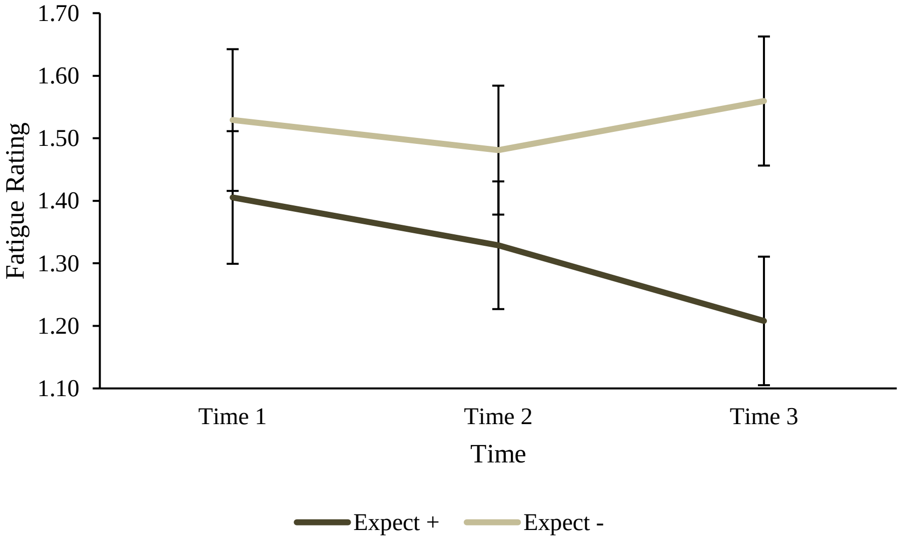
Boredom: There was a time x message interaction (*F* (1.74, 262.90) = 3.65, p=.033, η_p^2=.02; shown in figure 5.5) in this subsample. Post hoc analysis reveal an increase in boredom from pre-drink to both post-drink time points and at post-drink time points (p=.003) for those provided with the ‘expect-’ message ($ps \leq .028$). However, there was no significant change in boredom for those provided with the ‘expect+’ message ($ps \geq .657$).

Figure 5.5- Graph showing mean boredom ratings (±*SE*) for those provided with the ‘expect+’ and ‘expect-’ message at pre-drink (time 1) and post-drink (time 2 and 3) time points.



Fatigue SF-POMS: Analysis indicated a time x message interaction (*F* (2, 302) = 6.33, *p*=.002, ηp^2=.04; shown in figure 5.6) in this subsample. Post-hoc analysis revealed a significant reduction in fatigue from pre-drink to 35 minutes post-drink and between post-drink time points for those provided with the expect+ message (*p*=.004) but no significant changes in tiredness for those provided with the expect- message (*p*s≥.218). There was no effect of message at pre-drink or immediately post-drink (*p*s≥.261), but at 35 mins post-drink there was significantly lower fatigue ratings in those who received the expect+ than expect– message (*p*=.013).

Figure 5.6 – Graph showing mean fatigue ratings (±*SE*) for those provided with the 'expect +' and 'expect -' message, at both pre (time 1) and post-drink (time 2 and 3) time points.



5.3.3 Discussion

The aim of the current study was to investigate the influence of acute sugar consumption and expectancy effects, both alone and in combination, on subjective energy and cognition (executive function and recall) using a balanced placebo design. Results indicated that there was no effect of acute sugar consumption or expectancy effects on executive cognitive function or recall performance, even under the more difficult task condition. There was also no effect of acute sugar consumption on subjective energy or boredom, however sugar expectancy did influence subjective energy and boredom. Specifically, expecting a SSB resulted in a significant reduction in self-reported tiredness and fatigue, but this was not evident when participants expected a sugar-free drink. Furthermore, there was a significant reduction in self-reported vigour and an increase in boredom for those who expected a sugar-free drink, but not for those who expected a SSB.

The null effect of expectancy on cognitive performance is contrary to some previous findings demonstrating that sugar expectancy influenced cognitive performance in an attentional task and across a range of memory tasks (Green et al., 2001; Stollery & Christian, 2013), although research on sugar-related expectancies is limited and neither of these two studies included executive function tasks. The importance of expectancies related to other substances (e.g. caffeine, alcohol) has also been demonstrated, for example, on inhibitory control and psychomotor performance (e.g. Christiansen et al., 2016; Fillmore & Vogel-Sprott, 1995; Kirsch & Weixel, 1988). Therefore, this warranted further investigation of the anticipated effects of sugar on cognitive performance. For this reason, in the next experiment (study 5.2) cognitive measures were maintained (except free recall due to time restraints) to further explore the notion that anticipated effects of sugar may influence cognitive measures.

Previous research has demonstrated that manipulating the expected effects of a substance can influence cognitive performance. For example, Kvavilashvili and Ellis (1999) found that participants informed they were receiving a ‘memory impairing’ substance had impaired free recall following placebo, however, there was no change in free recall performance in those told they were receiving a ‘memory enhancing’ substance. Furthermore, Fillmore, Mulvihill and Vogel-Sprott (1994) demonstrated greater improvement in psychomotor performance following placebo-alcohol in those told alcohol would impair performance than those led to expected enhancement. Similar findings were also reported by Harrell and Juliano (2009) using placebo-caffeine in an information processing task, suggesting that with some substances individuals may challenge their expectations about a substance (e.g. resulting in increased/reduced effort). One explanation for the null finding of expectancy on cognitive performance in the current study may be that participants in the ‘expect sugar’ group put less effort into the cognitive tasks and/or those in the ‘expect sugar-free’ group put more effort into the tasks. Another possibility is that all participants expected improved cognitive performance in general following consumption of a sweet beverage, thus leading to a null effect.

Therefore, similar to previous studies using placebo alcohol and caffeine (e.g. Fillmore et al., 1994; Harrell & Juliano, 2009), manipulating specific beliefs about the expected effects of a sugar beverage may allow further understanding of the role of the anticipated effects of sugar on cognitive performance and subjective measures. Currently, no research has specifically manipulated individual’s beliefs about the effects of sugar on cognitive performance and subjective energy. Thus, in study 5.2, specific information about the cognitive and subjective effects of SSBs was provided to participants (e.g. it will improve performance and provide energy, it will have no effect on cognitive performance and energy) prior to consuming a placebo-sugar beverage, in an attempt to further understand the anticipated effects of sugar.

5.4 Study 5.2

Study 5.1 found only the anticipated effects of sugar to influence subjective measures of energy and boredom, and thus the current study focussed purely on expectancy effects using only a placebo-sugar beverage. Participants received one of four messages in which information about the cognitive and subjective effects of consuming a sugar beverage was manipulated. Participants in one group were informed that consuming the beverage would improve their cognitive performance and increase subjective energy (C+/S+). Those in another group were told that it would have no effect on cognitive performance but increase subjective energy (C-/S+). A third group were told that it would improve cognitive performance but have no effect on subjective energy (C+/S-). The final group were told that it would have no effect on cognitive performance or subjective energy (C-/S-). Performance on the Stroop and verbal fluency task, as well as self-report measures was assessed at time points pre and post-drink.

Based on findings from experiment 5.1, it was predicted that expecting increased energy following consumption of sugar would lead to increased subjective energy but expecting no effect would lead to no change in subjective energy. As study 5.1

found no expectancy effects across cognitive performance measures, the influence of cognitive expectancy manipulations on cognitive performance was exploratory.

5.4.1 Methods

Participants

294 first year undergraduates (248 females, 46 males) aged between 18 and 36 (*M*=18.96, *SD*=1.85) participated in the study during a weekly seminar. This sample size was deemed sufficient from a power calculation to detect a small to medium effect size with 80% power (Cohens f =0.15, α=.05), based on interactions involving drink, message and time in the previous study in this chapter. Eligibility criteria were the same as study 5.1.

Design

The study utilised a between-subjects design. Participants were allocated (random allocation by class) to one of four experimental conditions by class so that all students in the same class completed the same experimental condition. Each experimental condition received a different message informing them of the effects of consuming a SSB. The content of the four messages was manipulated based on two independent factors; cognitive effect (improve cognitive performance, have no effect) and subjective effect (increase subjective energy, have no effect).

Subjects in the first group (C+ / S+) were informed that consuming the beverage would improve cognitive performance and increase subjective feeling of energy. The second group (C- / S+) were informed that consuming the beverage would have no effect on cognitive performance but increase subjective feeling of energy. Another group (C+ / S-) were informed that consuming the beverage would improve cognitive performance but have no effect on subjective feeling of energy. The final group (C- / S-) were informed that consuming the beverage would have no effect on cognitive performance or subjective feeling of energy.

Stroop performance and verbal fluency was assessed both pre and post-drink. Self-report measures were assessed at three time points; once pre-drink and at two time points post-drink (immediately following absorption period and 10 minutes post absorption).

Seminar approach

The seminar approach followed that of study 5.1.

Measures

SSB expectancies – See chapter four methods section for description of SOES.

SSB Consumption – See chapter two, general methods.

Subjective Measures – As in study 5.1, the fatigue and vigor subscales of the SF-POMS and two scales assessing tiredness and boredom were used.

Cognitive Tasks

These two cognitive tasks (Stroop task and COWAT) are explained in methods of study 5.1.

Drink Preparation

See general methods for description of the placebo-sugar beverage (same as used in study 5.1).

Procedure

Upon obtaining informed consent, participants were asked to complete basic demographics including age, gender, height and weight, followed by completion of the SOES. Participants then completed the first Stroop and COWAT task and the subjective measures. Participants were then read one of four messages in which information about the short-term cognitive and subjective effects of consuming sugar were manipulated;

Message 1 (C+/S+): *'The drink provided on your desk is sweetened with sugar. Research has shown that consuming sugar leads to improved cognitive performance, an increase in self-reported energy and reduction in self-reported tiredness. The purpose of this study is to determine how sugar improves cognitive performance and increases energy. You now have five minutes to consume the beverage on your desk'.*

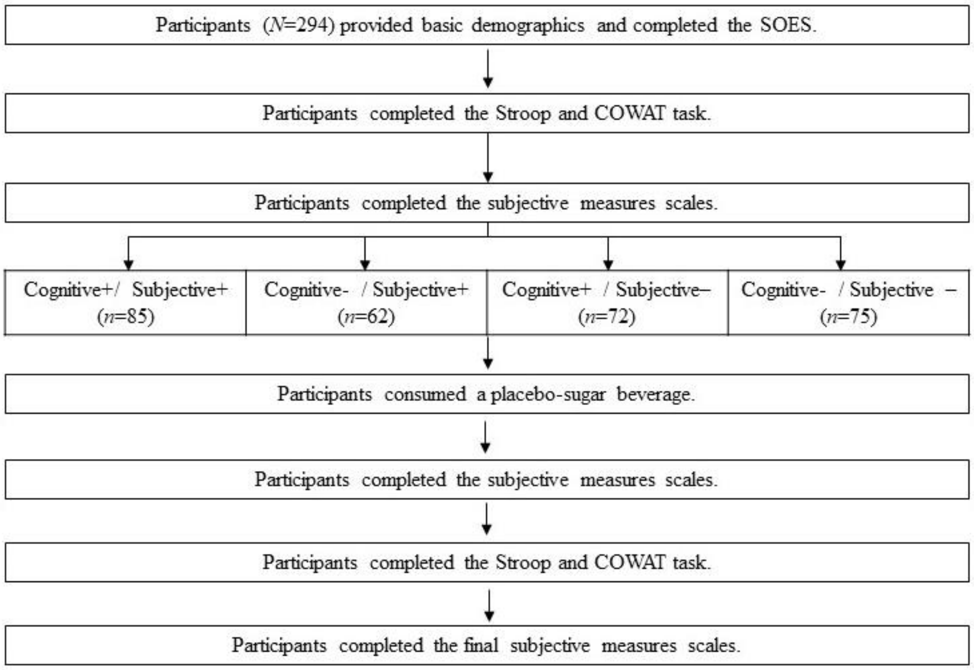
Message 2 (C-/S+): *'The drink provided on your desk is sweetened with sugar. Research has shown that consuming sugar leads to an increase in self-reported energy and a reduction in self-reported tiredness, however, has no effect on cognitive performance. The purpose of this study is to determine why sugar causes this increase in energy without a corresponding change in cognitive performance. You now have five minutes to consume the beverage on your desk'.*

Message 3 (C+/S-): *'The drink provided on your desk is sweetened with sugar. Research has shown that consuming sugar leads to improved cognitive performance, however, has no effect on self-reported energy and tiredness. The purpose of this study is to determine why sugar improves cognitive performance, without a change in self-reported energy and tiredness. You now have five minutes to consume the beverage on your desk'.*

Message 4 (C-/S-): *'The drink provided on your desk is sweetened with sugar. Research has shown that consuming sugar has no effect on cognitive performance or self-reported energy and tiredness. The purpose of this study is to determine why sugar has been found to have no effect on cognitive performance or self-reported energy and tiredness. You now have five minutes to consume the beverage on your desk'.*

Participants had five minutes to consume the beverage, followed by a 10 minutes absorption period (to increase credibility of the message). During the absorption period participants were asked to complete the BFQ. Post absorption, they completed the second set of subjective measures followed by the final Stroop and COWAT task. Participants then completed the final set of subjective measures, followed by an estimation of the number of calories in the beverage.

Figure 5.7 – Schematic overview of experimental procedure.



5.4.2 Results

Cognitive performance and subjective measures were analysed using a mixed analysis of variance (ANOVA). For each outcome measure, expected cognitive (improve cognitive performance, no effect on cognitive performance) or subjective effect (increased subjective energy, no effect on subjective energy) was the between-subject factor and time the within-subject factor. For all analyses, a Bonferroni Correction was used for *post hoc* testing.

Sample Characteristics

A summary of sample characteristics for each of the four groups can be seen in table 5.4. There were 10 missing values for age, 59 for BMI and 16 for daily SSB consumption (participants failed to report). For these measures, multiple imputation was carried out on the data. A one-way ANOVA revealed no significant difference between groups in age (*F* (3, 293) =1.97, *p*=.119, n_p^2=0.01), BMI (*F* (3, 293) = 1.12, *p*=.341, n_p^2=0.01) or daily SSB consumption (*F* (3, 293) =0.63, *p*=.596, n_p^2<.01). There were also no significant groups on the SOES cognitive and physical effects subscale (*F* (3, 293) =0.12, *p*=.950, n_p^2<0.01).

Table 5.4- Means (±*SD*) for age, BMI, Daily SSB consumption and the SOES cognitive and physical effects subscale for each group

	C+/ S+ ***n*=85**	**C-/ S+** ***n*=62**	**C+/ S-** ***n*=72**	**C-/ S-** ***n*=75**
Age	18.68 (±.79)	19.27 (±2.72)	19.07 (±2.11)	19.08 (±2.11)
BMI	21.50 (±4.17)	22.69 (±2.53)	22.77 (±3.95)	22.32 (±3.75)
Daily SSB Consumption	349.59 (±549.54)	310.33 (±314.52)	295.38 (±313.18)	258.19 (±293.78)
Cognitive/physical effects SOES	3.32 (±.54)	3.27 (±.67)	3.32 (±.63)	3.31 (±.60)

Cognitive Performance

A 2 (cognitive expectancy; C+, C-) x 2 (time; pre-drink, post-drink) ANOVA was carried out on Stroop and COWAT task performance. Eight participants were identified as outliers (more than 3 *SD*s) on Stroop performance and were excluded from the analysis.

Stroop performance: Time to complete the Stroop task (in secs) was used as a measure of Stroop performance. Results indicated a main effect of time (*F* (1, 284) = 272.30, *p*<.001, η_p^2=.49), with significantly lower Stroop times post-drink (*M*=48.95, *SD*=8.53) as opposed to pre-drink (*M*=55.86, *SD*=10.36). There was no main effect of cognitive expectancy (*F* (1, 284) =.01, *p*=.754, η_p^2<0.01) and the interaction between cognitive expectancy and time was non-significant (*F* (1, 284) = .22, *p*=.642, η_p^2<.01).

Verbal Fluency: Number of words produced in the COWAT was analysed. Results indicated a main effect of time (*F* (1, 292) =121.45, *p*<.001, η_p^2 =.29), with significantly more words produced post-drink (*M*=39.12, *SD*=9.60) than pre-drink (*M*=35.18, *SD*=9.33). There was no main effect of cognitive expectancy (*F* (1, 292) =.50, *p*=.482, η_p^2<.01), and the interaction between cognitive expectancy and time was also non-significant (*F* (1, 292) =.42, *p*=.519, η_p^2<.01).

Subjective Measures

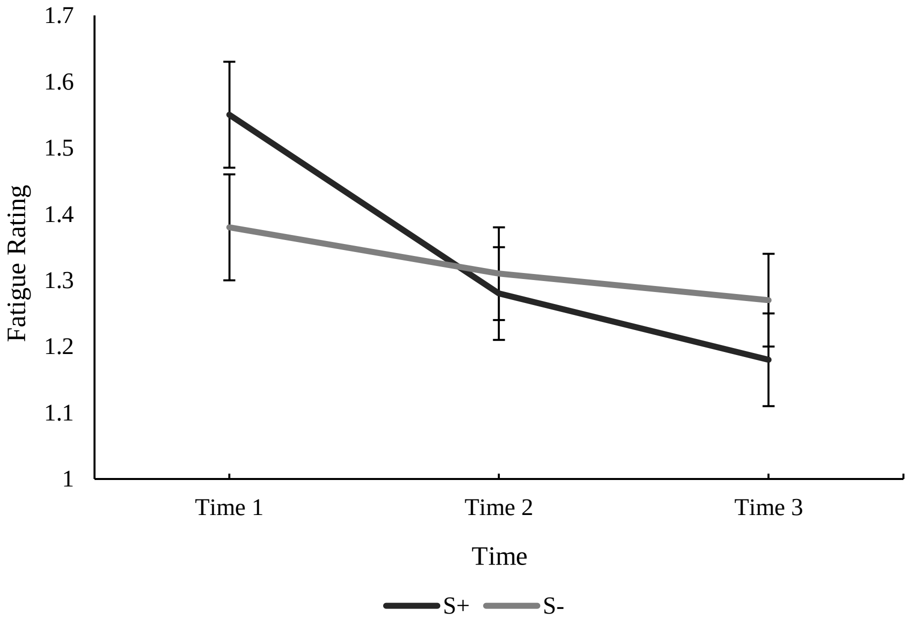
A 2 (subjective expectancy; S+, S-) x 3 (time; pre-drink (time 1), post-drink (time 2), post-drink (time 3)) ANOVA was carried out on all subjective measures. When Sphericity was violated for the within-subjects measure of time, Huynh-Feldt correction was reported (based on magnitude of ε, wherein values >.75 use the Huynh-Feldt correction). Table 5.5 shows descriptive statistics for subjective measures at pre and post-drink time points, for both expectancy conditions.

Table 5.5- Means (±*SD*) for subjective measures in each group at each time point.

	S+	**S-**
Fatigue SF-POMS		
Time 1	1.55 (±.91)	1.38 (±.91)
Time 2	1.28 (±.80)	1.31 (±.90)
Time 3	1.18 (±.85)	1.27 (±.89)
Vigour SF-POMS		
Time 1	1.05 (±.65)	1.33 (±.72)
Time 2	1.24 (±.70)	1.25 (±.76)
Time 3	1.28 (±.71)	1.24 (±.73)
Tiredness		
Time 1	15.03 (±4.74)	13.73 (±4.14)
Time 2	12.97 (±5.02)	13.16 (±4.48)
Time 3	11.96 (±5.06)	12.67 (±4.70)
Boredom		
Time 1	11.11 (±4.94)	10.78 (±4.69)
Time 2	11.05 (±5.12)	11.89 (±4.76)
Time 3	10.44 (±5.30)	10.96 (± 4.67)

Fatigue SF-POMS: There was a main effect of time (*F* (1.84, 537.90) =36.14, *p*<.001, η_p^2=.11) with a significant reduction in fatigue from pre (*M*=1.47, *SD*=.91) to both post-drink time points (*p*s<.001) and from time 2 (*M*=1.30, *SD*=.85) to time 3 (*M*=1.23, *SD*=.87, *p*=.016). This was qualified by a significant subjective expectancy by time interaction (*F* (1.84, 537.90) =12.02, *p*<.001, η_p^2=.04; see figure 5.8). Post hoc analysis revealed a significant reduction in fatigue from pre to both post-drink time points (*p*s<.001) and between post-drink time points (*p*=.010) for those in the S+ group, however there was no significant changes in fatigue from pre to post-drink time points for those in the S- group (*p*s≥.074).

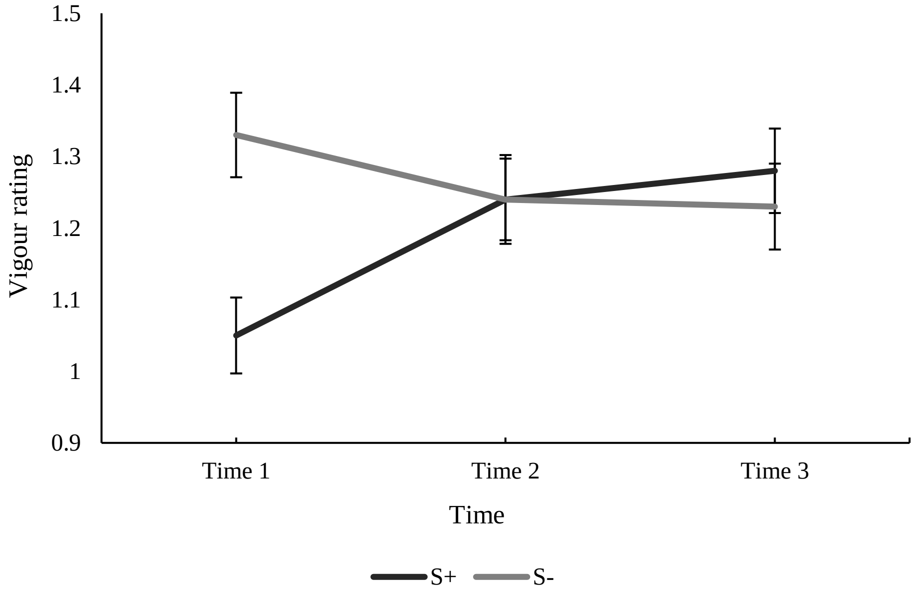
Figure 5.8- Graph showing means (±*SE*) for fatigue ratings at pre and both post-drink time points for each group.



Vigour SF-POMS: Results indicated a main effect of time (*F* (1.97, 576.42) =3.26, *p*=.040, η_p^2=.01), although very small effect size. There was a non-significant trend towards an increase in vigour from pre-drink to the final post-drink rating (*p*=.063), however no significant change from pre-drink to immediately post drink or between post-drink time points (*p*s≥.183). Marginal significance may have occurred due to Bonferroni correction being overly conservative (when Bonferroni correction was not applied significance was maintained (*p*=.021)). Importantly, there was a significant interaction between subjective expectancy and time (*F* (1.97, 576.42)

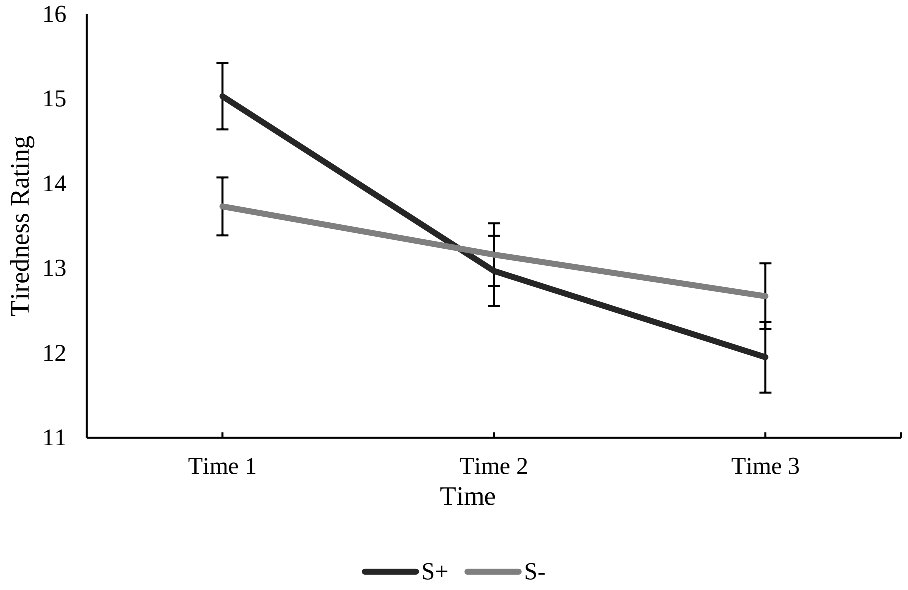
=18.71, $p<.001$, $\eta_p^2=.06$; see figure 5.9). Post hoc analysis indicated that for those in the S+ there was a significant increase in vigour from pre to both post-drink time points (*p*s<.001), but no significant difference between post-drink time points ($p=.975$). However, for those in the S- group there was no significant change in vigour from pre to both post-drink time points or between post-drink time points (*p*s≥.078).

Figure 5.9- Graph showing means (±*SE*) for vigour ratings at pre and both post-drink time points for each group.



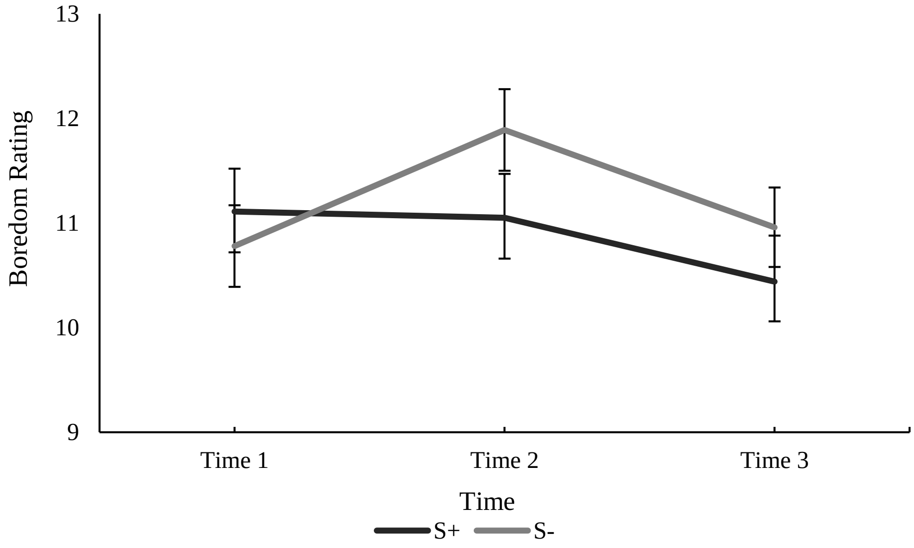
Tiredness: Results indicated a main effect of time (*F* (1.91, 558.17) =58.28, $p<.001$, $\eta_p^2=.17$), with a significant reduction in tiredness from pre (*M*=14.38, *SD*=4.49) to both post-drink time points (*p*s<.001) and from post-drink time 2 (*M*=13.06, *SD*=4.75) to post-drink time 3 (*M*=12.31, *SD*=4.89, $p<.001$). This was qualified by a significant interaction between subjective expectancy and time (*F* (1.91, 558.17) =14.55, $p<.001$, $\eta_p^2=.05$). As can be seen in figure 5.10, there was a significantly larger reduction in tiredness from pre- to immediately post-drink, and from pre-drink to post-drink (Time 3) in the S+ group than the S- (*p*s<.001). There were also significantly higher tiredness ratings in the S+ group than S- group at baseline ($p=.013$), however this difference disappeared by post-drink time points (*p*s≥.207).

Figure 5.10- Graph showing means (±*SE*) for tiredness ratings at pre and both post-drink time points, for each group



Boredom: ANOVA revealed a main effect of time (*F* (2, 584) = 6.87, *p* = .001, η_p^2 = .02), with a significant increase in boredom from pre to immediately post-drink (*p*=.046), followed by a significant reduction in boredom between post-drink time points (*p*=.001). This was qualified by an interaction between subjective expectancy and time (*F* (2, 584) = 4.08, *p* = .017, η_p^2 = .01). There were no significant changes in boredom from pre to post-drink time points for those in the S+ group (*p*s≥.076), however for the S- group, there was a significant increase in boredom from pre-drink to immediately post drink (*p*=.001) followed by a significant reduction between post-drink time points (*p*=.006).

Figure 5.11- Graph showing means *(±SE)* for Boredom ratings at pre and both post-drink time points for each group.



5.5 Discussion

This chapter investigated the influence of acute sugar consumption and the anticipated effects of sugar on a range of cognitive tasks and subjective measures. In study 5.1 it was hypothesized that acute sugar consumption would improve cognitive performance and increase subjective energy. It was also hypothesized that expecting sugar would improve cognitive performance and increase subjective energy. Therefore, it was predicted that the largest improvement would be in those who consumed sugar and expected to consume sugar.

To further explore the role of anticipated effects, study 5.2 investigated the influence of more specific message manipulations on cognitive performance and subjective measures following a placebo-sugar beverage. Based on findings from study 5.1, it was hypothesized that subjective expectancy would influence self-report measures in that there would be an increase in subjective energy for those who expected a SSB to increase energy but not for those who expected no effect. The influence of cognitive expectancy on cognitive performance was exploratory.

Summary of Findings: Study 5.1

Contrary to hypotheses, results indicated no effect of acute sugar consumption on performance in any of the cognitive task or on any subjective measures. There was also no influence of expectancy on any of the cognitive measures, however as predicted expectancy did influence subjective measures. In those that expected a SSB (but not those who expected sugar-free) there was a significant reduction in fatigue and tiredness from pre- to post-drink. However, for those who expected a sugar-free beverage (but not those who expected a SSB) there was a significant reduction in vigour and increase in boredom from pre-to post drink. This suggests that the beliefs people have about the effects of consuming a SSB can influence subjective measures. However, contrary to predictions there was no combined effect of sugar and sugar expectancy across any measures.

Summary of Findings: Study 5.2

Findings from study 5.2 found no expectancy effects on any cognitive performance measures, however, as predicted, the effect on self-report measures was replicated. There was a significant reduction in fatigue and an increase in vigour from pre- to post-drink for those in the S+ group (but not the S- group). There was also a greater reduction in tiredness from pre to post-drink for those in the S+ group than the S- group. For boredom, there was a significant increase in boredom from pre to immediately post-drink for those in the S- group (but not S+ group).

General Discussion

Although SSB consumers are more likely to expect SSBs to improve cognitive and physical performance and increase energy (revealed in chapter three), findings in study 5.1 found no effect of acute sugar consumption on any cognitive measures or subjective energy, failing to support the hypotheses that sugar would improve cognitive performance and increase subjective energy. This is contrary to findings from previous studies which found that, compared to a placebo (sugar-free) control, consuming a SSB (in the form of glucose) enhanced verbal fluency (e.g. Kennedy &

Scholey, 2000), inhibitory control (e.g. Brandt et al., 2013; Craft et al., 1994) and increased memory recall (e.g. Sünram-lea et al., 2001). Although other studies have also found no effect of glucose on word recall (e.g. Scholey & Kennedy, 2004; Green et al., 2001) and verbal fluency (Craft et al., 1994). In the free recall task consuming a SSB failed to produce an effect even in the more difficult task condition (abstract words), contrary to the findings of Riby et al. (2008). However, it is notable other studies have also found no effect of task difficulty following SSB consumption, including in a delayed free recall task (e.g. Stollery & Christian, 2013). Together, current findings suggest that SSBs are not a beneficial cognitive aid, at least for undergraduates in a naturalistic seminar environment, where similar aids may be sought out to enhance cognitive performance and increase energy (e.g. Bulut et al., 2014).

Contrary to predictions, both studies found no influence of expectancy on performance in any of the cognitive tasks, even when more specific expectancy manipulations were used in study 5.2. Findings for the free recall task are supportive of that from Green et al. (2001) who also found no influence of sugar expectancy on immediate free recall performance. Notably, contrary to findings, Stollery and Christian (2013) found that participants believing they had consumed glucose (regardless of the content) had improved performance on the delayed free recall task. Studies in this chapter also found no influence of expectancy on inhibitory control or verbal fluency. To the best of knowledge, no previous research has investigated the influence of sugar-related expectancies on inhibitory control or verbal fluency, however two studies (Green et al., 2001; Stollery & Christian, 2013) found some element of expectancy across a range of cognitive measures (e.g. sustained attention and semantic memory), suggesting the need for further research on the influence of sugar expectancies across different cognitive domains.

These findings are contrary to a considerable evidence base suggesting that the effects of a range of substances on cognitive performance are influenced by the expected effects of the substance (e.g. Fillmore et al., 1994). For example, placebo alcohol was found to impair inhibitory control performance, and performance was correlated with expectation of cognitive and behavioural impairment (e.g.

Christiansen et al., 2016). In addition, placebo caffeine improved cognitive motor performance in those who expected improvement following caffeine, but also led to increased subjective alertness (e.g. Kirsch & Weixel, 1988). One explanation for this is that sugar-related expectancies are weaker than that of alcohol or caffeine; however, this seems unlikely considering participants were provided with specific information about the cognitive and subjective effects of consuming sugar. In addition, expectancy effects have been found with substances that individuals have no cumulative experience (Kvavilashvili & Ellis, 1999).

Notably, the messages used in study 5.2 included information about the cognitive and subjective effects of SSB consumption which may have reduced focus on the cognitive aspect of the message. Future research could manipulate only the cognitive effects aspect of the message to increase focus and further explore the role of sugar-related expectancy effects on cognitive performance.

Consistent with the proposed hypothesis (and replicated across both studies), subjective reports are influenced by the anticipated effects of sugar. For example, in study 5.1 there was a reduction in self-reported tiredness and fatigue from pre- to post-drink for those that expected a SSB (but not who expected sugar-free), regardless of the beverage content. Furthermore, in study 5.2 using only a placebo-sugar beverage, there was a significant reduction in fatigue and increase in vigour for those who expected increased energy following a SSB (S+ group) but not those who expected no effect (S- group). This is consistent with previous research demonstrating the importance of the anticipated effects of several substances on self-report measures; for example, increased arousal from pre- to post-drink for those believing they had consumed glucose, regardless of the content (Stollery & Christian, 2013) and enhanced alertness following placebo caffeine (Kirsch & Weixel, 1988). The current findings suggest that the sugar content of a SSB does not increase subjective feeling of energy and this feeling of increased energy occurs due to the expectation of this effect.

Analyses from study 5.1 in the subsample who' believed' that the beverage contained sugar (using calories as an indicator) suggest that expectancy effects may be under-reported. Compared to analyses on the full-sample, results in this subsample revealed additional expectancy effects for subjective ratings of fatigue and boredom and small increases in effect sizes across subjective measures. Problematically, some individuals have poor understanding of calories (e.g. Carels, Harper & Konrad, 2006), and therefore participant's estimates may not fully reflect their beliefs about the content of the beverage. Thus, more accurate calorie estimates may have resulted in larger expectancy effects. These findings further suggest that future research investigating the anticipated effects of sugar should account for whether participants believe they had consumed sugar to provide a more accurate depiction of the role of the expectancies.

Notably, the studies reported in this chapter have some limitations. Firstly, the beverage was an orange flavoured drink with added sugar that participants may not necessarily associated with improved cognitive performance. It may be that individuals associate certain SSBs (e.g. energy drinks) more strongly with improved cognitive performance and increased energy (e.g. Bulut et al., 2014; Attila & Cakir, 2011). Therefore, future research should focus the messages around different categories of SSBs (rather than SSBs in general) to determine expectancy effects related to different SSBs on cognitive performance and subjective energy. In addition, the tasks may not be sensitive enough to detect sugar-induced performance changes and this may also be the case for expectancy effects. Tasks used were non computer-based tasks (due to study nature) which may not have required sufficient cognitive load. Hoyland et al. (2008) suggested that the choice of task can be critical in determining whether there is a sugar-induced effect, and thus other tasks within these cognitive modalities should be used to further understand the effects of sugar and expectancy on these cognitive measures. Finally, potential issues surround the seminar approach utilised to collect data. Participants may be distracted by other students, although participants were instructed to complete the tasks in silence and were monitored by the investigator. Students were also asked to complete the Stroop task in pairs which may influence their performance (with second person in the pair potentially performing better), although this was not explicitly tested. Future research could counterbalance the order of tasks between pairs to reduce any practise effects. Furthermore, mixed modelling could be utilised to control for any variance in performance that may have resulted from completing the task in pairs. Given the sample size and time constraints setting up the study, setting up the study in such a way was not possible.

In summary, the studies reported in this chapter demonstrate no effect of acute sugar consumption or sugar expectancy on cognitive performance across a number of tasks. There were also no effects of sugar on measures of subjective energy, however the anticipated effects of sugar did influence subjective measures. Merely, expecting sugar and expecting increased energy resulted in increased subjective energy, suggesting some contribution of expectancy to the positive subjective effects of SSBs. Taken together, results suggest SSBs are not a beneficial cognitive aid, at least in undergraduates who may seek out aids to enhance cognitive performance and increase energy. The increased energy some people may feel after consuming a sugary drink occurs due to individuals expecting this increased energy (but not due to the sugar content). Therefore, by modifying individual's beliefs about the short-term effects of low-calorie diet beverages, these beverages may be equally as effective in providing this 'energy boost'.

5.6 Supplementary Analysis

Study 5.2. Subsample analysis ('believed' manipulation)

This is supplementary analysis to study 5.2. Those who reported that the sugar-placebo beverage contained more than 100 calories were classified as those who believed they had consumed an SSB. Those who reported that the beverage contained less than 99.99 calories were classified as those who didn't believe they had consumed a SSB and were excluded from the analysis (148 participants retained).

In study 5.2 expected cognitive and subjective effects were manipulated, and thus estimated calorie content may be a less important factor to consider, however to maintain consistency with results reported for study 5.1 analyses are reported for this subsample here.

Analysis was carried out using a mixed ANOVA with expected effect (positive, no effect) as the between subject's factor and time as the within subject's factor. Results on this sub-sample are highly consistent with that of the whole sample.

Cognitive Performance

There were no main effects or interactions involving cognitive expectancy for Stroop or COWAT performance in this subsample, thus results are not reported here.

Subjective Measures

For subjective measures, results involving subjective expectancy are highly consistent with that of the whole sample (with some minor increases in effect size).

Fatigue SF-POMS: There was an interaction between subjective expectancy and time (F (1.84, 269.14) = 5.24, p=.007, η_p^2=.04). Post hoc analysis revealed a significant reduction in fatigue from pre- to both post-drink time points (ps<.001) for those in the S+ group but no significant changes in fatigue for those in the S- group (ps>.36).

Vigour SF-POMS: There was an interaction between subjective expectancy and time (F (1.89, 276.47) =10.96, p<.001, η_p^2=.07). Post hoc analysis revealed a significant increase in vigour from pre- to both post-drink time points (ps<.001), but not between post-drink time points (p=1.00) for those in the S+ group, however there was no significant change in vigour for those in the S- group (ps>.37).

Tiredness: There was an interaction between subjective expectancy and time (F (1.93, 6.40) =10.82, p<.001, η_p^2=.07). Post hoc analysis revealed a significant reduction in tiredness from pre to both post-drink time points (ps<.001) and between post-drink time points (p=.018) for those in the S+ group, but there were no significant changes in tiredness for those in the S- group (ps≥.33).

Boredom: There was a subjective expectancy x time interaction (F (2, 292) =

6.90, p=.001, η_p^2=.05). There was a significant reduction in boredom from pre-drink to immediately post drink (p=.003) and between post drink time points (p=.002) for those in the S+ group, however for those in the S- group there was a significant increase in boredom from pre-drink to immediately post-drink (p=.011), followed by a significant reduction at post-drink time points (p=.002).

Chapter Six:

The anticipated effects of sugar on attentional bias for SSBs in high consumers

6.1 Abstract

There is compelling evidence suggesting a link between SSB consumption, obesity and other negative health problems, and thus it is important to understand appetitive motivational processes that may act as a maintenance factor for the consumption of these beverages. Appetitive motivational processes have been linked to the consumption of high calorie foods, however, currently there are no studies exploring their involvement in SSB consumption. The current study explores the pharmacological and anticipated effects of a SSB on AB for SSB-related cues and craving, whilst isolating the contribution of individual's expectancies (suggested to be linked to SSB consumption in chapter three). Participants (*N*=89) were randomly allocated to one of four conditions based on a balanced placebo design in which beverage content (SSB, diet) and expected content (expected SSB, expected diet) was manipulated. Outcome expectancies were assessed pre-drink. Participants completed a visual probe task (with concurrent eye movement monitoring) and reported sugar craving at both pre- and post-drink time points. Results indicated no effect of sugar or sugar expectancy on any measure of AB for SSB-related cues. There were also no acute effects of sugar on sugar craving, however in the placebo-sugar condition, those who expected sugar reported a greater reduction in craving than those who expected no sugar. Results also indicated that increased craving was associated with heightened AB for SSB-related cues at both pre- and post-drink time points. There was no evidence that individual's outcome expectancies were associated with AB for SSB-related cues. Overall, sugar consumption and expectancy have no effect on AB for SSB-related cues, however, there is some contribution of sugar expectancy to sugar craving. Thus, findings suggest that diet (sugar-free) sweet beverages may be as effective in reducing AB for SSB-related cues and controlling sugar cravings, although further research is required.

6.2 Introduction

Chapter three indicated that high consumers are more likely to expect SSBs to improve cognitive and physical performance. However, cognitive/physical improvement represents a functional reason and involves a conscious decision to consume SSBs. Indeed, one of the biggest reasons for continual, excessive use may be purely appetitive reasons driven by underlying motivational processes. Therefore, exploring the influence of sugar consumption on craving and AB for SSB-related cues is important to provide insight into the potential role of these processes on SSB consumption.
Indeed, SSBs are ubiquitous in the obesogenic, western food environment, where they are available in the vast majority of food and convenience stores, as well as vending machines. They are also heavily advertised in the media with more than £37.8 million being spent on advertising soft drinks in 2016 (Statista, 2016). Consequently, individuals are constantly bombarded with SSB-related cues, intended to stimulate craving and ultimately consumption.

Borrowing from motivational models of addiction (e.g. Robinson & Berridge, 1993; Franken, 2003), Nijs and Franken (2012) argued that classical conditioning processes are involved in the development of food-related AB. In the case of SSB consumption, individuals would associate SSB-related cues with the positive motivational properties (e.g. pleasant taste) of SSBs. Through classical conditioning SSB-related cues would begin to grab the individual’s attention, cause increased craving, and drive calorific beverage consumption. According to these theories, AB should be a long-lasting characteristic (that predicts future behaviour). Indeed, it is notable that AB to food-related cues predicts future weight gain (e.g. Werthmann et al., 2015). It should also differentiate normal weight and obese individuals with the obese demonstrating greater AB to high-calorie foods (e.g. Werthmann et al., 2011; Nijs, Muris, Euser & Franken, 2010).

There are inconsistencies regarding the association between AB and consumption. For example, studies report heightened AB for food-related cues irrespective of weight status in both children and adults (see Werthmann et al., 2015; Nijs, et al, 2010; Doolan, Breslin, Hanna & Gallagher, 2015). Castellanos et al. (2009) found increased gaze duration towards food images when hungry (regardless of weight status), although only people with obesity showed an AB when sated. However, some studies have found evidence of attentional avoidance to food-related stimuli in obese individuals (e.g. Werthmann et al., 2011; Giel et al., 2014). Furthermore, AB to food-related cues does not consistently predict future weight gain (see Werthmann et al. 2015), suggesting that AB has little utility in predicting long term weight-related outcomes. However, several studies have found AB to be positively correlated with food intake immediately after assessment of AB (e.g. Nijs et al., 2010; Werthmann, Renner et al., 2014), indicating that AB may be more closely related to behaviour in the near future.

Recently, Field et al. (2016) proposed a theory that can explain inconsistencies. They argued that AB fluctuates and is determined by momentary food evaluations, current craving, and motivational conflict from competing goals (e.g. goal to consume the food vs. goal to lose weight). Whether the food is evaluated positively is dependent on incentive value of the food at that moment in time, influenced by motivational state, availability of the food and the presence of cues. Negative evaluations occur as a result of motivational conflict and can lead to attentional avoidance of cues. This theory also suggests a reciprocal relationship between craving and AB, inasmuch as craving increases the attention that is paid to food-related cues and this heightened attention to food-related cues can lead to increased craving. Similarly, a reduction in craving would lead to reduced AB, vice versa. Thus, it would be expected that SSB consumption would affect both AB for SSB-related cues and sugar craving.

There is considerable evidence demonstrating, as predicted by Field and Colleagues, an association between AB and underlying appetitive motivational processes (e.g. craving, hunger) inasmuch as when the motivational value of the stimuli is high, AB increases. Stockburger, Weike, Hamm and Schupp (2008) found enhanced processing of food-related cues in hungry, but not in satiated participants (see also, Piech, Pastorino & Zald, 2009). In a visual probe task (whereby faster responses to probes replacing food vs neutral images is indicative of an AB for food-related stimuli), Nijs et al. (2010) found faster responses to probes replacing food images in hungry versus satiated participants when images were presented for 100ms. Notably, there was no effect of hunger status when images were presented for 500ms nor was there any evidence of differential attentional focus when gaze duration was directly measured. There is also considerable evidence suggesting that AB for appetitive stimuli (e.g. food, alcohol, caffeine) correlates with craving (e.g. Field, Munafo & Franken, 2009; Werthmann, Roefs, Nederkoorn & Jansen, 2013; Smeets et al., 2009). Craving-induction studies for rewarding food (e.g. chocolate) produced heightened attention to chocolate-related cues following a craving induction (24-hour abstinence + chocolate present during task) compared to a non-craving induction control (Kemps & Tiggemann, 2009). Similar findings were reported in a visual search paradigm with induced chocolate craving leading to increased distraction by chocolate images in high trait chocolate cravers compared to controls (Smeets et al., 2009). Taken together, this research suggests that the motivational state of SSB consumers (i.e. level of sugar craving) may be related to AB for SSB-related cues.

One factor suggested to be an important consideration in AB research is individual's outcome expectancies (beliefs about behaviour leading to a certain outcome). As previously reported, individuals who report pleasant effects of consuming a drug also report higher consumption (e.g. McKay et al., 2011). Similarly, as found in chapter three, individuals who expect more positive SSB outcome expectancies, also report consuming more of these beverages (see also Yen-Lun Su, 2011). Research suggests that AB and outcome expectancies are closely related. For example, AB in smokers is positively correlated with reported positive outcome expectancies from smoking (Waters et al., 2009), with similar results reported in adolescent social drinkers (Melaugh McAteer, Curran & Hanna, 2015). This indicates that positive outcome expectancies related to SSB consumption and AB may also be closely related, and thus together may contribute to the continued SSB consumption.

As previously reported in section 1.2.3.1, an important area of debate is around the use of diet beverages in weight management. To provide a brief recap, some studies report that consuming diet beverages in place of full-sugar beverages can lead to increased calorie intake and weight gain, although the majority of research indicates that the consumption of diet beverages in place of SSBs can lead to reduced energy intake and weight loss. One possible explanation for this is that diet beverages satisfy an innate desire for sweetness and as a result can reduce subsequent desire for sweetness from other higher calorie sources, although limited research on this currently exists (e.g. Appleton, Tuorila, Bertenshaw, de Graaf & Mela, 2018). As mentioned in section 1.3.3 robust evidence from sensory-specific satiety research demonstrates that exposure to a particular sensory attribute (e.g. sweetness) can reduce desire for foods with the same attributes (e.g. Rolls, 1986). For example, Haversmans et al. (2009) found that participants showed less motivation (i.e. wanting) to obtain the chocolate milk than crisps (significantly lower responses for chocolate milk points than for crisp points) following consumption of chocolate milk. This suggests that consumption of an SSB may lead to a reduced desire for SSBs and other sweet products. One possibility is that, sweetness alone (without sugar content) provided by diet beverages satisfies sugar craving and subsequently influences AB for SSB-related cues.

This study will address the potential role of sweetness on AB for SSB-related cues and sugar craving. If sweetness alone reduces sugar craving and AB, an implication of this is that diet beverages may be successful in satisfying the desire for sugar and reducing AB towards it (which drives consumption of SSBs), which would help control sugar cravings as well as weight loss and maintenance. The study will also address the role of expectancy to determine how people’s beliefs about sugar (rather than the content) influence craving for sugar and AB and ultimately subsequent consumption.

The current study utilised a balanced placebo design, in which participants were randomly allocated to one of four conditions in which sugar content (SSB, sugar-free beverage) and sugar expectancy (expect SSB, expect sugar-free) was manipulated. This allowed the isolation of both pharmacological and anticipated effects of sugar and to determine whether merely expecting sugar (regardless of content) influences AB for SSB-related cues, in line with expectancy theory (Kirsch, 1997). It was hypothesized that there would be a reduction in AB for SSB-related cues and sugar craving following consumption of a SSB and that the anticipated effects of sugar (those in the Expect+ but not Expect- condition) would also lead to reduced AB for SSB-related cues and craving. It was also hypothesized that self-reported craving for sugar would be positively associated with AB for SSB-related cues. Finally, it was predicted that AB towards SSB-related cues would be associated with positive outcome expectancies.

6.3 Methods

Participants

89 high consumers of SSBs (consuming at least 271ml per day) aged between 18 and 49 (23.12 ± 7.38) were recruited to take part in the study (25 male, 64 female). This sample size was deemed sufficient from a power calculation to detect a small to medium effect size with 80% power (Cohen's f= 0.15, α=.05). According to this analysis 72 participants were required (we slightly over recruited to account for potential missing data resulting from issues with eye tracker calibration and outliers on the visual probe task). We chose a small to medium effect size based on the effect sizes identified for message and drink effects in previous studies in this thesis, as this is a new area of research.

The study was advertised via posters around the University of Liverpool campus, using the EPR Scheme (whereby participants receive course credits for participation), web advertisements (e.g. university website) and social media. Eligibility criteria included fluency in English, liking lemonade and normal to corrected-normal vision. They were not eligible to participate if they had a diagnosis of diabetes or a history of eating disorders or allergies.

High Consumers

BFQ data was pooled together from three studies (*N*=654) and the top tertile for ml of SSBs consumed per day was used as a cut-off to classify high consumers of SSBs. This was found to be 271ml, and thus individuals who consumed ≥ 271ml of SSBs per day were classified as a high consumer.

Design

This study utilised a balanced placebo design. Participants were allocated to one of four conditions defined by two independent factors; drink (SSB, sugar-free) and message (expect sugar, expect sugar-free). Performance on the visual probe task with concurrent eye movements was assessed at two time points; before and after beverage consumption. Thirst, hunger and craving for sugar was assessed at six time points; at baseline (T1), after craving induction (T2), after the visual probe task (T3), after the additional craving induction (T4), after beverage consumption (T5) and following the final visual probe task (T6).

Materials

Questionnaires:

*SSB consumption***.** See chapter two general methods for description.

Sugar Outcome expectancies scale (SOES; developed in chapter three). See chapter four methods for description.

Dietary Restraint. Dietary restraint was assessed using the Dutch Eating Behaviour Questionnaire (DEBQ; Van Strien, Frijters, Bergers & Defares, 1986). The restraint subscale consists of 10 items assessing restrained eating (e.g. ‘when you have put on weight, do you eat less than you usually do?’, ‘do you refuse food or drink offered because you are concerned about your weight?’). Participants were required to indicate on a 5-point scale how each statement applied to them from *never* (1) to *very often* (5).

Thirst. Measures of subjective thirst have been argued to provide a good indication of hydration status (Rogers, Kainth & Smit, 2001). Participants were asked to respond to the statement “How thirsty do you feel right now?” on a 100 mm visual analogue scale (VAS) ranging from *not at all* (0) to *very much* (100).

Hunger. Measures of subjective hunger were assessed on a 100mm VAS. The VAS was originally derived as a “gold standard” method to assess pain and has recently been validated as an adequate instrument to assess appetite (see for a discussion Flint, Raben, Blundell & Astrup, 2000) and has been used in previous AB research (e.g. Kemps & Tiggemann, 2009; Werthmann, Field, et al., 2014). Participants responses range from *not at all hungry* (0) to *extremely hungry* (100).

Craving for sugar (state). This was measured using a 100mm VAS scale. It has been used in several other studies as a measure of craving. E.g. for chocolate (Kemps & Tiggeman, 2009) and food in general (Werthmann et al., 2011).

Lemonade Liking. Prior to the study, participants were asked to rate on a 100mm VAS scale how much they like lemonade ranging from *not at all* (0) to *very much* (100).

Pleasantness of Beverage. Following beverage consumption, participants were asked to rate on a 100mm VAS how much they liked the beverage from *not at all* (0) to *very much* (100).

Attentional Bias Task:

Visual probe task with concurrent eye movement monitoring.

Overview: The visual probe was used as a measure of attention allocation. During each trial of the visual probe task, a central fixation cross appeared on the screen for 500ms. Immediately following this, image pairs were presented either side of the central fixation cross for 1000ms, followed by a visual probe (pointing upward or downward) in the position of one of the images. Participants were asked to indicate, as quickly as possible, whether the visual probe was pointing up or down using a keyboard. Probes remained on the screen until participant respond or timed out after 9000ms. There was an inter-trial interval of 500ms. Eye movement data was recorded during each trial, starting immediately before the onset of the fixation cross and terminating immediately after the participant had made a response. Using the visual probe and eye movement measures in combination is suggested to be a more reliable measure of attention allocation (e.g. Christiansen, Mansfield, Duckworth, Field & Jones, 2015).

Stimuli: Practise and buffer trials consisted of neutral image pairs depicting no relation to SSBs (e.g. pencil-spanner, plate-clock); there were seven possible pairs of neutral images randomly selected for each of these trials. Experimental trials were made up of 24 images; eight SSB, eight diet and eight water (control) beverages. This resulted in 24 image pairs consisting of SSB-water, diet-water and SSB-diet (see figure 6.1 for example). Each picture pair was matched as closely as possible for perceptual characteristics (such as brightness and complexity).

Figure 6.1- Example of image pair used in the visual probe task (SSB-water image pair shown).

Trial Types: The visual probe paradigm consisted of 204 trials in total; there were 10 practice trials, 2 buffer trials and 192 experimental trials (main task). During experimental trials, each of the 24 image pairs (eight SSB-water, eight diet-water, eight SSB-diet) were presented eight times, with probe and images in each of the possible combinations; image position (left, right), probe position (left, right), probe direction (up, down). This resulted in 64 SSB-water trials, 64 SSB-Diet trials and 64 Diet-water trials, presentation of which was in a random order. SSB-water and SSB-diet trials were utilised to determine whether participants were attending to sugar. Diet-water image pairs were utilised to determine if there was a change in AB for ‘sweetness’ in general.

Manual Response Latencies to Probes

Calculations of response latency bias were based on recordings of participants manual response latencies when indicating the direction of the probe. Response latencies were excluded from further analysis if they were faster than 200ms, slower than 2000ms, or if they were more than 3 *SD*s from each participant mean (e.g. Werthmann et al., 2013). For SSB-water image pair trials, bias scores were calculated by subtracting the mean response latency on trials when the probe replaced SSB images (i.e. sugar – congruent) from the mean response latency on trials when the probe replaced water images (sugar – incongruent). Similarly, in trials involving SSB-diet image pairs, bias scores were calculated by subtracting mean response latency on trials when the probe replaced the SSB images (i.e. sugar – congruent) from the mean response latency on trials when the probe replaced the diet beverage images (i.e. sugar – incongruent). A positive response latency bias score in these trials was interpreted as heightened AB for SSB-related cues, however a negative response latency bias score was interpreted as an AB away from sugar (attentional avoidance).

In diet-water image trials, bias scores were calculated by subtracting the mean response latency to probes replacing diet beverage images (i.e. diet – congruent) from mean response latency to probes replacing water images (i.e. diet – incongruent). In these trials, a positive response latency bias score was indicative of an AB for diet beverages, however a negative response latency was indicative of an AB away from diet beverages (i.e. attentional avoidance).

Attentional Bias Scores from Eye Tracking

Two AB scores were derived from eye movement data; gaze direction bias and dwell time bias.

A gaze direction bias score is a measure of the initial orientation to relevant stimuli. It was calculated for each participant and reflected the percentage of trials in which initial gaze was directed towards critical images as a proportion of the total number of trials in which gaze were directed towards critical or neutral images. For sugar-water and sugar-diet image pairs a bias score greater than 50% reflected a bias in the orienting of attention to SSB images as opposed to neutral images whereas a bias score less than 50% indicated a higher proportion of initial fixations directed towards neutral control images as opposed to SSB images (50% reflected no bias). For diet-water image pairs a bias greater than 50% reflected a bias in the orienting of attention to diet images as opposed to water images whereas a bias score less than 50% indicated a higher proportion of initial fixations towards water images than diet beverage images.

Dwell time bias is informative regarding the maintenance of attention on critical images (e.g. Mogg, Field & Bradley, 2005). The total dwell time was computed as the amount of time (ms) that participants spent fixating on each picture over the 1000ms of each trial. For SSB-water and SSB-diet trials, AB scores were calculated by subtracting dwell time on neutral (water/diet) images from dwell time on SSB images on each trial resulting in 64 AB scores for each image pair. These were then averaged resulting in one AB score for each image pair for each participant. On diet-water trials AB scores were calculated by subtracting dwell time on water images from dwell time on critical diet images on each trial resulting in 64 AB scores, which were also averaged for each participant. A positive AB score reflected increased AB towards relevant images as opposed to neutral images, whereas a negative dwell time bias score reflected attention away from relevant images (attentional avoidance).

Drink Preparation

Participants were required to consume 330ml of a full-sugar or diet (sugar-free) Sprite depending on the condition they were allocated to. See chapter two general methods for more information on drink preparation.

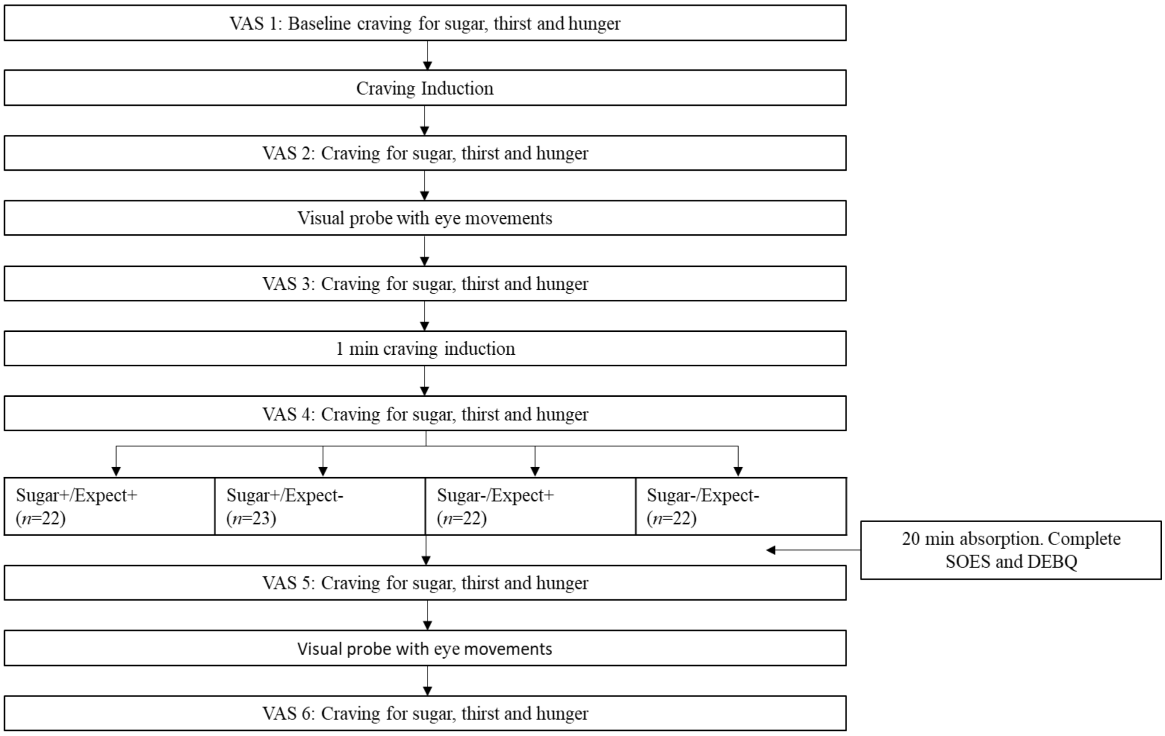
Procedure

Figure 6.2 presents an overview of the experimental procedure. Individuals were first sent a BFQ to determine whether they were high consumers of SSBs and eligible for participation in the study. If eligible, participants were asked to abstain from drinking any SSBs for 24 hours before the study. Participants were informed that a saliva sample would be taken when they arrived at the lab to measure glucose levels and ensure compliance with the study requirements.

Prior to the study, participants were asked to read the information sheet and provide informed consent. To follow through with study requirements, participants were asked to take a swab of the inside of their mouth using a cotton bud, however unknown to participants no further tests were carried out (e.g. Yeomans, Javaherian, Tovey & Stafford, 2005). Participant’s height and weight were then measured. Prior to commencing the study, participants were asked to rate how much they liked lemonade on a 100mm VAS, and then to complete baseline VAS (thirst, hunger and craving for sugar). As part of the sugar craving induction procedure, participants were provided with a 500ml full-sugar bottle of sprite, asked to open the beverage and given three minutes to look at and smell the beverage without consuming it. Following the craving induction, the items were removed, and participants were asked to complete the next VAS (i.e. VAS 2). They were then asked to complete the visual probe task, followed by the VAS again (i.e. VAS 3). Next, participants completed an additional one minute craving induction followed by completion of the VAS scales (i.e. VAS 4). They were then asked to consume either a SSB or diet beverage and provided with either the ‘told sugar’ or ‘told diet’ message depending on the condition in which they were allocated to. Those in the ‘told diet’ condition were told that they were consuming diet sprite however, those in the ‘told sugar’ condition were told that they were consuming full-sugar sprite.

Following consumption there was a 20 minute absorption period during which participants were asked to rate the pleasantness of the beverage (100mm VAS) and to complete the SOES and DEBQ. Following this, participants were asked to complete the VAS scales again (i.e. VAS 5), followed by the second visual probe task. Following completion of the visual probe participants were asked to complete the VAS for a final time (i.e. VAS 6). Upon completion of the study, participants were debriefed, thanked and compensated for their time and effort.

Figure 6.2- Schematic overview of experimental procedure.



6.4 Results

Participant Characteristics

A summary of sample statistics for each group are presented in Table 6.1. There was no significant difference between groups in age (F (3, 88) = 1.16, p=.329, η_p^2=.04), BMI (F (3, 88) = .82, p=.487, η_p^2=.03, liking for lemonade (F (3, 88) = 1.39, p=.252, η_p^2= .05), daily SSB consumption (F (3, 88) = 1.32, p=.275, η_p^2=.04), baseline sugar craving (F (3, 88) = .32, p=.815, η_p^2=.01), thirst (F (3, 88) = .10, p=.959, η_p^2<.01) and hunger (F (3, 88) = 1.48, p=.227, η_p^2=.05), in dietary restraint (F (3, 88) = 1.99, p=.122, η_p^2=.07) or beverage pleasantness (F(3, 88) = 2.15, p=.10, η_p^2=.07). There were also no significant differences between groups on any SOES subscale; cognitive and physical effects SOES (F (3, 88) = 1.71, p= .171, η_p^2= .06), hydration SOES (F (3, 88) = .87, p= .46, η_p^2=.03 and sugar craving SOES (F (3, 88) = .88, p= .454, η_p^2= .03).

Table 6.1– Means (±*SD*) of sample characteristics for each group.

	Sugar+		**Sugar-**	
	Expect+ *n*=22	**Expect-** *n*=23	**Expect+** *n*=22	**Expect-** *n*=22
Age	24.86 (±12.36)	22.82 (±6.84)	22.22 (±7.30)	26.45 (±11.71)
BMI	22.51 (±2.95)	24.36 (±5.18)	25.42 (±11.06)	25.01 (±4.51)
Lemonade liking	72.68 (±14.80)	71.18 (±13.87)	73.48 (±12.38)	65.27 (±16.07)
SSB Consumption	548.12 (±200.60)	613.12 (±314.26)	558.32 (±220.34)	681.75 (±318.07)
Baseline Sugar Craving	49.50 (±20.83)	43.14 (±24.62)	54.39 (±22.72)	48.27 (±25.95)
Baseline Thirst	64.41 (±16.35)	63.59 (±18.65)	68.61 (±16.99)	65.91 (±18.92)
Baseline Hunger	45.00 (±21.79)	50.68 (±21.24)	52.96 (±19.85)	59.05 (±26.30)
Dietary Restraint	2.62 (±.77)	2.32 (±.76)	2.69 (±.94)	2.25 (±.81)
Drink Pleasantness	71.00 (±17.35)	70.17 (±11.75)	67.86 (±20.54)	59.00 (±19.81)
Cognitive/physical effects SOES	3.73 (±.67)	3.33 (±.54)	3.76 (±.85)	3.64 (±.68)
Hydration SOES	3.91(± .77)	3.70 (±.85)	3.51 (±1.07)	3.92 (±.92)
Craving SOES	3.69 (± .88)	4.06 (±2.99)	3.47 (±.88)	3.32 (±1.06)

Manipulation Check

Paired samples t-tests were conducted using a Bonferroni adjusted alpha levels of .017 to determine if SSB exposure successfully increased sugar craving. Analyses revealed that compared to pre-craving induction (48.89 ± 23.54), there was significantly higher sugar craving after the first (59.89 ± 23.16), *t* (88) =7.65, *p*<.001, *d*=0.81 and second (62.67 ± 25.74; *t* (88) =8.27, *p*<.001, *d*=0.88) craving induction. However, there was no significant difference between sugar craving after the first and after the second craving induction, *t* (88) = 2.15, *p*=.032, *d*=0.23, suggesting that SSB exposure was successful in increasing and maintaining levels of sugar craving.

Attentional Bias

To determine the influence of SSB consumption and sugar expectancy on AB for SSB-related cues, a 2x2x2 ANOVA was performed on three AB measures (response latency bias, dwell time bias and initial gaze direction bias) during sugar-water and sugar-diet trials with drink content (sugar+, sugar-) and sugar expectancy (expect+,

expect-) as between subjects factors and time (pre-drink, post drink) as a within subjects factor. To also explore the potential role of these factors on AB for sweetness (regardless of sugar content) the analysis was also conducted on diet-water trials.

Response Latency Bias

For SSB-water trials there was a main effect of time (*F* (1, 85) = 4.82, *p*=.030, η_p^2=.05 indicating a significant reduction in attention for SSB-related cues from pre- (13.62 ± 92.15) to post-drink (-10.72 ± 108.82). However, there were no main effect of drink (*p*=.449) or message (*p*=.832) and no significant two or three-way interactions between drink, message and time (*p*s≥.20).

Analysis on trials involving SSB-diet trials also indicated a main effect of time (*F* (1, 85) = 4.19, *p*=.044, η_p^2=.05) with a significant reduction in AB for SSB-related cues from pre- (35.59 ± 92.25) to post-drink (13.78 ± 94.54). There were main effects of drink or message and no significant interactions between drink, message and time (*p*s≥.135).

ANOVA on diet-water trials to explore changes in AB for sweetness indicated no main effects of drink, message or time (*p*s≥.374) and no significant interactions between any of these factors (*p*s≥ .362).

Eye Movements

Dwell time bias.

Analysis conducted on data during sugar-water trials indicated no main effect of drink, message or time (*p*s≥.260) and no significant two or three-way interactions involving drink, message and time (*p*s≥.408).

Results for sugar-diet trials indicated a main effect of time (*F* (1,84) = 11.41, *p*=.001, η_p^2=.12 with a significant increase in dwell time bias scores from pre- (-36.40 ± 71.45) to post-drink (24.67 ± 121.00) suggesting an increase in attention to SSB related cues following beverage consumption. There were no significant main effects of drink or message (*p*s≥.271) and no significant interactions involving drink, message and time (*p*s≥.087).

ANOVA conducted on dwell time bias during diet-water trials indicated no main effect of drink, message or time (*p*s≤.535) and no significant two or three way interactions between drink, message and time (*p*s≤.300) suggesting these factors had no influence on changes in AB to sweetness.

Gaze direction bias.
Analysis revealed that on sugar-water trials there was no main effect of drink, message or time (*p*s>.281) and no significant two or three-way interactions involving drink, message or time (*p*s>.195).

Results for sugar-diet trials indicated no main effect of drink, message or time (*p*s>.169) and no significant two or three-way interactions involving drink, message or time (*p*s>.128).

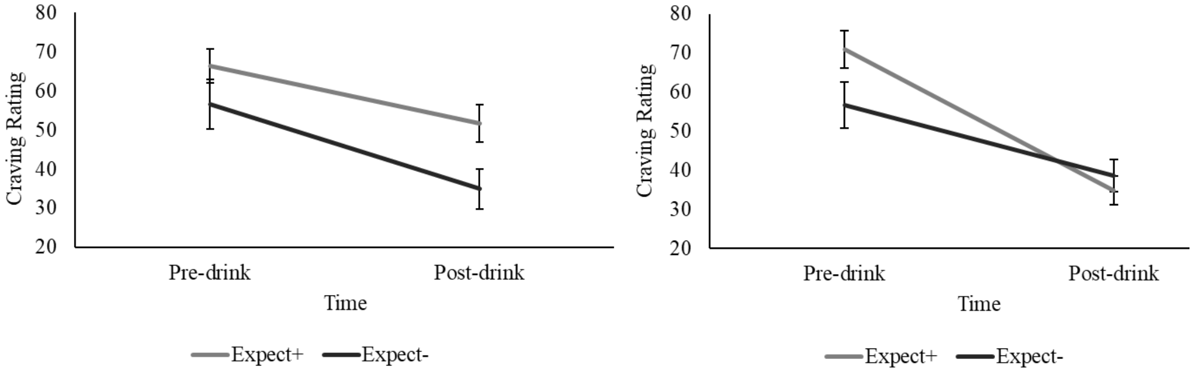
Analysis on diet-water trials revealed no main effect of drink, message and time (*p*s≥.096) and no significant two or three-way interactions between factors (*p*s≥.186).

Craving for Sugar

To determine the influence of SSB consumption and sugar expectancy on self-reported sugar craving, a 2x2x2 ANOVA was conducted with drink content (sugar+, sugar-), expectancy (expect+, expect-) as between subject factors and time (pre-drink, post-drink) as a within subject factor.
For ease of interpretation, analysis was only carried out on VAS 4 and 5 (immediately pre-drink and post-drink) as the study was interested in the effects of consuming/expecting sugar when the motivational value of sugar is high (following craving induction). Furthermore, changes in craving prior to and beyond this time point are confounded by craving induction procedures and completion of a visual probe task.

There was a main effect of time (F (1, 85) = 89.67, p<.001, η_p^2=.12 with a significant decrease in sugar craving from pre- (62.67 ± 25.74) to post-drink (39.99 ± 21.57), regardless of the sugar content. There was no main effect of drink (F (1,85) = .24, p=.627, η_p^2<.01, however there was a main effect of message (F(1, 85)=4.65, p=.034, η_p^2=.05, with significantly higher sugar craving for those in the Expect+ (55.89 ± 18.12) than those in the Expect- condition (46.67 ± 22.16). There was an interaction between drink, message and time (F (1, 85) = 6.78, p=.011, η_p^2=.07; see figure 6.3). Follow up analyses revealed no significant message x time interaction for those in the sugar+ group (F (1,42) =1.19, p=.281, η_p^2=.03), however there was a significant message x time interaction for the sugar- group (F (1, 43) = 6.34, p=.016, η_p^2=.13), with a greater reduction in craving for sugar for those who received the expect+ message than those who received the expect- message (p=.016). There were no significant two-way interactions between drink, message or time (ps≥.068).

Figure 6.3- Graphs showing mean craving ratings for the sugar+ (left) and sugar- (right) conditions. Results are shown separately for the Expect+ and Expect- groups at both pre- and post-drink time points. Error bars represent standard errors.



Relationship between Craving for Sugar and AB

Pearson's correlation was performed to explore the relationship between self-reported sugar craving and baseline AB for SSB-related cues (in sugar-diet and sugar-water trials) and AB for diet beverages (diet-water) using response latency bias, gaze direction bias and gaze duration bias scores. To further test this relationship, a Pearson’s correlation was also carried out on post-drink sugar craving and post-drink AB.

Results indicated no significant correlations between self-reported sugar craving and response latency bias in sugar-water (*p*=.164), sugar-diet *(p*=.569) and diet-water trials (*p*=.071). However, there were significant positive correlations between self-reported sugar craving and gaze direction bias scores in sugar-water (*r*=.295, *p*=.005), sugar-diet (*r*=.295, *p*=.005) and diet-water trials (*r*=.367, *p*<.001). In addition, there were significant positive correlations between self-reported sugar craving and dwell time bias scores in sugar-water (*r*=.394, *p*<.001) and diet-water trials (*r*=.375, *p*<.001), however self-reported sugar craving was significantly negatively correlated with dwell time bias scores in sugar-diet trials (*r*=-.225, *p*=.034).

Results indicated a significant positive correlation between post-drink sugar craving and post-drink response latency bias during the sugar-water (*r*=.295, *p*=.005) and diet-water trials (*r* =.259, *p*=.014) but not during the sugar-diet trials (*p*=.105). There were also significant positive correlations between post-drink sugar craving and post-drink gaze direction bias in sugar-water (*r*=.361, *p*=.001) and diet-water trials (*r*=.277, *p*=.009), but not in sugar-diet trials (*p*=.059). Finally, there were significant positive correlations between post-drink sugar craving and post-drink dwell time bias in sugar-water (*r*=.359. *p*=.001) and sugar-diet trials (*r*=.257, *p*=.016) but not in diet-water trials (*r*=.149, *p*=192).

Relationship between SOES Subscales and AB

Pearson’s correlations were conducted to determine the relationship between SOES subscale scores (cognitive and physical effects, hydration and sugar craving) and baseline AB scores (response latency bias, gaze direction bias and gaze duration bias).

Results indicated no significant correlations between any SOES subscale scores and response latency bias in SSB-water trials (*p*s≥.261) or SSB-diet trials (*p*s≥.078).

However, there was a significant positive correlation between cognitive and physical effects SOES scores and response latency bias during diet-water trials (*r* (87) =.256, *p*=.017), indicating that individuals who expected more positive and physical effects from sugar had heightened attention to diet beverages. There were no significant correlations between SOES subscale scores and gaze direction bias during SSB-water (*p*s≥ .114), SSB-diet (*p*s≥ .166) or diet-water trials (*p*s≤.107). Finally, there was no significant correlations between SOES subscale scores and gaze duration bias during SSB-water (*p*s≥ .205), SSB-diet (*p*s≥ .157) or diet-water trials (*p*s≥.175).

6.5. Discussion

The aim of the current study was to explore the pharmacological and anticipated effects of sugar on AB for SSB-related cues and sugar craving. Participants were allocated to one of four conditions in which the beverage content and expected content was manipulated. A visual probe task with concurrent eye movement monitoring and self-reported sugar craving were completed at both pre- and post-drink. It was hypothesized that both the pharmacological and anticipated effects of sugar would lead to a reduction in AB for sugar and sugar craving from pre- to post-drink. However, results indicated no effects of sugar consumption or sugar expectancy on AB for SSB-related cues across any of the AB measures. There was also no effect of sugar consumption on sugar craving, although expecting sugar (but not expecting no sugar) led to a reduction in sugar craving following placebo-sugar. It was also hypothesized that reported sugar craving would be positively correlated with subsequent AB for SSB-related cues. In line with this, increased sugar craving was associated with heightened AB for SSB-related cues across AB measures, at both pre- and post-drink time points. Finally, it was hypothesized that those with more positive outcome expectancies would have heightened attention for SSB-related cues, however, result indicated no significant association between SOES subscales and AB for SSB-related cues. Therefore, hypotheses were only partially supported by study findings.

The main focus of the study was to explore the role of underlying appetitive motivational processes involved in SSB consumption. Contrary to predictions, the current study demonstrated that following a craving induction, SSB consumption (in comparison to a sugar-free control) did not influence AB for sugar across any of the AB measures (response latency bias, dwell time bias, initial gaze direction bias) in high consumers. This contrasts with findings from previous research suggesting that AB for appetitive-related stimuli fluctuates in line with a person's motivational state (e.g. Stockburger et al., 2008; Kemps & Tiggemann, 2009). For example, a number of studies have demonstrated heightened AB for food-related stimuli when individuals are in a state of hunger (but not sated) (e.g. Stockburger et al., 2008; Piech et al., 2010) and heightened attention to chocolate-related stimuli when chocolate craving was experimentally induced (but not a non-craving induction control; Kemps and Tiggeman, 2009; Smeets et al., 2009). However, manipulating motivational state in the current study appeared to have no impact on AB for sugar, and thus, in contrast with food-related studies, this suggests attentional processes may not be involved in the maintenance of unhealthy beverage consumption.

The current study also reported no effect of SSB consumption on self-reported sugar craving, suggesting that the SSB did not influence motivational state beyond that of the placebo sugar-free beverage. Notably, if appetitive motivational processes are influenced by an automatic response to sweetness then SSB and diet beverages would influence motivational state similarly and may provide one explanation as to why the study found no effect of sugar consumption on AB for SSB-related cues or sugar craving. Indeed, findings did indicate an overall reduction in attention to SSB-related cues (as indicated by response latency bias) from pre to post-drink (regardless of sugar content), in both sugar-water and sugar-diet trials. There was a concomitant significant reduction in self-reported sugar craving from pre- to post-drink (regardless of the sugar content), suggesting that sweetness alone may influence appetitive motivational processes. Thus, consuming a diet beverage (providing the sweet taste without the calories) may provide one strategy to reduce craving-related AB for SSBs and to control sugar cravings in high consumers during weight loss and maintenance (in line with Rogers et al., 2016). However, the current study did not include a water-control comparison, which should be included in future research to determine whether these changes are only evident following sweet beverage consumption.

Notably, sweet beverage consumption (regardless of sugar content) had no effect on the gaze direction bias measure of AB and, surprisingly, resulted in increased dwell time bias on sugar-diet trials (greater attention paid to SSB-related cues over diet beverage-related cues). Inconsistent findings across AB measures may be reflective of the different stages of attentional processing being captured by the different AB measures with gaze direction bias reflecting automatic initial orienting of attention and dwell time bias able to capture more conscious later stages of attentional processing. Also, the extent to which the visual probe response latency measure of AB reflects initial orienting versus maintenance of attention is uncertain due to beverage images being presented for a relatively long duration (1000ms) to allow eye movement monitoring. Thus, further research is required involving a range of stimulus presentation times. Furthermore, the unexpected increase in AB for SSB-related cues in sugar-diet trial only may have occurred due perceptual similarities between images in SSB-diet trials or the attentional avoidance of SSB images at pre-drink.

Importantly, results confirmed that AB for SSB-related cues were related to self-reported craving. Specifically, self-reported sugar craving was consistently positively correlated with subsequent AB for SSB-related cues at both pre- and post-drink during sugar-water image trials. These findings are consistent with the theoretical model proposed by Field et al. (2016) which argues that AB fluctuates over time depending on momentary food evaluations (influenced by motivational state and current craving), and thus suggests a reciprocal relationship between craving and AB. Results also support a number of studies demonstrating increased craving to be correlated with heightened AB to both substance and food-related cues (Field et al., 2009; Werthmann et al., 2013; Smeets et al., 2009) and suggests the potential role of craving-related attentional processes on the motivation to consume unhealthy foods/beverages. Although SSB intake was not assessed in the current study, previous research suggests that craving is closely related to food consumption immediately after assessment (e.g. Nijs et al., 2010; Werthmann, Renner, et al., 2014) and this presents an important avenue to explore in future research to further determine the role of attentional processes in unhealthy SSB consumption.

An important consideration in the current study was the contribution of expectancy (the belief that sugar had been consumed). Contrary to predictions, sugar expectancy did not influence AB for sugar across any AB measures suggesting that people's beliefs about sugar do not influence the motivational impact of SSB-related cues. These findings are in contrast with expectancy theory (Kirsch, 1997). However, in line with predictions, sugar expectancy did influence self-reported craving ratings in that those in the placebo-sugar condition had a greater reduction in self-reported craving from pre- to post-drink when they expected they had consumed sugar compared to when they expected no sugar. Thus, it may be that expectancy works explicitly on craving but not on implicit measures of AB. These findings suggest that sugar expectancy (as opposed to sugar content) can influence subsequent reported sugar craving, and thus the role of expectancy should be considered in future research.

Contrary to predictions, the current study provided no evidence for a relationship between positive outcome expectancies and heightened AB for SSB-related cues. These findings contrast with that of some previous studies which demonstrate that more positive outcome expectancies are associated with heightened AB to both alcohol-related cues (Melaugh McAteer et al., 2015) and smoking-related cues (Waters et al., 2009). This suggests that outcome expectancies and AB may not covary to influence SSB consumption and may act independently of one another. Notably, research in this area is limited and the current sample only included high consumers of SSBs. The role of outcome expectancies on AB should be explored in a sample including a variety of consumer types (from non-consumers to high consumers) where there would be more variability in reported outcome expectancies and AB for SSBs.

In summary, the current study provides new insights into the role of AB for SSB-related cues as a maintenance factor for SSB consumption. Although findings indicated no effect of SSB consumption on AB for SSB-related cues and reported sugar craving when compared to a diet beverage, they do suggest that sweetness alone may influence AB for SSBs and sugar craving. This presents an avenue for further exploration of the potential role of diet beverages as an aid to control sugar craving and reduce attention to sugar. Importantly, current craving was related to the ability of SSB-related cues to attract attention suggesting that they may function together as a maintenance factor for SSB consumption. Moreover, the current study indicated that sugar expectancy did not influence AB for sugar but did influence reported sugar craving suggesting that people’s beliefs may contribute to changes in motivational state. Finally, SOES subscales were not related to AB for SSB related cues, suggesting that they may act independently of one another to the maintenance of SSB consumption. Taken together, current findings provide new insight into potential role of AB for SSB-related cues and sugar craving in the maintenance of SSB consumption and suggests that diet beverages could be utilised as an intervention for weight maintenance and control, although further research is required.

Chapter Seven:
General Discussion

The overarching aim of this thesis was to explore the pharmacological and anticipated effects of sugar on behaviour. First, a novel questionnaire was developed to explore the influence of individuals beliefs about the short-term effects (anticipated effects) of SSBs on SSB consumption. Next, the thesis utilised the balanced placebo design to examine the influence of both the pharmacological and anticipated effects of sugar, combined and in isolation across, cognitive performance, physical endurance, subjective energy, and both implicit and explicit appetitive motivational processes. This chapter will summarise the main findings and discuss theoretical and real-world implications. The methodological weaknesses are then considered, followed by directions for future research.

7.1 Results Summary

Studies 3.1 and 3.2 involved the development of the SSB outcome expectancies scale (SOES) to assess individual's beliefs about the short-term effects of SSB consumption and provided initial validation of the scale. Furthermore, the relationship between SOES subscales and SSB consumption was explored. Results of exploratory (study 3.1), and confirmatory (study 3.1 and 3.2) factor analysis indicated that outcome expectancies can be described in terms of three factors; positive cognitive and physical effects, craving for sugar, and hydration. Each subscale had high internal consistency and test re-test reliability. In study 3.1, all subscales were positively correlated with SSB consumption (ml/day), with similar findings reported in study 3.2 apart from there was no significant correlation between the craving subscale and SSB consumption. In both studies, high consumers had significantly higher scores on the positive cognitive and physical effects and hydration subscale than non-consumers, however there was no significant group differences on the craving subscale. These findings suggest that the short-term anticipated effects of SSBs are one factor influencing the consumption of these beverages.

The subsequent chapters utilised a balanced placebo design to explore the influence of sugar (pharmacological effects) and these anticipated effects across several aspects of behaviour (including several objective and subjective measures);

Chapter four investigated the pharmacological and anticipated effects of sugar on physical endurance (handgrip and leg-raise task) and measures of subjective energy. There was no evidence that the pharmacological effects of sugar influenced performance in any of the physical endurance tasks or measures of subjective energy. However, sugar expectancy did lead to a significant increase in persistence from pre- to post-drink on the leg-raise task, but not on the handgrip, or measures of subjective energy. These results suggest no influence of sugar on physical endurance or subjective energy under mild physical exertion, however there may be some contribution of expectancy.

The next chapter included two studies. Study 5.1 explored the pharmacological and anticipated effects of sugar, both combined and in isolation on cognitive processing (executive function tasks and memory recall) and subjective measures (subjective energy and boredom). It was found that there was no effect of sugar consumption or expectancy effects on executive function tasks (verbal fluency, inhibitory control) or memory recall performance, even under more difficult task conditions. There was also no effect of sugar consumption on measures of subjective energy and boredom, however they were influenced by sugar expectancy. Specifically, expecting a SSB resulted in a significant reduction in self-reported tiredness and fatigue, but not when participants expected a sugar-free beverage. Furthermore, there was a significant reduction in self-reported vigour and an increase in boredom for those who expected a sugar-free drink, but not for those who expected a SSB. To further explore anticipated effects and expand on these findings, study 5.2 utilised more explicit message manipulations following a placebo-sugar beverage. Participants received one of four messages in which information about the cognitive and subjective effects of SSB consumption was manipulated. Replicating findings from study 5.1, results indicated no expectancy effects on any cognitive performance measures, however expectancy effects influenced self-report measures. There was a significant reduction in fatigue and increase in vigour for those who expected increased energy, but no significant change in those who expected no effect. There was also a greater reduction in tiredness for those who expected increased energy compared to those who expected no effect. These results suggest that the beliefs people have about the effects of consuming a SSB can influence subjective feelings of energy.

The final study (chapter six) investigated the pharmacological and anticipated effects of sugar, both combined and in isolation, on explicit and implicit automatic appetitive motivational processes (craving and attentional bias-AB). The relationship between sugar craving and AB for SSB related cues, and between individual’s outcome expectancies and AB for SSB-related cues, was also assessed. Results indicated no effect of sugar or sugar expectancy on any measure of AB for SSB-related cues. There were also no acute effects of sugar on sugar craving, however in the placebo-sugar condition, those who expected sugar reported a greater reduction in craving than those who expected no sugar. Results also indicated that increased craving was associated with heightened AB for SSB-related cues at both pre- and post-drink time points. However, there was no evidence that individual’s outcome expectancies were associated with AB for SSB-related cues. Overall, sugar consumption and expectancy have no effect on AB for SSB-related cues, however, there is some contribution of sugar expectancy to sugar craving.

7.2 Theoretical Synthesis

To briefly summarize, expectancy theory postulates that individuals have expectancies regarding the outcomes of their behavior (e.g. individuals may expect to feel more alert following caffeine or expect impaired cognitive performance following alcohol). These expectancies are considered when individuals choose a course of action (Kirsch, 1997) and have been found to be predictive of several unhealthy behaviors, with positive expectancies predicting alcohol consumption and unhealthy diet choices (Fromme & D’Amico, 2000; Leigh & Stacy, 1993; Reid et al., 2005). According to expectancy-based conceptualizations of placebo effects, the belief that one has consumed a specific substance (e.g. caffeine, alcohol, etc.) activates response expectancies which drives behaviour, and produces responses consistent with the expected effects of the substance (Kirsch, 1999). This has been demonstrated across several domains; for example, placebo painkillers reduce pain and placebo-alcohol impairs cognitive performance in those who expect they have consumed the substance (e.g. Benedetti et al., 2003; Gilbertsen, Prathers & Nixon, 2010). It is believed that response expectancies also influence the pharmacological effects of the substance (Kirsch,1999), with evidence that expectancies influence the pharmacological effects of alcohol on cognitive performance, sports supplements on physical performance (e.g. Fillmore & Vogel-Sprott. 1995; McClung & Collins, 2007). Although, expectancy theory has been considered across a range of domains, there is limited research exploring the contribution of expectancy to the behavioural effects of sugar. If expectancy theory has application in understanding SSB consumption, then relationships between outcome expectancies and SSB consumption should be explored. Furthermore, if expectancy theory has application in understanding the behavioural effects of sugar, then fully balanced-placebo designs are required to explore the pharmacological and expectancy effects. Thus, this was the focus of the current thesis. The following section of this thesis will discuss the contribution of expectancy to SSB consumption, and to the behavioural effects of sugar, as well as whether the thesis findings were supportive of expectancy theory.

The first aim of the thesis was to determine whether people’s beliefs about the short-term effects of SSBs is related to SSB consumption. Utilising the scale developed in chapter three, study 3.1 found that all three expectancy subscales (expected positive cognitive and physical effects, hydration and craving) were positively correlated (albeit relatively weakly) with SSB consumption (ml/day). This relationship was further replicated in study 3.2, apart from there was no significant association between SSB consumption and expected sugar craving. This inconsistent finding may reflect differences between samples. For example, participants in study 3.1 were higher consumers than those in study 3.2, and there was also less variability in consumption in the second study. To better understand whether differing belief exist in high and non-consumers, both studies compared consumers on each subscale. Results indicated that high consumers scored significantly higher on expected positive cognitive/physical effects and hydration but not on expected craving. Findings from this chapter are consistent with previous research suggesting the anticipated effects contribute to the participation in unhealthy behaviors, such as alcohol consumption, smoking and unhealthy diet (e.g. Fromme & D'Amico, 2000; Van der Plight & de Vries, 1998; Reid et al., 2005). These findings are supportive of the element of expectancy theory which indicates that expectancies are considered when choosing a course of action and highlight the importance of short-term response expectancies as one of the drivers of SSB consumption. Indeed, these findings indicate that despite awareness of the long-term negative effects of SSB consumption (e.g. increased weight gain), these short-term anticipated effects of sugar may override this and influence the decision to consume SSBs. This suggests that the application of expectancy theory to SSB consumption should be considered in future research and is fundamental to understanding decision-making mechanisms involved in unhealthy behaviour choices.

The current thesis assessed the pharmacological effects of sugar on physical endurance and cognitive performance. Despite the fact chapter three found high consumers were more likely to expect positive cognitive/physical effects from consuming SSBs, subsequent studies failed to find any acute effects of sugar across any tasks assessing physical endurance (chapter four) or cognitive performance (chapter five). This was surprising considering a large body of research demonstrates sugar to improve physical performance (e.g. Wilber & Moffatt, 1992; Ventura et al., 1994; Spendiff & Campbell, 2002). This may reflect the intense conditions utilised in previous studies, while the current thesis utilised mild endurance conditions, and thus glucose levels may not have been sufficiently depleted for a SSB to benefit physical performance. Notably, the potential benefit of glucose under milder exertion (handgrip) has been previously been demonstrated by Gaillot et al. (2007), however participants completed a self-control task prior, which may have depleted glucose levels prior to the task, although recent research into the ego depletion effect suggests this is unlikely (e.g. Vadillo, Gold & Osman, 2016). Chapter six also failed to find pharmacological effects of sugar on executive function or memory recall. This is in contrast with some research demonstrating glucose to improve inhibitory control (e.g. Gaillot et al., 2007; Brandt et al., 2013), verbal fluency (Kennedy & Scholey, 2000) and recall performance (Stollery & Christian, 2013; Sünram-lea, Foster, Durlach & Perez, 2001; Riby, Mclaughlin & Riby, 2008), however is consistent with some research also failing to find effects of glucose on cognition (e.g. Ginieis, Franz, Oey & Peng, 2018). Notably, cognitive performance was assessed in a naturalistic seminar environment, whereas previous studies were laboratory-based, and thus findings in the current thesis are more reflective of the effects of sugar on cognition in the real world.

Notably, students report the highest rates of SSB consumption (e.g. West et al., 2006) and reportedly consume these drinks to improve cognitive performance and concentration whilst studying (chapter three; see also Malinauskas et al.,2007; Attila & Cakir, 2011; Bulut et al., 2014) and to aid with physical performance (Costa et al., 2014; O'Dea, 2003). However, thesis findings suggest that these beverages may not be a beneficial cognitive or physical aid during mild physical endurance conditions and cognitively demanding situations. Indeed, low-calorie beverages, containing ingredients such as caffeine, have been consistently linked to improvements in cognitive and physical performance (e.g. Forbes et al., 2007; Smith, 2002; Harrell & Juliano, 2009), and would contribute less to the obesity pandemic, and thus may represent a better cognitive and physical aid.

Expectancy theory posits that sugar related expectancies will influence individual's performance in accordance with their expectations. Thus, the contribution of the anticipated effects of sugar to cognitive and physical performance was also assessed in chapter four and five of this thesis. Findings indicated no influence of sugar related expectancy effects across any of the cognitive performance measures (chapter 5), however there was some contribution to physical endurance (chapter 4). Sugar expectancy significantly increased persistence on the leg-raise task, but not on the handgrip. However, when breakfast consumption was accounted for, individuals who consumed no breakfast prior to the session had greater persistence in the handgrip task post-drink when they expected sugar compared to when they expected no sugar. Notably, there were no sugar-related expectancy effects in those who had consumed breakfast. Indeed, those who consumed no breakfast reported significantly lower vigor at baseline than those who had consumed breakfast, suggesting that anticipated effects may be more sensitive when participants have lower energy levels (when there is more room for improvement), although further studies explicitly exploring

this are required. Consistent with previous studies, which have demonstrated the anticipated effects of several substances on physical performance (e.g. Kalasountas et al., 2007, McClung & Collins, 2007), these findings suggest that anticipated effects may be, at least in part, responsible for some of the effect of sugar on physical performance (attributed to pharmacological effects in previous research).
Since the anticipated effects of sugar did not influence cognitive performance this suggests that they may produce stronger effects in some domains than others. Notably, previous research has demonstrated anticipated effects to influence cognitive performance following placebo caffeine and placebo-alcohol (e.g. Fillmore & Vogel-Sprott, 1992; Christiansen et al., 2016), suggesting the contribution of expectancy effects to cognitive performance may differ by substance. Taken together, this thesis provides some support for the application of expectancy theory to the behavioural effects of sugar, in that sugar expectancy effects did influence performance in the mild endurance tasks. However, inconsistency in the role of expectancy effects across physical and cognitive tasks suggests that expectancy theory may not be universally applicable to the behavioural effects of sugar and demonstrates the need for further research exploring the role of expectancy theory in relation to sugar.

The current thesis also explored the role of pharmacological and anticipated effects across measures of subjective energy (chapters four and five) and self-reported boredom (chapter five). Findings indicated no anticipated effects of sugar on measures of subjective energy in chapter four, however in chapter five, the anticipated effects of sugar did influence subjective measures. Indeed, Study 5.1 found sugar expectancy reduced tiredness and fatigue, however expecting no sugar reduced vigor and increased boredom. In addition, study 5.2 found responses to be in line with individual’s expectations in that expecting increased energy led to increased sense of energy across measures. These findings are consistent with previous research demonstrating anticipated effects to influence subjective measures, such as placebo-caffeine increasing alertness and reducing tiredness (Mills et al., 2016; Schneider et al., 2006) and expecting sugar leading to increased arousal, regardless of whether a SSB or placebo was consumed (Christian & Stollery, 2013), and suggest the importance of accounting for response expectancies when utilising self-report measures. Notably, inconsistencies between chapters may reflect the type of energy individuals associate measures of subjective energy with, in each study. For example, in chapter four participants may relate to physical energy (energy to complete physical tasks), however in chapter five participants may relate to mental energy (ability to complete cognitive work). These findings provide some support for the application of expectancy theory to the subjective effects of sugar and demonstrates that the short-term increase in energy felt after consuming a SSB is solely due to expectation of this effect. This suggests that reliance on standard-placebo designs used in previous research (which does not isolate the role of expectancy), is not sufficient to fully understand the subjective effects of sugar.

Since one of the biggest reasons for SSB consumption may be underlying appetitive motivational processes, chapter six assessed the pharmacological and anticipated effects of sugar on AB for SSB-related cues and sugar craving. The study indicated no pharmacological effects of sugar on AB for SSB-related cues or sugar craving. However, there was a reduction in AB for SSB-cues and sugar craving following sweet beverage consumption (regardless of sugar content). This may suggest that sweetness alone satisfies a desire to consume sugar and that this desire for sweetness drives SSB consumption. Although, further research is required utilising an additional non-sweet control drink to determine whether this reduction was purely due to ‘sweetness’, rather than just an automatic response to beverage consumption. Notably, consistent with the theory by Field et al. (2016), and other previously discussed research, AB for SSB-related cues and sugar craving were positively related suggesting that AB for SSB-related cues and sugar craving may together contribute to continued SSB consumption.

There were also no anticipated effects of sugar on AB for SSB related cues, however there was some contribution of sugar expectancy to self-reported sugar craving. In the placebo sugar condition, there was a greater reduction in craving for those who expected sugar but not those who expected no sugar. This is consistent with research demonstrating anticipated effects to influence craving following placebo alcohol and placebo nicotine (e.g. Christiansen et al.,2016; Juliano & Brandon, 2002), although, to the best of knowledge, is the first study to provide insight into the role of expectancy on the desire to consume SSBs. However, in contrast with previous research demonstrating AB in smokers and drinkers to be related to positive outcome expectancies (e.g. Waters et al., 2009; Melaugh et al., 2015), chapter six demonstrated no relationship between SSB outcome expectancies and AB to SSB-related cues, suggesting that expectancies and AB for SSB-related cues may not covary to influence SSB consumption. Taken together, expectancies do not influence implicit motivational processes, but do influence explicit motivational processes (i.e. sugar craving) involved in SSB consumption. This is further supportive of the application of expectancy theory to self-report responses (also found in chapter five), in that expectations tend to influence self-report measures in the direction expected. Notably, more research is required assessing the anticipated effects of sugar on other implicit appetitive motivational processes (e.g. automatic approach responses) that may underlie SSB consumption.

Taken together, these findings suggest that the isolated pharmacological effects of sugar have little to no impact on any of the objective or subjective measures taken across the entire thesis. This suggests that past studies, which have found pharmacological effects of sugar, may be contaminated with expectancy effects, or in the case of physical performance requires severe depletion of blood glucose. On the other hand, there were some anticipated effects of sugar on physical endurance and particularly subjective measures. This suggests that increased energy and reduced sugar craving following consumption of sugar is, in part, due to the beliefs people have about sugar consumption.

Notably, the current thesis provides some insight into the development of sugar-related outcome expectancies/ beliefs about the effects of sugar. Expectancy theory postulates that outcome expectancies can form through our own personal experience with the substance. The fact that the current thesis found no pharmacological effects of sugar across any aspects of behaviour suggests that sugar response expectancies are unlikely to have formed from personal experience, at least under non-demanding physical and mental conditions. However, it is possible that expectancies related to cognitive and physical effects form under more demanding conditions (when blood sugar would be sufficiently depleted for sugar to have an effect), although this was not explicitly tested. This thesis highlights the influence that observations of social models and marketing techniques could have on behaviour. As previously mentioned, individuals may observe other individual's use SSB's under certain conditions (e.g. at sporting event, during lectures). Also, SSB's (particularly sports and energy drinks) are directly marketed as physical performance enhancers/ energy boosters. Together, this would lead to the development of beliefs about the effects of sugar and which could influence behaviour following consumption of an SSB (e.g. physical performance and subjective feeling of energy), perhaps beyond the pharmacological effects of sugar.

Taken together, given the fact the current thesis demonstrated the contribution of the anticipated effects of sugar on physical endurance and subjective measures, it is important for research to control for these anticipated effects of sugar. Indeed, previous research using the standard placebo design has demonstrated mixed effects of sugar across aspects of behaviour assessed in the current thesis and it is possible that response expectancies account for some of the mixed findings. It is possible that some of the effects of sugar (attributed to pharmacological effects), may be due to expectancies, and thus highlighting the importance of research utilising sufficient control conditions to account for what may be critical anticipated effects of sugar on behaviour.

7.3 Real World Implications

The findings of this thesis have some real-world implications. Firstly, the finding that expectancies influence SSB consumption suggests that they may be one target for interventions to reduce calorific beverage consumption. Indeed, research indicates that outcome expectancies are related to dietary behaviour change (e.g. Doerksen & McAuley, 2001), and thus educating individuals by reducing the perceived benefits/increasing negative consequences of consuming SSBs, but also highlighting the contribution of anticipated effects to behaviour, may be one strategy to reduce consumption. Notably, a component of motivational interviewing when done targeting alcohol-related problems alcohol has focussed on expectancy theory with positive expectancies representing an important component of motivation to drink and negative expectancies representing a component of motivation to refrain from drinking (Jones et al., 2001). Motivational interviewing techniques integrating expectancy theory may be a beneficial intervention to reduce calorific beverage consumption and obesity. Alternatively, increasing the perceived benefits and reducing negative expectancies (e.g. weight gain, cancer) associated with low-calorie beverage alternatives, may increase the consumption of healthier beverages. For example, healthy eating messages need to be developed and incorporated into campaigns that reinforce that there are healthier (diet) beverages that quench thirst and that can improve cognitive and physical performance.

Furthermore, the finding that expectancy effects influence physical performance and subjective energy suggests the potential influence that sport-related marketing strategies used by SSB companies could have on individual’s behaviour. Merely marketing SSBs (particularly in the case of sports and energy drinks) as physical performance enhancers/ energy boosters could lead individuals to expect positive effects from consumption, strengthen current beliefs about the effects of these beverage, and in turn contribute to improved physical performance and increased energy. If physical effects are merely due to expectancies under milder physical exertion, marketing non-calorific beverages as physical performance enhancers could lead individuals to associate non-calorific beverages with these effects and thus lead to similar effects being produced as the full-sugar versions.

Finally, in chapter six, sugar expectancy was found to reduce sugar craving. This suggests that people’s beliefs (rather than sugar content) are more important determinants of sugar-cravings. Therefore, interventions should target individual’s beliefs about the use of diet beverages (which provide the sweet taste without the calories) as aids to control sugar cravings. Chapter six also found AB for SSB-cues and sugar craving to be related. Thus, reducing AB for SSB-related cues provides another scope for reducing craving for SSBs. Indeed, studies utilising the modified visual probe paradigm, have demonstrated that, training individuals to attend away from alcohol-related cues reduces AB to these cues in heavy and social drinkers (Field et al., 2007; Field & Eastwood, 2005; Schoenmakers, Wiers, Jones, Bruce, & Jansen, 2007) and training smokers to attend away from cigarette-related cues reduces AB towards these cues (e.g. Attwood, O'Sullivan, Leonards, Mackintosh, & Munafo, 2008; Robinson et al., 2017), Importantly, studies in the food domain report reduced AB for food-related cues following attentional avoidance training (e.g. Kemps, Tiggemann & Hollitt, 2014; Kemps, Tiggemann & Stewart-Davis, 2018; Kemps, Tiggemann & Hollitt, 2015) but also increased attention to healthy food in those trained to attend to healthy food cues (e.g. Kakoschke, Kemps & Tiggemann, 2014). Therefore, attentional avoidance training may provide one strategy to reduce sugar craving and calorie intake. Notably, no effect of attentional avoidance training on AB for food-related cues has also been reported (Hardman, Rogers, Etchells, Houstoun & Munafò, 2013) and Christiansen, Schoenmakers and Field (2015) has exercised caution over the use of AB modification in clinical settings. However, given the high abundance of SSB-related cues in our environment and the strong association between SSB consumption and obesity, AB modification interventions may have some utility in reducing attention to SSB-related cues and sugar cravings, which may influence subsequent drinking behaviour.

7.4 Limitations

Research in the current thesis has some limitations. Firstly, the participants who took part in the studies were mainly recruited through the University of Liverpool, and therefore mainly consisted of university students. Although students comprise one of the largest consumer groups of SSBs (e.g. West et al., 2006), the pharmacological and anticipated effects of sugar may differ in other groups of the population, and therefore potentially limiting the generalizability of study findings. Furthermore, the samples recruited across studies mainly consist of female participants. Previous research demonstrates alcohol expectancies differ across males and females (Lundahl, Davis, Adesso & Lukas, 1997), and as indicated in chapter three, gender differences exist on the positive cognitive/physical effects and hydration SOES subscale. Subsequent chapters were not powered to detect gender effects. Although, to explore this, gender was added as an additional factor to the ANOVAs and across studies all relevant effect sizes were small, apart from a medium size and significant gender effect for the influence of sugar expectancy on leg-raise performance (η_p^2=.06), in that sugar expectancy influenced handgrip performance in males, but not females. Notably, there were only six males in one of the conditions, and thus findings are tentative, and further research is required.

For studies in chapters four and five, pre-study drink matching involved individuals around the department being asked to taste beverages and indicate whether they could tell the difference between the full sugar and placebo sugar beverage. Although all individuals reported not being able to distinguish between the beverages, this method of drink matching is potentially subject to demand characteristics resulting in individuals guessing the aims and thus giving the desired response. However, the method did appear successful in matching beverages considering no participants reported deceived about the drink contents when asked to guess study aims upon completion of each study (i.e. they believed the message that they receive regardless of whether it was congruent with the contents of the beverage). One method of drink matching which may be more reliable for future research is sensory triangle testing, during which individuals are presented with two identical samples (i.e. glucose beverage) and one that is different (i.e. beverage sweetened with sucralose) and are asked to indicate which sample is the odd one out.

Furthermore, although this thesis reports no pharmacological or anticipated effects of sugar across any cognitive or physical endurance tasks, only a limited number of tasks were utilized. It is possible that tasks assessing other components of executive function or memory may be more sensitive to the effects of sugar and sugar-related expectancy effects. As previously reported, research has demonstrated sugar to be more sensitive under cognitively demanding conditions and intense physical task conditions, and therefore it is possible that tasks in the current study were not demanding enough to sufficiently deplete glucose levels for a SSB to be beneficial. Moreover, the anticipated effects of sugar may have a differential influence under more demanding task conditions.

Participants were given a 50g dose of glucose across all studies to maintain consistency. Although sugar content of many SSBs has recently been reduced due to the sugar tax, we wanted to reflect the effects of SSBs in the real world and 50g represented a similar sugar content to a number of SSBs (e.g. 380ml lucozade sport, 500ml coca cola/pepsi) at the time of study design. This dosage is also used across a number of previous studies (e.g. Green et al., 2001; Stollery & Christian, 2013; Sünram-Lea et al., 2012). Although, no pharmacological effects of sugar were found across any measures used in the thesis, conclusions cannot be made about the effects at other glucose doses. Indeed, some studies exploring the effects of glucose on cognitive performance have reported glucose effects using 25g dose (e.g. Kennedy & Scholey, 2000; Brandt et al., 2013), and a range of glucose concentrations have been used in physical performance studies (e.g. 75 g in Ventura et al., 1994; 7.6% glucose in Spendiff & Campbell, 2002), and thus further research is required to explore the pharmacological and anticipated effects under different doses.

An additional limitation relates to the SOES scale developed in chapter three. Items in the questionnaire resulted in three expectancy factors, however, it is possible that other expectancies, not assessed in the current scale, are also important influences on SSB consumption. For example, expected social benefits, found to influence vegetable consumption (Domel et al., 1995), may also influence participation in SSB consumption (e.g. my friends will like me more), although this is probably only likely in children. Also, as previously mentioned, some research reports positive expectancies to be more predictive of behaviour, however there is evidence for negative expectancies acting as a deterrent for behaviour (e.g. Jones et al., 2001). Therefore, negative expectancies, such as expected, guilt about health, dental problems, weight gain, bloating, etc, may lead to avoidance of SSBs and should be explored.

In relation to the last three chapters (four, five and six), it is possible that some individuals did not believe the expectancy manipulation, and thus expectancy effects were underestimated. As mentioned previously, Christian and Stollery (2013) highlighted the fact participants expectations may not be in line with the message given. For example, even though participants were told they had consumed a placebo beverage they may believe that it contained glucose, which would lead to expectations incongruent to the message given. Although, this seems unlikely as upon completion participants were asked to guess the study aims, and no participant mentioned about the beverage content being manipulated. Furthermore, due to the large sample size of study 5.1 and 5.2, we used calorie estimates to exclude those who reported calorie estimates incongruent with the message given and found a slight increase in the effect size of expectancy effects for subjective measures. This suggests that expectancy effect may be even larger than reported across studies. Problematically, some individuals have poor understanding of calories (Carels et al., 2006) and therefore a forced-choice paradigm at the end of the experiment (where participants choose whether they consumed the glucose or placebo beverage) may be a better procedure to determine whether drink choice is in line with the expectancy manipulation.

Finally, due to limitations in time and funding, blood glucose levels were not assessed, and therefore it is possible that, some participant’s blood glucose levels were high to start with, and thus glucose would have limited effect. In addition, participants may have completed cognitive/physical tasks during periods when blood glucose levels were not at peak. For example, during the cognitive test battery, glucose levels may have decreased by the time some of final tasks (e.g. delayed recall) and subjective measures of energy were completed. Therefore, to further explore the pharmacological effects of sugar across these measures, future research should assess blood glucose levels to ensure that cognitive/physical tasks are completed while blood glucose levels are raised.

7.5 Future Research

The findings discussed in this thesis highlight interesting avenues for future research. The first chapter demonstrated that SSB expectancies were related to SSB consumption, although causality cannot be inferred from these findings. In order to assess whether there is a causal relationship between SSB expectancies and consumption, future research could directly manipulate people’s beliefs about the effects of SSBs. For example, one group could be provided with positive message manipulations to increase positive expectancies and another group provided with negative message manipulations to increase negative expectancies. To determine influence of expectancies on SSB consumption, subsequent *ad lib* SSB intake could be assessed in each group.

In chapters four and five of the current thesis participants were provided with an unbranded SSB and participants were told that they were consuming a ‘SSB’, with no specific reference to the category of SSB (e.g. soft drink, sports drink, energy drink). Indeed, the anticipated effects of sugar on cognitive/physical performance may be stronger for some categories of SSBs than others. For example, participants may anticipate stronger cognitive/physical effects from consumption of sports and energy drinks which are directly marketed as cognitive/physical performance enhancers and energy boosters, as compared to soft drinks which are less closely linked to these effects. Therefore, future research could investigate the strength of these anticipated effects across different categories of SSBs.

The final study demonstrated an overall reduction in AB for SSB-cues and sugar craving from pre-to post drink (regardless of whether SSB or diet was consumed). This suggests that sweetness alone, provided by a diet beverage, may satisfy sugar craving. Future studies should include a non-sweet control beverage to determine whether this reduction in sugar craving and AB for SSB-related cues is due to sweetness or an automatic response to beverage consumption.

To allow for better assessment of the causal relationship between sweet beverage consumption and underlying appetitive processes in the real world, ecological momentary assessment trials should be carried out. These would involve the assessment of fluctuations in underlying appetitive motivational processes at different time points throughout the day. Indeed, such studies have reported that increased AB for smoking related cues, precede increases in craving during smoking cessation, and that increased AB precedes relapse, and temptation to use a drug (e.g. Waters et al., 2014; Begh et al., 2016; Marhe, Waters, van de Wetering & Franken, 2013; Waters, Mahre & Franken, 2012). Although limited studies exist with food, research has demonstrated increased craving to precede chocolate and snack food consumption (e.g. Richard, Meule & Blechert, 2019; Richard, Meule, Reichenberger, & Blechert, 2017). Thus, using ecological momentary assessment, future trials could determine whether elevated sugar craving and AB for SSB-related cues precedes SSB consumption in high consumers. Furthermore, during periods when sugar craving is high, participants could be prompted to consume a ‘low calorie’ sweet beverage to determine the subsequent influence on sugar craving and AB for SSB-related cues. This would provide further insight into whether low calorie beverages are successful in controlling the desire to consume sugar in the real world.

7.6 Conclusions

The overarching aim of the thesis was to explore the pharmacological and anticipated effects of sugar on behaviour. Firstly, the thesis assessed whether individuals' beliefs about the short-term effects (anticipated effects) of SSBs were related to SSB consumption. Findings indicated that individuals with more positive beliefs about the short-term effects of SSBs (e.g. cognitive/physical benefits and hydration) consumed a larger quantity of these drinks. The aim of next sections explored both the pharmacological and anticipated effects of sugar, both combined and in isolation, on several aspects of behaviour including cognitive performance, physical endurance, subjective energy, and explicit and implicit appetitive motivational processes. Overall, findings indicated no pharmacological effects of sugar across any objective or subjective measures assessed across the thesis. The anticipated effects also had no effect on any objective measures, apart from there was some contribution of sugar expectancy to physical endurance. Furthermore, there was consistent evidence for the role of anticipated effects of sugar on subjective measures, including measures of energy and sugar craving. Taken together, these findings suggest that anticipated effects of sugar appear to be more important influences on behaviour (particularly subjective measures) than the pharmacological effects of sugar and that expectancies may account for some of the positive effects of sugar found in previous research, particularly in the case of physical endurance. Furthermore, findings suggest that consuming sugar may not be necessary to control sugar cravings. Thus, interventions to reduce consumption should address people's beliefs about the effects of sugar and educate individual's about contribution of expectancy to behaviour.

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Appendices

Appendix A:

This appendix includes chi-squared results for the pilot drink taste test used to determine which beverage to use in chapter six (see table A1).

During the pilot, participants (*N*=32) were asked to taste a number of beverages and indicate whether it was the full-sugar or diet version. The table below shows the percentage of individuals who guessed each drink to be either the full sugar or diet version. Although there were a number of full-sugar/diet pairs which appeared to taste alike, Sprite (highlighted in red) was chosen, as both the full sugar and diet version of the drink were highly indistinguishable.

Table A1- Chi-squared results for pilot drink taste test.

Drink	Guessed Regular (%)	Guessed Diet (%)	χ^2	*p*
Regular Coke	53.1	46.9	.13	.724
Diet Coke	12.5	87.5	18.00	<.001
Regular Sprite	59.4	40.6	.13	.289
Diet Sprite	46.9	53.1	.13	.724
Regular 7 Up	65.6	34.4	3.13	.077
Diet 7 Up	59.4	40.6	1.13	.289
Regular Cherry Coke	50	50	.00	1.00
Diet Cherry Coke	37.5	62.5	2.00	.157
Regular Asda Lemonade	46.9	53.1	.13	.724
Diet Asda Lemonade	40.6	59.4	1.13	.289
Regular Pepsi	46.9	53.1	.13	.724
Diet Pepsi	37.5	62.5	2.00	.157

Appendix B:

This appendix refers to the general methods (chapter two) and includes the beverage frequency questionnaire used to assess SSB consumption across all studies in the thesis.

Beverage Questionnaire

For this experiment we are trying to get an idea of your average beverage consumption.
INSTRUCTIONS - Please consider each of the following beverages, and mark down the quantity of each you consume, at present. Delete whether each is consumed on a daily or weekly rate.

Bottled water
(e.g. still, sparkling) - .... bottles per day / week

Tap Water -..................... glasses per day/ week

Regular Squash (i.e. Cordial)
(e.g. Robinsons, Kia Ora, etc.) - ....glasses per day / week

‘No added sugar’ Squash (i.e. Cordial)
(e.g. ‘no added sugar’ Robinsons, - .... glasses per day / week
‘no added sugar’ Kia Ora, etc.)

Carbonated drinks -.................... cans per day / week and/or
(e.g. Pepsi, Coke, Sprite, Fanta, etc.) -.................... bottle per day/ Week

'Diet' carbonated drinks
(e.g. Diet coke, Pepsi Max, - .... cans per day/ week and/or
Fanta zero, etc.) -.................... bottle per day/ week

Coffee - ....cups per day / week, each with .... sugar
- .... cups per day / week, each with .... artificial sweetener

Tea - ....cups per day / week, each with .... sugar
- .... cups per day / week, each with .... artificial sweetener

Hot Chocolate - ....cups per day / week

Milk - ....glasses per day / week

Milkshake
(e.g. Yazoo, Nesquik, Frijj, Mars, etc.) - .... glasses per day / week

Fruit Juice (100% Fruit Drinks)
(e.g. Pure orange, pure apple, etc.) - .... glasses per day / week

Energy drink - ....bottles per day/ week and/or
(e.g. Red bull, Monster, Lucozade, - ....cans per day/ week
Rockstar, Relentless, etc.)

Diet energy drink -............. bottles per day/ week and/or
(e.g. Sugar free red bull, Monster -............... cans per day/ week
absolutely zero, Rockstar Zero, etc.)

Sports drinks
(e.g. Lucozade Sport, Gatorade, -....................bottles per day/ week
Powerade, etc.)

Bottled juice drink
(e.g. Ribena, Vimto, Oasis, etc.) -.................... bottles per day/ week

‘No added sugar’ Bottled juice drink
(e.g. Ribena light, no added sugar Vimto, -..................... bottles per day/ week
Oasis light, etc.)

Appendix C:

This appendix refers to chapter three and includes the initial SSB outcome expectancies scale (SOES) (66 item).

SSB outcome expectancies scale

Sugar-sweetened beverages are defined as beverages that contain added sugar and include; regular (non-diet) soft drinks, fruit and juice drinks (excluding 100 % juice), and non-diet sports drinks, and energy drinks. Here is a list of some affects you may experience after consuming sugar.

How likely is it that these things would happen to **you** when you consume a sugar-sweetened beverage? Please indicate on the scale what best describes how sugar beverages would affect you.

After consuming a sugary drink:

	No Chance	Very Unlikely	Unlikely	Likely	Very Likely	Certain To Happen
1. I am happier	1	2	3	4	5	6
2. I feel more relaxed	1	2	3	4	5	6
3. I can't concentrate as well	1	2	3	4	5	6
4. I would get tired quicker during exercise	1	2	3	4	5	6
5. I have more strength	1	2	3	4	5	6
6. I feel more depressed/sad	1	2	3	4	5	6

7. I have a stronger desire for more unhealthy foods	1	2	3	4	5	6
8. It satisfies my desire for sugar	1	2	3	4	5	6
9. It gives me a boost of energy to complete chores	1	2	3	4	5	6
10. I crave more sugary foods and drinks	1	2	3	4	5	6
11. I feel like I need more fluid	1	2	3	4	5	6
12. It makes me want to go to sleep	1	2	3	4	5	6
13. I feel less thirsty	1	2	3	4	5	6
14. I feel less de-hydrated	1	2	3	4	5	6
15. I feel hydrated	1	2	3	4	5	6
16. I feel more agitated	1	2	3	4	5	6
17. My thinking becomes slowed	1	2	3	4	5	6
18. It would be detrimental to my physical performance	1	2	3	4	5	6

19. I have less energy to complete daily tasks	1	2	3	4	5	6
20. It is detrimental to my performance on mental tasks	1	2	3	4	5	6
21. I crave healthier foods to compensate	1	2	3	4	5	6
22. I become weaker	1	2	3	4	5	6
23. I would get tired quicker during a workout	1	2	3	4	5	6
24. I am more active	1	2	3	4	5	6
25. I become de-hydrated quicker	1	2	3	4	5	6
26. I would be able to run further	1	2	3	4	5	6
27. I feel more tired	1	2	3	4	5	6
28. I am slower at solving problems	1	2	3	4	5	6
29. I am restless	1	2	3	4	5	6
30. I feel that my sweet tooth is satisfied	1	2	3	4	5	6
31. It provides me with mental energy to complete cognitive tasks	1	2	3	4	5	6

32. My performance on mental tasks improves	1	2	3	4	5	6
33. I can concentrate more when reading	1	2	3	4	5	6
34. I think less about eating other sugary food and drinks	1	2	3	4	5	6
35. I keep thinking about consuming more sugar	1	2	3	4	5	6
36. I have a stronger urge to consume more sugary drinks	1	2	3	4	5	6
37. I find it harder to focus while reading	1	2	3	4	5	6
38. I feel more cheerful	1	2	3	4	5	6
39. I can solve problems faster	1	2	3	4	5	6
40. I think more about consuming healthier foods	1	2	3	4	5	6
41. I am more sleepy	1	2	3	4	5	6
42. I feel like I need to drink more water	1	2	3	4	5	6
43. I feel more positive	1	2	3	4	5	6
44. It quenches my thirst	1	2	3	4	5	6

45. I feel more de-hydrated	1	2	3	4	5	6
46. I would not be able to run as far	1	2	3	4	5	6
47. I am more alert	1	2	3	4	5	6
48. I can think quicker	1	2	3	4	5	6
49. I feel calmer	1	2	3	4	5	6
50. I am less able to focus on my work	1	2	3	4	5	6
51. I would be able to exercise for longer	1	2	3	4	5	6
52. I feel that I need to consume another sugary drink	1	2	3	4	5	6
53. I feel less anxious	1	2	3	4	5	6
54. I feel more tense	1	2	3	4	5	6
55. I have less energy	1	2	3	4	5	6
56. It makes me more thirsty	1	2	3	4	5	6
57. It satisfies my need for fluid	1	2	3	4	5	6
58. I feel I have let myself down	1	2	3	4	5	6

59. I have more energy to complete daily activities	1	2	3	4	5	6
60. I feel more energized	1	2	3	4	5	6
61. I am more likely to retain information	1	2	3	4	5	6
62. I feel more gloomy	1	2	3	4	5	6
63. My performance would be improved during physical activity	1	2	3	4	5	6
64. It drains me of mental energy	1	2	3	4	5	6
65. I could spend longer working out in the gym	1	2	3	4	5	6
66. I have better memory and concentration	1	2	3	4	5	6

Appendix D:

This appendix concerns chapter three and includes the final SSB outcome expectancies scale (SOES) (36 item).

SSB Outcome Expectancies Scale

Sugar-sweetened beverages are defined as beverages that contain added sugar and include; regular (non-diet) soft drinks, fruit and juice drinks (excluding 100 % juice), and non-diet sports drink, and energy drinks. Here is a list of some affects you may experience after consuming sugar.

How likely is it that these things would happen to **<u>you</u>** when you consume a sugar-sweetened beverage? Please indicate on the scale what best describes how sugar beverages would affect you.

After consuming a sugary drink:

	No Chance	Very Unlikely	Unlikely	Likely	Very Likely	Certain to Happen
1. I have a stronger desire for more unhealthy foods	1	2	3	4	5	6
2. It gives me a boost of energy to complete chores	1	2	3	4	5	6
3. I crave more sugary foods and drinks	1	2	3	4	5	6
4. I feel less thirsty	1	2	3	4	5	6
5. I feel hydrated	1	2	3	4	5	6
6. I am more active	1	2	3	4	5	6

7. I would be able to run further	1	2	3	4	5	6
8. It provides me with mental energy to complete cognitive tasks	1	2	3	4	5	6
9. I keep thinking about consuming more sugar	1	2	3	4	5	6
10. I have a stronger urge to consume more sugary drinks	1	2	3	4	5	6
11. I feel more cheerful	1	2	3	4	5	6
12. I can solve problems faster	1	2	3	4	5	6
13. I feel more positive	1	2	3	4	5	6
14. It quenches my thirst	1	2	3	4	5	6
15. I am more alert	1	2	3	4	5	6
16. I can think quicker	1	2	3	4	5	6
17. I would be able to exercise for longer	1	2	3	4	5	6
18. I feel that I need to consume another sugary drink	1	2	3	4	5	6
19. I feel less anxious	1	2	3	4	5	6
20. It satisfies my need for fluid	1	2	3	4	5	6

21. I have more energy to complete daily activities	1	2	3	4	5	6
22. I feel more energized	1	2	3	4	5	6
23. I am more likely to retain information	1	2	3	4	5	6
24. My performance would be improved during physical activity	1	2	3	4	5	6
25. I could spend longer working out in the gym	1	2	3	4	5	6
26. I have better memory and concentration	1	2	3	4	5	6

Appendix E:

This appendix concerns study 5.1 and includes the results of ANOVA on cognitive performance and subjective measures data for the 'females only' subsample.

Since the participant sample consists of an unequal number of males and females and there are a small number of males in each condition, gender cannot be explored as a variable in ANOVA. Analysis of cognitive performance and self-report measures conducted on 'female only' data is highly consistent with that of the whole sample, and thus, in Chapter five, males were retained in the sample. This appendix presents analysis on female participants only (n=261).

The basic design across all analyses is a two-factor independent Analysis of Variance (ANOVA) involving drink (Sugar+, Sugar-) and Message (Expect+, Expect-). Any related samples factors are identified at the start of each analysis.

Cognitive Performance

COWAT: Number of words produced was analysed and time (pre-drink, post-drink) was the related factor. Results indicated a main effect of time (F (1, 257) =164.12, p<.001, η_p^2=.39); significantly more words were produced post-drink (M=49.10, SD= 7.86) as opposed to pre-drink (M=35.39, SD=8.05). There were no main effects of drink or message and no significant interactions involving drink, message and time (ps≥.143).

Stroop Task: Stroop times were analysed with time (pre-drink, post-drink) as the related samples factor. Results indicated a significant main effect of time (F (1, 257) = 145.37, p<.001, η_p^2=.36) with significantly lower Stroop times post drink (M=47.53, SD=8.39) as opposed to pre-drink (M=54.13, SD=12.10). There were no other significant main effects of drink or message and the predicted two-way interaction between drink and time and message and time interaction were non-significant (ps≥.102). The predicted three-way interaction between drink, message and time was also non-significant (p=.171).

Free Recall: Number of words remembered was analysed. The related samples factors were word type (abstract, concrete) and delay (immediately post-drink, 35 minutes post-drink). There was a main effect of word-type (*F* (1, 257) =29.35, $p<.001$, $\eta_p^2=.10$) with significantly more concrete words (*M*=6.65, *SD*=2.59) recalled than abstract words (*M*=5.56, *SD*=2.37). There was also a main effect of delay (*F* (1, 257) =387.68, $p<.001$, $\eta_p^2=.60$) with more words remembered immediately post-drink (*M*=4.74, *SD*=1.22) than 35 minutes post-drink (*M*=3.74, *SD*=1.36). There was a main effect of drink (*F* (1,257) = 5.31, $p=.022$, $\eta_p^2=.02$) with more words recalled in the diet beverage condition (*M*=4.42, *SD*=1.24) than glucose condition (*M*=4.06, *SD*=1.20). However, the predicted two-way interactions between drink and time, and message and time were non-significant (*p*s≥.516). The predicted three-way interaction between drink, message and time was also non-significant (*p*=.114).

Self-report Measures

For all mood outcome measures a three-way mixed ANOVA was conducted with time (time 1: pre-drink, time 2: immediately post-drink, time 3: 35 minutes post-drink) as the related subject's factor. Table E1 shows means (±*SD*) for mood measures under all combinations of conditions, at each time point.

Tiredness VAS: There was a main effect of time (*F* (1.75, 449.27) = 10.04, $p<.001$, $\eta_p^2=.04$). Post hoc comparisons revealed a significant reduction in tiredness from pre to both post-drink time points (*p*s≤.011) however, no significant change in tiredness at post drink time points (*p*=1.00). No other significant main effects were revealed. Critically, there was a significant interaction between time and message (*F* (1.75, 449.27) =5.60, $p=.006$, $\eta_p^2=.02$). Post-hoc analyses revealed that the reduction in tiredness from pre-drink to both post-drink time points (*p*s≤.001) was only evident in those provided with the 'expect+', but not those provided with the 'expect-' message (*p*s>.969). There were no other significant interactions (*p*s>.513).

Boredom VAS: Results indicate a significant main effect of time (*F* (1.78, 456.11) =18.44, $p<.001$, $\eta_p^2=.07$). Post hoc analyses revealed a significant increase in boredom from pre-drink to both post-drink time points (*p*s$<.004$). There was also a significant increase in boredom from immediately post-drink to 35 minutes post-drink ($p=.002$). The two-way interactions between message and time, and drink and time and three-way interaction involving drink, message and time were non-significant ($p\geq.275$).

Vigour Subscale: There was a main effect of time (F (1.99, 511.64) = 6.30, $p=.002$, $\eta_p^2=.02$). Although there was no significant change in vigour from pre to immediately post-drink ($p=.105$) or at post drink time points ($p=.388$), there was a significant reduction in vigour from pre-drink to 35 minutes post drink ($p=.003$). This was qualified by an interaction between time and message (F (1.99, 511.64) = 6.39, $p=.002$, $\eta_p^2=.02$). Post hoc analyses revealed that for those provided with the 'expect-' message, there was a reduction in vigour from pre-drink to 35 minutes post drink ($p<.001$) but not to immediately post-drink ($p=.098$). There was also a significant reduction in vigour between post-drink time points ($p=.006$). However, there was no significant change in vigour for those provided with the 'expect+' message (*p*s=1.00). The interaction between drink and time, and between, drink, message and time were non-significant ($p\geq.198$).

Fatigue Subscale: Results indicated a main effect of time (F (1.88, 482.61) = 6.79, $p=.002$, $\eta_p^2=.03$). Post hoc analyses revealed a significant reduction in fatigue from pre-drink to immediately post drink and 35 minutes post-drink (*p*s$\leq.032$), however there was no significant change in fatigue at post-drink time points ($p=1.00$). There were no other significant main effects or interactions involving drink, message and time (*p*s$\geq.105$).

Table E1- Means (± *SD*) of self-report measures for each of the four experimental conditions in females only.

	Sugar+		**Sugar-**	
	Expect+ *n*=67	**Expect-** *n*=82	**Expect+** *n*=76	**Expect-** *n*=82
Tiredness VAS				
Time 1	15.08 (±3.69)	14.54 (±4.44)	15.18 (±3.67)	14.58 (±4.38)
Time 2	13.84 (±4.16)	14.40 (±4.37)	13.45 (±3.77)	14.20 (±4.31)
Time 3	13.76 (± 4.61)	14.73 (±4.74)	13.87 (±4.72)	14.13 (±4.83)
Boredom VAS				
Time 1	11.28 (±3.80)	11.17 (± 5.41)	10.27 (±4.48)	11.22 (±5.05)
Time 2	11.46 (± 4.39)	12.29 (± 5.03)	11.35 (±4.86)	11.72 (±4.98)
Time 3	12.44 (± 5.63)	12.85 (± 5.47)	12.49 (±5.78)	12.55 (±5.84)
Vigour POMS				
Time 1	.92 (±.64)	1.03 (±.66)	.98 (±.68)	1.04 (±.68)
Time 2	.85 (±.69)	.95 (±.68)	.98 (±.64)	.96 (±.58)
Time 3	.83 (±.67)	.83 (±.62)	1.07 (±.82)	.87 (±.58)
Fatigue POMS				
Time 1	1.30 (± .85)	1.53(± .93)	1.57 (± .92)	1.41 (±.98)
Time 2	1.21 (±.81)	1.48 (±.89)	1.40 (±.88)	1.32 (±.87)
Time 3	1.16 (±.86)	1.59 (±.85)	1.40 (±.99)	1.31 (±.88)

Appendix F:

This appendix concerns study 5.1 and includes analysis on self-report measures for the 'believed' subsample.

Beliefs about the contents of the drink may differ from the actual message given. For example, some people in the Expect+ group may in fact believe they have consumed a diet drink, which could alter expectancies formed by the individual. Estimated drink calories were used as an indicator of whether participants believed the message manipulation. In the 'expect-' condition, those who reported that the drink contained less than 50 calories were classified as believing the 'told diet' message. In the 'expect+' condition, those who reported that the drink contained more than 100 calories were classified as those who believed the 'told glucose' message. Consequently, 152 participants who did not believe the message manipulations were excluded and analysis was conducted on the 'believed' subsample (n=155).

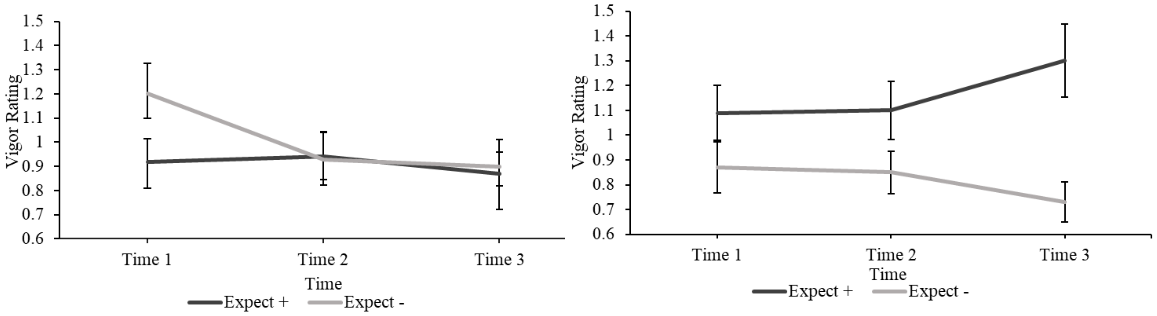
As in the full sample, there were no effects of message on any cognitive performance measures, and thus analysis is not reported below. For all self-report measures, a drink (Sugar+, Sugar-; between) x message (Expect+, Expect-, between) x time (Pre-drink, immediately post, 35 minutes post drink; within) ANOVA was conducted and message x time interactions were explored. The influence of message on self-report measures was largely unchanged from that of the full sample, although there was a small increase in effect sizes. Thus, significant message x time interactions for subjective measures in this sub-sample are reported below.

Tiredness VAS: There was an interaction between time and message F (1.78, 268.20) = 7.03, p=.002, η_p^2=.05. Post hoc tests revealed a significant reduction in tiredness from pre- to both the post-drink time points for those provided with the 'expect+' message (ps≤.001), although post-drink time points did not differ (p=1.00). However, there was no significant change in tiredness for those provided with the 'expect-' message (ps=1.00).

Boredom VAS: There was a time x message interaction (*F* (1.74, 262.90) = 3.65, p=.033, η_p^2=.02). Post hoc analyses reveal an increase in boredom from pre-drink to both post-drink time points (ps≤.028) and between post-drink time points (p=.003) for those provided with the ‘expect-’ message. However, there was no significant change in boredom for those provided with the ‘expect+’ message (ps≥.657).

Vigour Subscale: There was a time x message interaction (*F* (1.87, 282.68) = 8.56, p<.001, η_p^2=.05). Post hoc analyses revealed a significant reduction in vigour from pre-drink to both post-drink time points for those in the provided with the ‘expect-’ message (ps<.020), however there was no significant change in vigour for those provided with the ‘expect+’ message (ps≥.510). There was also a significant time x drink x message interaction (*F* (1.87, 282.68) =3.52, p=.034, η_p^2=.02; depicted in figure F1), although the effect size is small, and thus the three-way interaction should be treated with caution. Follow up analyses revealed that the message x time interaction was evident in both the Sugar+ (*F* (1.66, 117.73) =7.00, p=.003, η_p^2=.09; shown in left graph) and Sugar- drink conditions (*F* (1.92, 153.41) =5.88, p=.004, η_p^2=.07; shown in right graph). Post hoc analysis indicated that three-way interaction is driven by the significant reduction in vigour from pre-drink to post-drink time points (ps≤.001) for those who received the expect- message , not no significant change for those who received the expect+ message (ps=1.00) for those in the sugar+ beverage condition. However, in the sugar- beverage condition this was reversed, there was an increase in vigour from time 2 to time 3 for those who received the expect+ message (p=.030), however no significant change in vigour at any time points for those who received the expect - message (ps≥.090).

Figure F1- Graphs showing mean vigour ratings for the sugar+ drink (left) and the sugar- drink (right) conditions. Results are shown separately for those provided with the ‘expect+’ and ‘expect-’ message at pre (time 1) and post-drink time points (time 2 and time 3). Error bars represent standard errors.



Fatigue Subscale: There was a time x message interaction (F (1.85, 279.95) = 6.33, p=.003, η_p^2=.04). Post-hoc analyses revealed a significant reduction in fatigue from pre-drink to 35 minutes post-drink, and between post-drink time points, for those in the expect+ condition (ps≤.026) however, there was no significant change in fatigue for those in the expect- condition (ps≥.218).

Table F1- Descriptive statistics (mean ± *SD*) of self-report measures for each of the four experimental conditions for those who 'believed' the message

	Sugar+		**Sugar-**	
	Expect+ ***n*=67**	**Expect-** ***n*=82**	**Expect+** ***n*=76**	**Expect-** ***n*=82**
Tiredness VAS				
Time 1	14.99 (±4.04)	14.06 (±4.71)	14.76 (±4.09)	15.22 (±4.81)
Time 2	13.71 (±4.45)	14.97 (±4.08)	12.85 (±4.14)	14.24 (±5.13)
Time 3	13.60 (± 4.83)	15.06 (±4.41)	12.65 (±4.65)	14.58 (± 5.68)
Boredom VAS				
Time 1	11.29 (±3.98)	9.79 (±5.38)	10.81 (± 4.63)	12.31 (±5.17)
Time 2	11.37 (± 4.91)	11.79 (± 5.11)	11.36 (± 4.58)	12.33 (± 5.08)
Time 3	11.55 (± 5.41)	12.81 (± 5.32)	11.89 (± 5.08)	14.07 (±6.21)
Vigour POMS				
Time 1	.92 (±.60)	1.20 (±.74)	1.09 (±.67)	.87 (±.68)
Time 2	.94 (±.63)	.93 (±.67)	1.10 (±.72)	.85 (±.58)
Time 3	.87 (±.56)	.90 (±.64)	1.30 (±.90)	.73 (±.54)
Fatigue POMS				
Time 1	1.30 (± .90)	1.50 (± .93)	1.51 (± .95)	1.55 (±1.07)
Time 2	1.22 (±.91)	1.61 (±.83)	1.44 (±.86)	1.39 (±.98)
Time 3	1.15 (±.88)	1.72 (±.80)	1.26 (±.92)	1.44 (±.99)