Psychological antecedents and consequences associated with low-calorie sweetened beverage consumption in frequent consumers

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By

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Author’s Declaration

This thesis is the result of my own work. The material contained in this thesis has not been presented, nor is currently being presented, either in part or wholly for any other degree qualification.

I designed this research in conjunction with my supervisors and was responsible for data collection, analysis and write-up.

Abstract

Introduction: Low-calorie sweetened (LCS) beverages may help consumers to satisfy their hedonic food cravings without violating dieting goals, however this remains to be empirically investigated. The present thesis aimed to establish the psychological antecedents (i.e., attitudes, beliefs, cognitive representations) underpinning LCS beverage consumption (Chapters 2-3). A second aim was to examine the psychological mechanisms and consequences associated with LCS beverage consumption in frequent consumers (Chapters 4-5). **Methods:** A mixed-methods approach was taken. To address the first aim, a novel questionnaire (Chapter 2) and feature-listing task (Chapter 3) were used to identify the specific drivers (i.e., attitudes, beliefs) and cognitive-related desires which motivate consumption of LCS beverages. To address the second aim, experimental methods were used to examine the impact of priming hedonic eating motives on eating behaviour in consumers and non-consumers of LCS beverages (Chapter 4); specifically, a "chocolate craving" manipulation was implemented and compared to a non-craving control condition in terms of the effects on *ad libitum* energy intake. These findings were extended by experimentally manipulating the availability of LCS beverages (Chapter 5). **Results:** The questionnaire developed in Chapter 2 consisted of two sub-scales: 1) LCS beverages aiding weight management and satisfying cravings, and 2) palatability and enjoyment of LCS beverages. Frequent consumers had significantly higher beliefs that LCS beverages are palatable and effective in controlling appetite and weight relative to non-consumers. Consistent with these findings, Chapter 3 found that frequent consumers (but not non-consumers) generated hedonic eating simulations for LCS beverages, and LCS beverages were also strongly associated with positive health attributes. Regarding the second aim of the thesis, study 3 (Chapter 4) found that non-consumers of LCS beverages showed increased energy intake in the chocolate-craving condition relative to the control condition, whereas frequent LCS beverage consumers had similar energy intake in both conditions. Study 4 (Chapter 4) failed to replicate this apparent protective effect of LCS beverage consumption. However, Study 4 did find that overall energy intake and eating-related guilt were significantly greater, and perceived behavioural control was lower, when LCS beverages were unavailable compared to when they were available. Finally, in line with Chapter 4, Chapter 5 found that 7-day deprivation of LCS beverages led to increases in craving, eating-related guilt and energy intake, while reducing mood, compared to a non-deprived group of participants. **Conclusions:** Overall, findings suggest that consumption of LCS beverages is driven by the belief that they are a *helpful* tool in managing weight concerns and cravings whilst also offering hedonic enjoyment. Findings thus support the goal conflict model of eating suggesting that LCS beverages enable consumers to satisfy their hedonic eating motivations whilst also managing their weight/weight loss goals. Findings also suggest that consuming LCS beverages has a beneficial impact on consumers' control over energy intake by reducing craving, eating-related guilt and increasing mood. Future research should establish the longer-term effects of LCS beverage consumption on food intake and appetitive motivations in frequent consumers.

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List of abbreviations

ACQ-Attitudes to Chocolate Questionnaire

ADI-Acceptable Daily Intake

ANOVA-Analysis of variance

BMI-Body Mass Index (kg/m^2)

BSDA-British Soft Drink Association

CFA-Confirmatory Factor Analysis

DEBQ-Dutch Eating Behaviour Questionnaire

DM2-Diabetes Mellitus Type 2

EDI- Eating Disordered Inventory

EFA-Exploratory factor analysis

EFSA-European Food Safety Authority

EI-Elaborated Intrusion

FAO-Food and Agriculture Organization

FCQ-S-The Food Cravings Questionnaire-State.

FCQ-T-r-Food Craving Questionnaire-Trait-reduced

FSA-Food Safety Authority

FDQ-Food Desirability Questionnaire

FFQ-Food Frequency Questionnaire

GLP-1-Glucagon-like peptide-1

GPCRs-G-protein-coupled receptors

IFICF-International Food Information Council Foundation

JECFA - Joint Expert Committee on Food Additives

Kcal- Kilocalorie

KMO-Kaiser–Meyer–Olkin

LCS-Low-calorie sweeteners

NDNS-National Diet and Nutrition Survey

NHANES-National Health and Nutrition Examination Survey

NOEL-No Observed Adverse Effect Level

PANAS-Positive and Negative Affect Scales

PBC-Perceived behavioural control

PCA-Principle components analysis

PYY-peptide YY

SACN- Scientific Advisory Committee on Nutrition

SD – Standard deviation

SSB-Sugar sweetened beverages

TFEQ – Three Factor Eating Questionnaire

VAS – Visual Analogue Scale

WHO-World Health Organisation

VPT -Visual probe task

Chapter 1: General Introduction

Obesity has increased significantly worldwide in the past decade with tangible consequences for public health such as type 2 diabetes mellitus, hypertension and cardiovascular diseases (Apovian, 2016; Bray & Popkin, 2014; Butland et al., 2007). Obesity is a complex condition that is a result of a myriad of factors, including genetics, epigenetics, eating behaviours, physical activity, metabolism, psychosocial influences and environmental factors. One factor implicated in promoting the development of weight gain, obesity and other metabolic diseases, is the increased consumption of *added sugars*, specifically in the form of sugar-sweetened beverages (SSB) (Azaïs-Braesco, Sluik, Maillot, Kok & Moreno, 2017; Malik, Schulze & Hu, 2006; Malik et al., 2010; Vartanian, Schwartz & Brownell 2007; Te Morenga, Mallard & Mann, 2013; Xi et al., 2014). In an effort to tackle these growing issues, it seems only logical to reduce the consumption of SSB, however, given humans innate hedonic response for sweet tasting foods, this may be challenging (Drewnowski, Mennella, Johnson, & Bellisle, 2012; Mennella, Bobowski & Reed, 2016). Accordingly, one approach is to reduce the consumption of *added sugars* by substituting SSB with low-calorie sweetened (LCS) beverages. Potentially, these beverages could offer health benefits without exacerbating the problem of overconsumption of *added sugars*, specifically in their ability to provide sweetness with little or no energy. These benefits appear to provide the basis for consumption in consumers.

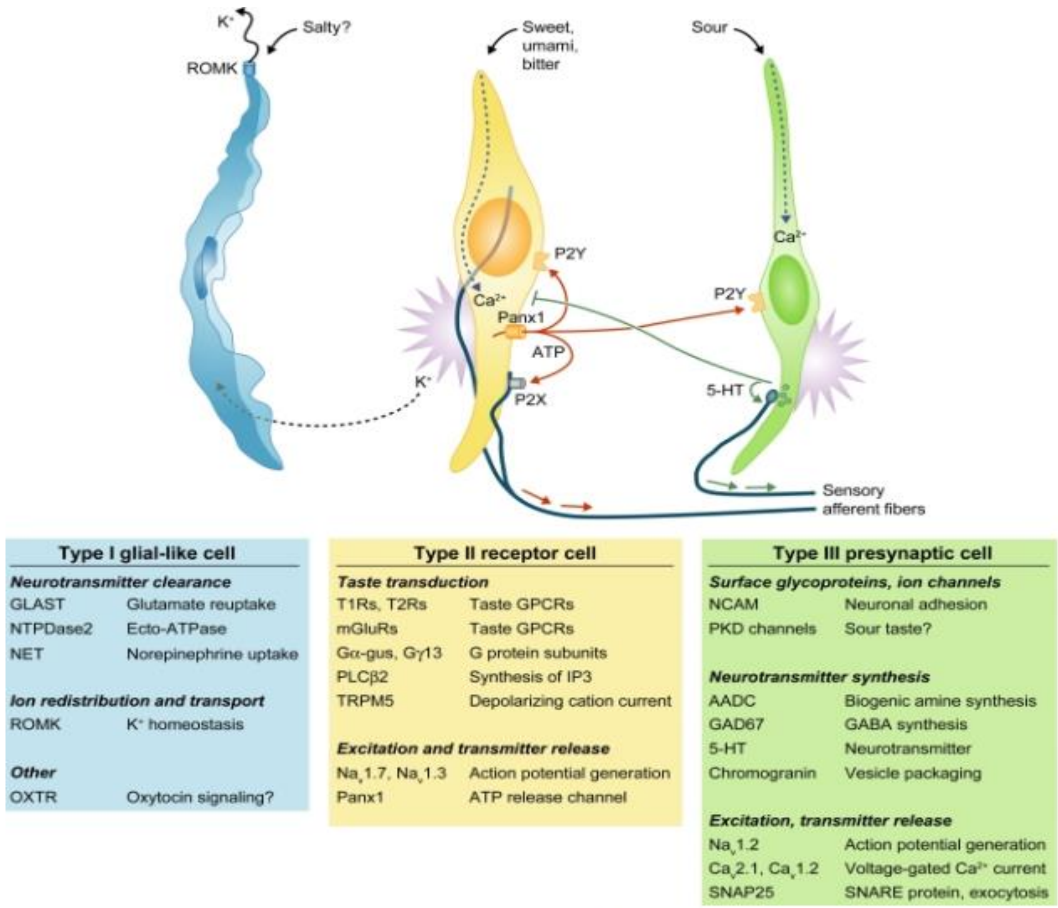
In section 1.1 of this chapter, I introduce an overview of sugar consumption and human desire for sweetness. In addition, I examine the evidence behind LCS beverages and their impact on weight gain and obesity. In section 1.2, I discuss the current evidence on the characteristics associated with LCS beverage consumption. In addition, I present several potential psychological theories and mechanisms that may explain why consumers use LCS beverages. Specifically, I examine the current evidence surrounding LCS beverage consumption and their psychological implications and discuss potential consequences associated with their consumption among frequent consumers.

1.1. Low-calorie sweetened beverages and their role in food reward and energy intake

1.1.1. The physiology of sweet taste

The tasting of sweetness is a complex physiologic occurrence. Taste cells are held together in a unit called the ‘taste bud’. The perception of taste is determined by these taste buds which are located at several sites within the mouth including the tongue, soft palate and epiglottis (Chaudhari & Roper, 2010). Humans have approximately 5,000 taste buds, consisting of cells that can specifically detect the five main tastes; sweet (allows the identification of energy-dense nutrients), sour or bitter (cautions against the intake of potentially poisonous substances), salt (encourages dietary electrolyte balance) and umami (enables the identification of savoury amino acids) (Chandrashekar, Hoon, Ryba & Zuker, 2006). The taste bud contains four cell types which are responsible for the detection of taste: basal cells, light (type I), intermediate (type II), and dark (type III) taste cells, (Breslin & Huang, 2006; Nelson et al, 2001), see Figure 1.1.

These different cell types have distinctive responsibilities for taste signal transduction (Zhang et al., 2003). Type I cells are signal supporting cells that enable clear taste signal transduction and type II cells are taste receptor cells and express G-protein-coupled receptors (GPCRs) for taste perception. Specifically, type II receptor cells are necessary for sensing sweet, bitter and umami taste (Chandrashekar et al., 2006; Chaudhari & Roper, 2010; Fernstrom et al., 2012). Activation of these cells by taste stimuli releases neurotransmitters onto afferent cranial nerve fibres, causing transmission of taste information to the brain. The brain subsequently processes this taste information, in addition to other sensory information (including olfactory, thermal, and textural), to evoke the perception of flavour and promote an appropriate ingestive response. GPCRs have been shown to play a prominent role in taste recognition; activating taste cells to send electrical messages to the brain. Two receptor sub-types (encoded by the T1R2 and T1R3 genes) detect molecules disseminating sweet taste qualities including saccharides, sweet proteins and synthetic sweeteners (Nelson et al., 2001). Differences in these genes have been shown to influence taste sensitivity to nutritive (e.g., sucrose) and low-calorie sweeteners (e.g., sucralose) (Nelson et al., 2001) and habitual consumption of sugars (Eny, Wolever, Corey & El-Sohemy, 2010). Finally, type III cells contain synapses and mainly respond to acids, and they are responsible for releasing serotonin (5-HT), which inhibits receptor cells (see Roper, 2013 review for further information concerning the function of taste cells).



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In addition to the mouth, sweet taste receptors are expressed in a range of other tissues including the airways (Tizzano, Cristofoletti, Sbarbati & Finger, 2011), throughout the gut (Raybould, 1998), the pancreas (Kojima & Nakagawa, 2011), the brain (Ren, Zhou, Terwilliger, Newton & de Araujo, 2009) and even in the testes (Li, 2013), suggesting that these receptors have other valuable functions within the body that are yet to be elucidated fully.

1.1.2. Human preference for sweetness

Research on the development of sweet taste preferences suggests humans have a universal liking and preference for sweetness that is inherent and apparent in early human development prior to and after birth (Beauchamp, 2016; Beauchamp & Cowart, 1985; Mennella & Beauchamp, 1998; Steiner, 1973; Ventura & Mennella, 2011; Yeomans, Tepper, Rietzschel & Prescott, 2007). This contrasts with other taste preferences (i.e., sour, salty, umami) and food dislike, which tends to develop later in life, from experiences that are influenced by our attitudes and beliefs (Beauchamp & Mennella 2009; Clarke, 1998).

Newborns' taste responses have been shown to respond even to diluted sweet taste and they will consume more of a sweet-tasting sucrose solution compared to water (Maone, Mattes, Bernbaum & Beauchamp, 1990; Steiner, 1977). This suggests that sweetness alone is rewarding. Throughout evolution, sweetness has had a valuable role in human nutrition, helping to direct feeding behaviour towards foods providing both energy and essential nutrients. This attraction for sweetness in humans is most likely an evolutionary survival mechanism, in that foods that are naturally sweet such as fruits and honey tend to be a safe and a good source of nutrients and energy (Drewnowski et al., 2012). Furthermore, when infants are presented with tasting something sweet, they respond by a characteristic "gusto-facial response", (Steiner, 1977). Contrastingly, generating a negative response (distress and rejection) when tasting a bitter-tasting substance (Ganchrow Steiner & Daher, 1983; Steiner et al., 2001), suggests an innate preference for sweet taste and dislike of bitter taste. Some researchers argue that the innate acceptance of sweet foods and rejection of bitter ones is a result of evolution, preparing the infant to accept safe sources of energy and to decline potentially toxic bitter substances (Drewnowski et al., 2012). By associating pleasant taste sensations with nutrition, our evolutionary responses have made sweetness a powerful driver of eating behaviour.

Through learned associations between feeding and nurturing, an infant's preference for sweetness is thought to be strengthened (Elfhag & Erlanson-Albertsson, 2006). Indeed, brain responses during infant feeding have been shown to reflect the pleasurable tastes and smells, the satiation of hunger, as well as the calming effects of consuming milk. Additionally, early exposure to sugar-sweetened items encouraged both an increased preference for sweetened items and a preference for higher levels of sugar in foods (Beauchamp & Moran, 1984; Beauchamp & Moran, 1982; Liem & de Graaf, 2004). Together, these findings highlight some of the biological mechanisms that influence sweet taste preferences and encourage the consumption of sweet-tasting foods.

Responses to sweet tastes influence food acceptability and choice throughout life (Birch, 1999, Blundell et al., 1988). This preference for sweet taste tends to decline as we age and as preferences for other tastes are learned (Birch, 1999; De Graaf & Zandstra, 1999). For instance, adolescents have been shown to prefer lower intensity of sweetness than in younger children, and this preference for sweet taste is lower in adults than in adolescents (De Graaf & Zandstra, 1999; De Graaf, van Staveren & Burema, 1996). Some researchers suggest that this decline in preference for sweetness is possibly due to the cessation of growth (Coldwell, Oswald & Reed, 2009; Drewnowski et al., 2012). However, the mechanisms underlying the age-related decline of preference for sweetness and consumption remain unclear. Nevertheless, preference for sweetness does not seem to disappear, even in old age, sweetness provides the motivation to eat (Drewnowski et al., 2012). Finally, while this innate preference for sweet taste has been well documented, the extent of this preference differs between individuals, therefore genetics also appear to play a role (Keskitalo et al., 2007). To summarise, it seems that sweetness is inherently rewarding, evokes a positive hedonic response and increases the palatability of foods and beverages, thereby stimulating intake. This hedonic response is likely to have an evolutionary basis and is present across an individual's lifespan. Thus, sweet taste appears to have a powerful impact in influencing consumption and motivating eating behaviour (Beauchamp, 2016).

1.1.3. Sugar consumption

Sugar has been part of the human diet for thousands of years (Mintz, 1985), providing a strong, pleasant, sweet taste as well as delivering energy when ingested. Additionally, sugars have other practical roles including the provision of texture and food preservation (Sigman-Grant &, Morita, 2003). Intrinsic sugars are generally found in foods with positive nutrient profiles including fruits, vegetables, nuts and dairy. In contrast, free sugars are often found in foods and beverages lower in nutrient density (Bailey & Barr, 2017; Clemens et al., 2016). The term *free sugars* includes “all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and fruit juices” [World Health Organisation (WHO), 2003]. According to the WHO (2015), free sugars also include *added sugars* (i.e., sugars that are not naturally found in the food product and are added during the production of the food). The reason for including fruit juices in the definition is that these beverages have the potential to deliver large amounts of sugar but have lower satiety effects compared to solid foods (Cassady, Considine & Mattes, 2012). Naturally present sugars found in jams, honey and preserves are also categorized as *free sugars* on the basis that the cellular structure of the fruit in such products is predominantly broken down and the proportion of sugars naturally present from the fruit is small in comparison to the amount of added sugar (Swan, Powell, Knowles, Bush, & Levy, 2018). The simplest molecule of sugars is the monosaccharide and includes galactose, fructose and glucose. Disaccharides include lactose, maltose and sucrose (sugar) and trisaccharides, include raffinose (found in cottonseed and sugar beets). All of these sugars provide approximately 4 kcal/g (Anderson, Stewart & Kaplan, 1998).

Given the powerful hedonic appeal of sweetness, over-consumption of *added sugars* has risen consistently among children, adolescents, and adults globally (Bailey, Fulgoni, Cowan & Gaine, 2018; Drewnowski et al., 2012). Consequently, the increased consumption of *added sugars* in the diet has been shown to be implicated in the development of overweight and obesity, which is now recognised as a global public health concern (Public Health England, 2015b; Scientific Advisory Committee on Nutrition (SACN), 2015; WHO, 2015). In an effort to tackle this growing issue, leading organizations including the WHO (2015) and the SACN (2015) issued guidelines recommending that the average intake of free sugars should not exceed 5% of total energy intake. Furthermore, WHO recommends that a target of less than 10% of total energy intake being derived from free sugars is necessary, and a desirable target of less than 5% (WHO, 2015), while SACN more recently recommended a 5% of total energy intake (SACN, 2015). Despite these guidelines, average intakes of sugar in the United Kingdom have exceeded recommendations across all age groups (Figure 1.2.) since 2014 (Bates et al., 2014). For instance, in school-aged children and teenagers, mean sugar intakes are three times above the recommended 5% maximum level (14.7% to 15.6% of energy intake). In adults, mean intakes are approximately twice the maximum recommended level (12.1% of energy intake). Soft drinks (excluding fruit juice) were one of the leading sources of sugar for both children and adults (4 to 65 years). In particular, soft drinks, on average, were the largest single source of sugar (29% of daily sugar intake) for children aged 11 to 18 years (Bates et al., 2014).

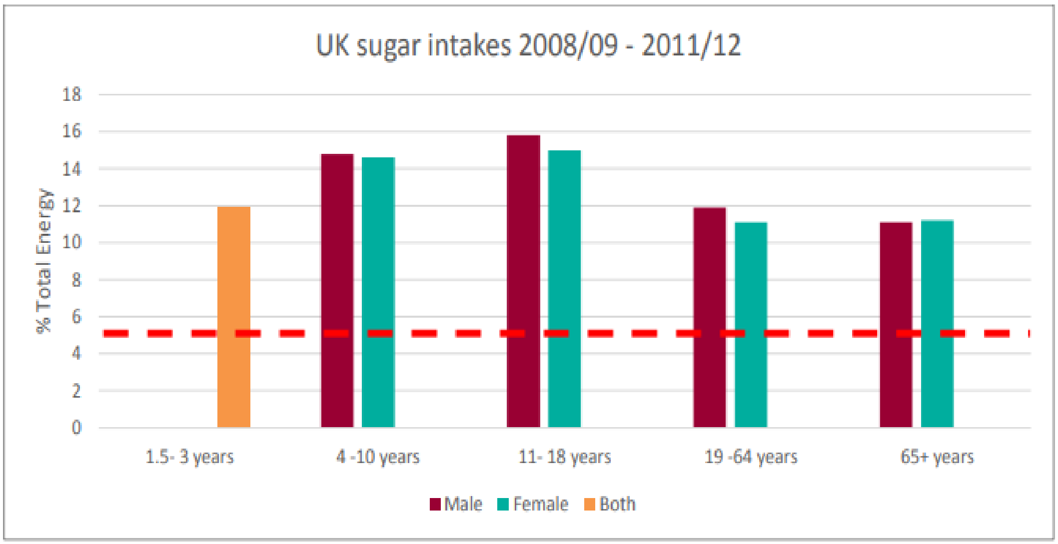

Figure 1.2. UK sugar intake compared to the recommended maximum of 5% energy (Public Health England, 2015a).

Sugar-Sweetened beverages

Sugar-sweetened beverages (SSBs) have emerged as a major source of added sugars across age groups (Bailey et al., 2018; Ludwig, Peterson & Gortmaker, 2001; Miller, Merlo, Demissie, Sliwa & Park, 2017) and have come under scrutiny as significant contributors to the obesity epidemic worldwide due to their high added sugar content, calories and low satiation power (Anderson & Woodend, 2003; Bray & Popkin, 2014; Ebbeling, Feldman & Osganian, 2006). Certainly, the argument against consumption of SSBs, particularly among children and adolescents, has arisen from concern that they contribute to excess energy intake and therefore to obesity, although cause and effect remains to be established. Nevertheless, there is considerable research demonstrating an association between SSB consumption, increased energy intake and obesity (Dietz, 2006; Gibson, 2008; Malik, Pan, Willett & Hu, 2013; Mattes, Shikany, Kaiser & Allison, 2011, Pereira, 2014; Vartanian, Schwartz & Brownell, 2007). Indeed, Chen et al. (2009) showed that by reducing consumption of SSB among adults, calorie intake and body weight was significantly reduced at 6 months. While a number of meta-analyses have been conducted in this area, not all have reported a significant link (Forshee, Anderson & Storey, 2008; Mattes et al., 2011). Kahn and Sievenpiper (2014) argue that there is no direct evidence that added sugar, whether in a solid or liquid form, results in an increase in appetite, reduces satiety, or development of obesity and diabetes. Indeed, two six-month trials showed a trend towards increased body weight with increased energy intake following consumption of SSB in adults who were overweight and obese, however, the difference between groups was not significant, perhaps due to small number of participants (Maersk et al., 2012; Tate et al., 2012). Furthermore, Ebbeling et al. (2012) found body mass index (BMI) and body weight were significantly reduced after one year in the intervention group (displacing SSB with bottled water and LCS beverages as a strategy to decrease consumption) compared with the control group (consumed SSB as normal). However, this was no longer apparent after a further year's follow-up with no further intervention. The authors suggest that this lack of effect at follow-up could reflect participants in the intervention group increasing their energy intake by reverting back to consuming SSB.

Addressing these inconsistencies, a recent systematic review and meta-analysis on sugar consumption found a positive association between SSB consumption and BMI (Luger et al., 2018). Their findings on prospective cohort studies and trials showed an overall positive association between consumption of SSBs and body weight gain in both children and adults. Interestingly, among children and adolescents, a one-serving per day increase in SSBs consumption was associated with a 0.06-unit increase in BMI over a one-year period and an additional weight gain of 0.12 to 0.22 kg over one-year period among adults. The authors note that there is difficulty establishing the impact of their findings in children due to the fact that weight gain varies as a function of age and growth during childhood. However, adult weight gain is a gradual process, occurring over decades and averaging with 1 lb/year. Nevertheless, elimination of SSB from the diet in favour of LCS beverages may be a possible solution in helping to tackle this issue.

1.1.4. Low-calorie sweeteners

The innate desire for sweet tasting foods and beverages means that strategies to reduce intake of free sugars may be less successful unless there is additional assistance of sweetness within the diet. Thus, low calorie sweeteners (LCS) have emerged as a potential solution. LCS have been used in the diet for many years; however, it is only in the past 30 years that their applications have become more extensive.

Low-calorie sweeteners (LCS) represent a broad class of sweet compounds used in a wide variety of food products. LCSs are primarily added to products for their sweetening property in addition to a range of other functional purposes such as preservation and as bulking agents. In the European Union, there are currently eleven (Table 1.1.) different low-calorie sweeteners approved for use in Europe including Saccharin, Acesulfame-K, Aspartame Cyclamate, Thaumatin, Neohesperidine dihydrochalcone, Aspartame-acesulfame salt, Sucralose, Steviol glycosides and Advantame. Each sweetener has unique sweetness intensity, persistence of the sweet taste, coating of the teeth and aftertaste. Importantly, the sweetness of each sweetener is measured in relation to sucrose, which is the reference sugar (Carocho, Morales & Ferreira, 2017). For instance, using sucrose as a reference (it has a reference value of 1), advantame is a sweetener which is 37,000 times stronger in sweetness power compared to sucrose, which is detailed in Table 1.1.

Table 1.1. *The sweetness potency of eleven approved low-calorie sweeteners licensed for use in the Europe.*

Sweetener	ADI (EFSA) (mg/kg Body Weight)	Discovery Date	Approval in the EU	Sweetness Power[1]
Saccharin	5	1879	1977	300 - 500
Acesulfame-K	9	1967	1984	200
Aspartame	40	1965	1984	200[2]
Cyclamates	7	1937	1984	30-40
Thaumatin	Not specified	1979	1984	2000-3000[3]
Aspartame-acesulfame salt	0-15	1995	2003	350
Sucralose	15	1976	2000	600-650[4]
Steviol glycosides	4 [5]	1931	2011	200-300[6]
Advantame	5	2012	2014	37,000[7]
Neotame	2	1990	2007	7,000-13,000[8]
Neohesperidine dihydrochalcone	5	1963	1988	1,000-1,8000[9]

ADI=Acceptable Daily Intake; EFSA=European Food Safety Authority; [1]Sweetness power based on the assumption that sucrose is equivalent to 1 unit of sweetness, adapted from Carocho et al., 2017; [2]EFSA Scientific Opinion on Aspartame (2013a); [3]EFSA (2015); [4]Opinion of the Scientific Committee on Food on sucralose (2000); [5]Expressed in Steviol equivalents; [6]EFSA Scientific Opinion on Steviol glycosides (2010); [7]EFSA Opinion on Advantame (2013b); [8]EFSA Scientific Opinion on Neotame (2007); [9]EFSA Opinion on neohesperidine dihydrochalcone (2011a).

1.1.4.1. Acceptable Daily Intake (ADI)

To ensure safety regulation for LCS use, the regulatory authorities establish the Acceptable Daily Intakes (ADI) for each sweetener (Benford, 2000). An ADI is an estimate of the amount of a food additive that incorporates a considerable safety factor. It is expressed as mg/kg body weight and has been defined as "the amount of a chemical that can be consumed daily over the period of a lifetime with no conservable risk to health" (WHO, 1987). To assign an ADI, long-term, multiple-dose animal studies are typically used to initially establish the 'No Observed Adverse Effect Level' (NOAEL) by identifying the highest level of exposure at which no adverse effects were observed in animal studies (Herman & Younes, 1999; Logue, Peters, Gallagher & Verhagen, 2015; Renwick, 1990). To ensure a large safety margin for even the most sensitive consumer, the ADI is generally set at 1/100th of the NOAEL (10-fold reduction for inter-species variation and 10-fold reduction for intra-species variation). The ADI refers to a lifelong exposure, not a single occurrence; thus infrequent consumption of levels exceeding the ADI are not a health concern. The large safety margin used in setting the ADI means that an ADI for a given additive would have to be exceeded by a considerable amount for a lengthy period of time before there could be any risk of harm to human health. Importantly, the ADI applies to children on the basis that toxicological protocols cover the periods of rapid growth, development and maturation. The possible exceedance of the ADI, on occasion including periods of childhood, has been emphasised by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in relation to the large safety factor applied within its derivation. Nevertheless, if an intake estimate suggests that the ADI may be regularly exceeded by particular groups of the population, the regulatory authority may recommend that levels of the additive are reduced in foods, or to reduce the range of foods in which the additive is permitted for use (European Food Information Council, 2013).

The saftety of LCS has subsequently raised questions regarding the increasing trend in the intake of these ingredients and the potential impact in relation to the respective ADIs. Addressing these concerns, Ashwell et al. (under review) recently developed an expert consensus on the use of LCS. The experts agreed that there is a substantial body of evidence supporting the safety of LCS use (Buffini et al., 2018; Le Donne et al., 2017). For instance, Martyn et al. (2018) reviewed the evidence on exposure of LCS in the diet and concluded that there are no concerns with respect to exceedance of individual LCS ADIs among the general population globally. Finally, there is no suggestion of a significant shift in exposure over time, with several studies indicating a reduction in intake. The continous monitoring and modelling of LCS exposures have shown that intakes of LCS, even among high consumers, are within

ADIs (Serra-Majem et al., 2018). Therefore, the expert opinion is that there are no concerns about adverse safety effects of LCS use.

1.1.5. Low-calorie sweetened beverages, appetite and food intake

In relation to the preceding argument on SSB consumption, the use of LCS beverages has emerged as an attractive strategy to achieve these reductions in sugar. Their ability in providing both palatability and sweetness with little or no energy is an effective combination (Anderson, Foreyt, Sigman-Grant, & Allison, 2012; Drewnowski & Rehm, 2016). Hence, it is not surprising that the consumption of beverages containing LCS has increased substantially over the past 30 years (European Parliament and Council, 2008). Findings from the latest National Diet and Nutrition Survey (NDNS) in the UK indicate that 44% of all soft drinks consumed (in terms of their weight), are LCS beverages in adults aged 19 to 64 years (Gibson, Horgan, Francis, Gibson, Stephen, 2016). Despite their potential benefits, their role in energy intake, weight management, metabolic health and gut function have been questioned on several issues. In the following sections, I discuss the role of LCS beverages in relation to these health outcomes, with a particular focus on addressing some of the main arguments for and against LCS beverage consumption.

1.1.5.1. Learned response to low-calorie sweetened beverages: Uncoupling of sweetness from calories

It has been proposed by some authors that exposure to LCS beverages uncouples the experience of sweet taste from the energy content from food and beverages. In this way, prolonged ingestion of LCS beverages could undermine the learned control of energy intake that normally contributes to energy homeostasis and body weight control, thereby impairing energy intake and body weight regulation (Burke & Small 2015; Swithers, 2015; Shearer & Swithers, 2016) and may increase the desire for sweet food consumption (Yang, 2010). For example, proponents of this view argue that repeated LCS consumption may lead to the disruption of cephalic-phase insulin secretion (Burke & Small, 2015; Berthoud, Bereiter, Trimble, Siegel, & Jeanrenaud, 1981). In support of this, Swithers, Martin and Davidson (2010) conducted a study where one group of rodents had intermittent access to food sweetened with glucose (nutritive), whereas the other group of rodents had intermittent access to food sweetened with saccharin (LCS). Both groups were administered continuous *ad libitum* access to (slightly sweet) laboratory chow, 3 days per week, in addition to a fixed portion of sweetened yogurt and unsweetened yogurt on another 3 days per week. They found that the rats consumed all or nearly all of the entire yogurt offered. Over several weeks, the rats who were given saccharin were found to have higher overall energy intake, gain more weight, and have relative hyperglycaemia compared to the rats who were given glucose (Swithers et al., 2010). As such, they argued that these effects were due to LCS consumption weakening the cephalic phase response that is triggered by sweet taste. This may lead to increased energy intake by increasing the appetite for sweet tasting foods. The cephalic phase responses potentially exist as an anticipatory response to prepare the body to digest, absorb, metabolize, and store nutrients and serves as a neural regulation of food intake prior to ingestion (Power & Schulkin, 2008). By providing the sweetness without the energy, Swithers et al. argue that physiological responses are blunted (i.e., disrupts the delicate balance among taste responsiveness, appetite and energy intake), even when sugar is consumed. This results in sweet taste no longer being a reliable indicator of energy.

Despite these findings, replication of the same paradigm as Swithers et al. (2010) have failed to support their argument. For instance, Boakes, Kendig, Martire and Rooney (2016) found that rodents exposed to glucose also had increased body fat. Rogers (2018) argues that the disparity of findings could be the due to a methodological difference. For example, Swithers et al. (2010) excluded individual rats that exhibited a low preference for the saccharin-sweetened yogurt and subsequently biased the sample to include fast-growing individuals; saccharin acceptance is positively associated with later weight gain on laboratory chow (Boakes et al., 2016). In support of this, Palframan and Myers (2016) found that exposing rats to a large variety of highly processed foods did not impair flavour-nutrient learning, compared to exposure to either a variety of minimally processed foods or a standard chow diet. Rogers (2018) thus argues that the notion LCS beverages consumption undermines the learned control of energy intake can be disputed because sweetness alone is not a reliable predictor of energy intake in the diet, even when LCS beverages are ignored.

Drawing from above, it appears that LCS beverages are unlikely to disrupt the learned control of energy intake. Instead, energy density itself (rather than any learning about energy density) is likely to have a dominant influence on energy intake so that intake is lower when the food is sweetened with LCS than when it is sweetened with sugar (Boakes et al., 2016).

1.1.5.2. Exposure to low-calorie sweetened beverages increases preference for sweetness

Another argument opposing LCS beverage consumption is that exposure to sweetness encourages a ‘sweet tooth’ and consequently exacerbates the liking for and intake of sweet energy-containing foods and beverages, preventing consumers from managing their response to sweetness. According to Sclafani and Ackroff (2012), highly palatable sugar-containing beverages are thought to elicit strong reinforcing effects through positive feedback generated by these nutrients and subsequently stimulate appetite. On this basis, they argue that consumption of LCS beverages may promote appetite by encouraging a preference for sweetness, thus encouraging higher dietary energy intake. In support of this, Casperson, Johnson and Roemmich (2017) found that consumption of LCS beverages compared to SSBs subsequently increased the motivation to consume sweet snack foods relative to those that were salty/savoury. Seferidi, Millett and Laverty (2018) also reported similar effects in children. However, despite Casperson et al. finding an apparent LCS effect on the reinforcing value of sweet foods, overall snack food energy intake did not differ after LCS beverage consumption compared to SSB in their study. If LCS beverages did induce an appetite for sweet foods, this would be expected to lead to greater energy intake compared to individuals who consumed SSB. Given that this was not the case, it suggests that LCS beverages have similar satiating powers to SSB, and do not appear to induce an energy compensation response. This is further evidence that LCS consumption does not result in full energy compensation, relative to SSB. There were also a number of methodological issues that should also be mentioned. Firstly, there was no main effect of beverage sweetener type on the total amount of energy earned during the relative reinforcing value (RRV) computer task. Secondly, despite reporting greater motivation (i.e., earned more rewards) to consume sweet snack foods during the RRV computer task, when given the portion they earned of the energy-dense snack foods, participants consumed less of the sweet snack foods. Finally, there was no main effect of beverage sweetener type on the total amount of energy consumed from the sweet snack foods or the savoury snack foods. In view of these findings, it does not suggest that consumption of LCS beverages encourages a preference for sweetness.

A review by Bellisle (2015) examined the specific effects of LCS consumption on appetite for sweet products and the impact on weight maintenance. She concluded that both short and long-term consumption of LCS beverages showed no consistent association with an increased appetite for sugar or sweet products. In fact, for many studies, the consumption of LCS beverages resulted in lower intake of sweet tasting foods; suggesting that LCS beverages may help to satisfy a desire for sweetness and do not encourage a preference for sweet foods. In support of Bellisle's findings, Rogers (2018) argues that there is little direct evidence to support this "sweet tooth" argument. For instance, preload test-meal studies showed no difference between water and LCS beverages in their effects on test-meal *ad libitum* energy intake. Similarly, no difference was found for equi-caloric LCS-sweetened *v* non-sweet food preloads (Rogers et al., 2016). Similar findings were found in a 12-week trial where participants were involved in a weight loss trial and randomised to continue to consume LCS beverages or switch to water (at least 710 ml/day) (Peters et al., 2014). However, these participants were already consumers of LCS beverages so compliance with the LCS beverages diet would have been easier than switching to water. To address this potential issue, in a six-month weight loss intervention (the CHOICE trial), adults with obesity (*N*=104) were asked to replace daily intake of SSB with LCS beverages, while another group (*N*=106) was asked to replace SSB with water. The authors found that both the water and LCS beverage groups significantly reduced their total daily energy intake at 6 months compared to their baseline intake. Participants exposed to high consumption levels of LCS beverages had reduced energy intake from desserts during the intervention compared to the water group at 6 months (Piernas, Tate, Wang, & Popkin, 2013). Similarly, Fantino, Fantino, Matray and Mistretta (2018) compared LCS beverages consumption to water (when consumed with meals) on subsequent energy intake in acute trials and after long-term habitual consumption. Consumption of LCS beverages did not increase motivation to seek sweet foods, nor did it increase food intake, or specific selection and consumption of sweet foods, compared to water. These findings oppose the notion that exposure to LCS beverages exert an enhancing effect on appetite for sweet-tasting products in particular. Indeed, they indicate that exposure to LCS beverages may satisfy rather than increase desire for sweetness.

Contrary to the above findings, a study with people who were overweight and obese compared the replacement of LCS beverages with water against continuation of LCS beverages use. These researchers reported a greater weight loss in the group consuming water relative to the LCS beverage group (Madjd et al., 2015). The reason behind the opposing findings to Peters et al. (2014) and Piernas et al. (2013) could be due to the difference in methods. Madjd et al. (2015) allowed consumption of only one LCS beverage per day, after lunch. In comparison, Peters et al. asked participants to consume at least 710 ml/day of LCS beverage per day and their water consumption was not restricted. It is possible that if the LCS beverage was given before lunch, this may have reduced consumption of sweet food. Additionally, participants may have subsequently consumed more sweet foods through the day because they did not have access to LCS beverages to satisfy this hedonic need for sweetness. Finally, a follow-up to the Peters et al. (2014) found that this effect on weight favouring LCS compared to water was increased after 1 year (Peters et al., 2016).

Overall, these findings are in line with the concept of 'sensory-specific satiety', which describes the short-term decline in liking or pleasantness associated with a recently consumed food or taste (Hetherington, 2013; Hetherington, Rolls & Burley, 1989; Rogers & Hardman, 2015; Rolls, 1986; Snoek, Huntjens, Van Gemert, De Graaf, & Weenen, 2004). Specifically, it could be argued that the repeated exposure to sweet taste via LCS beverage consumption may have subsequently reduced the pleasantness (and energy intake) of caloric sweet products elsewhere in the diet. As such, these results suggest that by using LCS beverages in favour of SSB, not only do they not encourage weight gain, but instead, by satisfying that desire for sweetness, they could reduce motivation to consume other sweet foods. In support of this, a systematic review by Appleton, Tuorila, Bertenshaw, de Graaf and Mela (2018) found initial evidence suggesting that exposure to sweet taste leads to a *reduced* preference for sweet products in the short term. However, the authors acknowledged that further research is needed to determine their effects in the longer term.

To summarise, the existing studies implemented a range of differing methodologies, consumers (children, men and women) and BMIs (lean, obese, formerly obese and never obese) and came to mostly similar conclusions; short-term or longer-term consumption of LCS beverages does not consistently lead to an increased appetite for sugar or sweet products. Furthermore, leading experts have concluded that consumption of LCS beverages does not result in increased appetite for sweet foods but in fact may help to reduce intake for sweet tasting products and helps to facilitate weight loss by replacing sugar (Gibson, Drewnowski, Hill, Raben, Tuorila & Widström, 2014).

1.1.5.3. Energy compensation

A third argument is that consumption of LCS beverages will result in compensatory behaviour, justifying the consumption of a higher calorie food and subsequently negating the calories saved (Mattes & Popkins, 2009). Specifically, it is argued that consumers may use LCS beverages as a way to justify further consumption of calorie-dense foods and beverages. Relatively few studies have investigated this; however existing studies have shown that changing the energy density of a food did not consistently result in compensation in energy intake at subsequent meals. For instance, Anton et al. (2010) found that participants did not compensate by consuming more at either lunch or dinner when they consumed low-calorie preloads containing stevia or aspartame compared to when they consumed high-calorie preloads containing sucrose. Furthermore, results of longer-term studies further support this suggestion that full compensation does not occur. Sorensen Vasilaras, Astrup and Raben, (2014) reported that the group consuming LCS food beverages had lower energy intake compared to the group consuming SSBs and sucrose sweetened foods over a 10-week period. Similarly, de Ruyter, Olthof, Seidell and Katan (2012) found that children did not compensate for the absence of energy from LCS beverages. Collectively, these findings show no support for the hypothesis that LCS might lead to full or over-compensation of energy in children or adults.

1.1.5.4. Low-calorie sweetened beverages in energy intake and weight management

Interest in the role of LCS beverages in the control of energy intake and body weight has grown considerably. Some researchers argue that LCS beverages may not have the intended benefit and may even increase the risk of overweight and obesity (Berkey, Rockett, Field, Gillman, & Colditz, 2004; Fowler et al., 2008; Fowler Williams, & Hazuda, 2015; Morenga, Mallard & Mann, 2013; Swithers et al., 2010), recommending against the use of LCS beverages to replace SSB. Sylvetsky and Rother (2018) argue that LCS consumption is associated with a higher body weight, whilst also having a damaging effect on health outcomes such as obesity, cardiovascular disease and nonalcoholic fatty liver disease in observational studies. In support of this, some observational studies have shown a positive correlation between LCS beverages and obesity (Piernas et al., 2013) as well as type 2 diabetes (Nettleton et al., 2009). More recently, Mulle et al. (2019) reported that consumption of LCS beverages (≥2 glasses per day) was associated with deaths from circulatory diseases. While it was a large observational study (*n*= 451 743), cause and effect can nevertheless not be determined. Their positive association could be explained due to the fact these individuals were obese and most likely consuming LCS beverages as a way to manage their weight. Another issue it that confounders and exposure were measured at baseline, and the mean follow-up was over 16 years. In view of this, it’s possible other factors may have contributed to these associations.

In response to the contradictory findings, a systematic review and meta-analysis conducted by Rogers et al. (2016) revealed that consumption of LCS compared to sugar either had no effect or reduced body weight in animal studies. Furthermore, they found that the majority of the studies that implemented a paradigm involving intermittent exposure to food supplemented with glucose or LCS (based on Swithers et al., 2010 paradigm) found that weight increased more in the rats who consumed LCS (Rogers et al., 2016). However, as mentioned earlier, this paradigm was developed to test the hypothesis that LCS uncouples sweet taste from energy intake. As such, the applicability of these learning effects in a human population remains to be explored.

Critically, meta-analyses of both short-term and longer-term human studies found LCS beverages reduced energy intake, and body weight in sustained studies when compared to both sugar alternatives and water (Peters et al., 2014; Peters et al., 2016). These findings are consistent with the outcomes of another systematic review (Miller & Perez, 2014), which concluded that there is a considerable amount of evidence (mainly from acute and sustained human intervention studies) indicating that LCS beverages, when used as a substitute for sugar, lead to reduced energy intake and body weight and can be a beneficial tool to improve dietary compliance with weight loss and weight maintenance [see Zheng, Allman-Farinelli, Heitmann, & Rangan, (2015) review for similar findings]. Most importantly, Miller and Perez (2014) found that LCS beverages' effects on body weight were comparable to water (the gold standard) or even superior in some contexts. These findings support previous findings by Mattes and Popkin (2009) which concluded that in longer-term feeding studies, substitution of sugar for LCS in the diet suggest that energy compensation is incomplete (5–15% reductions of daily energy intake); LCS thereby have potential in weight management by helping to reduce energy intake [see Drewnowski & Bellisle, (2007) and De La Hunty, Gibson & Ashwell, (2006) reviews for comparable findings]. The main reason for confusion is likely that observational studies consistently show that consuming LCS is correlated with an increased BMI. However, these data are correlational, and the evidence from controlled trials is more supportive of reverse causality. It is more likely that individuals are motivated to consume LCS beverages due to being overweight, rather than vice versa.

Taken together, there is substantial evidence that LCS beverages can reduce energy intake and body weight, when used as an alternative to SSB. LCS beverages may allow a more versatile approach to weight management and may help individuals to maintain their body weight in the long-term. Their efficacy has been confirmed repeatedly both in short-term laboratory studies. Any association with obesity or diabetes is more likely due to reverse causality. Thus, LCS beverages are widely viewed by researchers as a useful overall tool that can help reduce caloric intake (Archibald, Dolinsky & Azad, 2018; Rogers et al., 2016).

1.1.5.5. Low-calorie sweetened beverages and gut function

Several biological mechanisms have also been debated surrounding the impact of LCS on the activation and binding of sweet taste receptors and alteration of the gut microbiota (Bryant & McLaughlin 2016; RomoRomo et al., 2016). Some researchers argue that LCS beverages may modify dietary patterns by altering calorie prediction of energy dense foods and thereby changing the gut microflora (Palmnäs et al., 2014; Suez, Korem, Zilberman-Schapira, Segal & Elinav, 2015; Suez et al., 2014). Indeed, initial in vitro data resulted in increased glucose absorption following treatment with LCS in rodents (Mace, Affleck, Patel, & Kellett, 2007), however this was not confirmed in human studies (Bryant, Wasse, Astbury, Nandra & McLaughlin, 2014; Sylvetsky, Brown, Blau, Walter & Rother, 2016). Consequently, research has focused on the biological fate of LCS to address questions of their effect on the gut microbiota (Magnuson, Carakostas, Moore, Poulos, & Renwick, 2016; Pepino, 2015; Romo-Romo et al., 2016). The ingestion of glucose results in increased circulating levels of glucose, insulin and satiety-inducing peptides, however, consumption of LCS does not exert these effects (Ford et al., 2011; Steinert, Frey, Topfer, Drewe & Beglinger, 2011). Two human studies, however, have reported that consumption of LCS beverages results in an augmented GLP-1 response, suggesting that there might be a LCS beverage specific effect following consumption (Brown Walter & Rother, 2012; Sylvetsky et al., 2016). Nevertheless, prolonged exposure in humans is required to understand the metabolic effects of LCS before any conclusions can be drawn.

Currently, LCS are ingested at such minute levels that they are unlikely to have a direct and meaningful impact on the gut microbiota. Saccharin, however, has been shown to affect the microbiota composition. Suez et al. (2014) reported a higher blood glucose response following an oral glucose tolerance test and change in microbial composition after 6 days exposure to 100% of the ADI of saccharin. However, there were several methodological limitations, including a small sample of human subjects, no control group and the 100% ADI dose of saccharin, which is an unrealistically high intake of LCS (Suez et al., 2014).

To summarise their effect on the human gut microbiota, current evidence is limited and does not provide adequate evidence of effects of LCS, whether they are positive or negative effects (Lobach, Roberts & Rowland, 2018; Ruiz-Ojeda, Plaza-Díaz, Sáez-Lara, & Gil, 2019). Consequently, long-term RCTs using a large human sample and realistic daily doses intakes rather than supraphysiological doses (which exceed real-life intakes) are necessary to elucidate this relationship further. Nevertheless, the current evidence indicates that there is no evidence that LCS beverages may lead to any adverse health outcome and supports food safety and health regulatory authorities that LCS are safe for consumption at the current approved ADI levels (Ashwell et al., under review; Bryant & McLaughlin 2016; Rowland et al., 2018).

1.1.5.6. Low-calorie sweetened beverages on glycaemic control and insulin sensitivity

The impact of LCS beverages on glucose and insulin response is another contentious area. Several observational and interventional studies report positive associations between LCS beverage consumption and increased risk of Diabetes Mellitus Type 2 (DM2). However, this association seems to be mediated, to some extent by confounding factors, in particular adiposity, and reverse causation. Contrastingly, the National Health and Nutrition Examination Survey reported that where LCS beverages are implemented as a replacement for sucrose, small benefits on outcomes including glycosylated haemoglobin (HbA1C), blood insulin, and fasting or postprandial glucose levels can be found (Leahy, Ratliff, Riedt & Fulgoni, 2017). Similarly, Ma et al. (2009) showed that LCS do not raise blood sugar or impact insulin or gut peptide release. In support of this, a review by Romo-Romo et al. (2016) examined the effect of LCS on the metabolism of carbohydrates. They found that the majority of the intervention studies showed LCS beverages had no effect on blood glucose. Studies reporting improvements in metabolic parameters suggest that this is probably the result of substitution for sugars, rather than to an intrinsic effect of LCS. Similarly, a review by Archibald et al. (2018) further confirmed these findings and suggested that LCS beverage consumption can be used in place of sugars for better glycaemic control in people with type 1 and type 2 diabetes. Higgins, Considine and Mattes (2018) examined the glycaemic response to aspartame ingestion of either 0 (control), 350 mg, or 1050 mg aspartame while following a habitual diet over 12 weeks in healthy adults. They found no difference in the insulin, GLP-1, and GIP responses between doses and the control condition, or differences at baseline and 12 weeks. Consistent with this previous work, Higgins and Mattes (2019) found that consumption of different sweeteners (aspartame, saccharin, sucralose and rebaudioside A) over 12 weeks, had no effect on glucose tolerance. In support of this, the European Food Safety Authority (EFSA) have approved the health claim that LCS help to reduce post-prandial glycaemic response (EFSA, 2011b) suggesting their overall effect on glucose and insulin response is positive. Collectively, the evidence supports the argument that LCS have no adverse effects on blood glucose and insulin response (Ashwell et al., under review).

1.2. The psychological motivations for low-calorie sweetened beverage consumption

Given the controversy surrounding LCS beverage consumption, identifying the key motivations behind consumption is of importance. Certainly, the complexities of an individual's eating and drinking behaviours reveal a lot about them (Sobal, Bisogni, & Jastran, 2014). The motivation to consume a food is more complex than just liking or disliking a food product. Attitudes can influence food and beverage preferences and have even been shown to predict dietary behaviour (Hearty, McCarthy, Kearney & Gibney, 2007). Indeed, an individual's food-related motivations and attitudes have been associated with different patterns of food preferences (Cliceri, Spinelli, Dinnella, Prescott, & Monteleone, 2018; Köster, 2009). For instance, a number of studies have examined the associations between attitudes towards health and taste with regards to the consumption of particular foods (i.e., fruits, vegetables, high-fat foods or organic foods), individuals with positive attitudes are more likely to make healthier dietary choices compared to individuals who have negative attitudes towards these health and taste (Aggarwal, Monsivais, Cook & Drewnowski, 2014; Kowalkowska et al., 2018; Pelletier, Laska, Neumark-Sztainer & Story, 2013). To date, however, the underlying psychological drivers behind frequent consumption of LCS beverages and how these psychological factors impact on eating motivations and behaviour remain unclear.

In an effort to address this gap, Appleton and Conner (2001) explored the characteristics associated with frequent consumption of LCS beverages. Specifically, they investigated the relationship between body weight, body weight concerns and eating styles in frequent consumers relative to non-frequent consumers of LCS beverages. Frequent consumers were defined as individuals who consume over 825ml of LCS beverages per day. This included ``diet/reduced-sugar/sugar-free squash", ``diet carbonated drinks" and ``LCS used in tea/coffee sweetened" reported to be used. Contrastingly, they classified non-consumers as those who reported consumption of 0 ml of LCS beverages/day but also consumed ≥825 ml of naturally-sweetened beverages/day or ≥825 ml of unsweetened beverages (e.g. water) /day. They reported that frequent consumers had a higher BMI, dietary restraint and weight concerns relative to non-consumers. These consumers also reported higher levels of eating-related guilt, suggesting frequent consumers are more likely to try to control their energy intake through this feeling of guilt compared with non-habitual users. This is consistent with the idea that restrained eating is driven by a fear of fatness rather than by a desire to become thin (Chernyak & Lowe, 2010). Similarly, Wardle and Beales (1986) reported guilt to be closely associated with highly controlled and highly restrained eating (see Kristeller & Rodin, 1989 for similar findings). Finally, Appleton and Conner found that BMI and concerns about body weight were independent predictors of LCS beverage consumption. These findings suggest that LCS beverages may offer a viable strategy for weight control in individuals who struggle with their weight and concerns about their body. Following these findings, Elfhag, Tynelius and Rasmussen (2007) also found that consumption of LCS beverages was associated with higher eating restraint and BMI. As previously mentioned, this link between LCS beverage consumption and a higher BMI is most likely due to individuals with higher BMI utilising LCS beverages to avoid additional calories (e.g. see Rogers et al., 2016). In support of this, Paulsen, Myhre and Andersen (2016) explored LCS beverage consumption in a Norwegian population, they found that LCS beverage consumption was higher among females compared to men and individuals who were overweight compared individuals of normal weight. Similarly, Sylvetsky and Rother (2016) examined consumption trends of LCS beverages in the US, females were more likely to consume LCS beverages than males and a positive association between LCS beverage consumption and socioeconomic status was observed (Sylvetsky & Rother 2016). Studies examining the dietary profile of consumers of LCS beverage have reported higher healthy eating index scores and physical activity levels among these consumers compared to non-consumers (Drewnowski & Rehm, 2016; Gibson, et al., 2016). These findings suggest that these beverages are being used as a tool to help make healthier choices and reduce energy intake for individuals who are primarily female and are already overweight and obese.

Despite these insights, these studies fail to unravel the psychological drivers behind appetitive desire for LCS beverages, nor do they quantify the relative importance of these drivers or explicitly assess their subsequent impact on eating motivations or behaviours. It has been suggested that to understand the influence of different psychological factors on food choice and behaviour, we need to understand the beliefs and attitudes associated with specific foods (Forestell, Spaeth, & Kane, 2012; Zandstra, de Graaf, & Van Staveren, 2001). Indeed, food choice motivations are likely to be mediated by the beliefs and attitudes held by an individual (Shepherd & Raats, 1996).

Furthermore, in order to identify these motivations and attitudes, desire and craving are important constructs, given that they often motivate appetitive behaviour without the occurrence of physiological deprivation. According to Papies (2016b), desire describes a psychological state of motivation for a particular stimulus or experience that is anticipated to be rewarding and can be consciously experienced or not. As previously mentioned, human's desire for sweetness is innate and is a strong motivator due to the positive hedonic response derived from tasting sweet substances (Mennella et al., 2016; Mennella, 2007). Attempts to limit the consumption of sweet foods and beverages may therefore be more difficult given the inherent hedonic value of sweet taste and how sweetness makes people feel. In view of this, LCS beverages are possibly being used to satisfy both thirst and this innate desire for sweetness. These beverages may be psychologically fulfilling and could perhaps inhibit consumers' hedonic eating desires by providing an alternative source of sweetness. A clear understanding of the cognitive processes underpinning desire for LCS beverages is therefore needed to determine how these beverages affect cognition and subsequent appetitive behaviour.

The grounded cognition and the elaborated intrusion (EI) theories are heavily focused on craving and desire. Applying these cognitive theories may be useful in examining the effects of LCS beverages on craving and exploring possible mechanisms in which these beverages may exert any effects on eating behaviour. Indeed, both theories share the important assumption that representations of consumption can produce desire. As such, these theories offer insight into the potential psychological mechanisms that may help determine how consumers employ LCS beverages. However, understanding how LCS beverages influence craving-related outcomes has yet to be tested experimentally.

Frequent consumers' attitudes and beliefs towards LCS beverages also remain unclear, as well as whether these beverages exert a helpful or counterproductive effect on eating behaviour. In addition, we lack a full understanding of the mechanisms whereby LCS beverages might influence cravings and intake in consumers. These are important considerations given the growing popularity of LCS beverages and will yield important implications for potential policies and interventions in the fight against obesity. In this section, I will discuss the relevant cognitive theories and potential mechanisms for how LCS beverages might influence consumption in individuals who frequently consume them. Finally, I will explore the potential consequences that LCS beverages may have on dietary choices and eating behaviour in frequent consumers.

1.2.1. Theory of grounded cognition

The theory of grounded cognition (Barsalou, 2008) has emerged as a model of mechanisms that underlies desire; how it develops and motivates appetitive behaviour for a particular food or beverage (Papies & Barsalou, 2015). As such, this theory has important relevance in conceptualising how appetitive desire for sweetness and/or LCS beverages might affect motivation and behaviour among frequent consumers.

The theory suggests that when individuals encounter an attractive stimulus in their environment (e.g. a sweet-tasting food), they draw on previous experiences to simulate interacting with the stimuli. These stimulate similar areas of the brain to real interactions, triggering associated bodily responses, increasing both conscious desire and appetitive behaviours (Papies & Barsalou, 2015). Papies and Barsalou further suggest that this theory involves three important constructs, which are thought to play pivotal roles in grounded accounts of conceptual processing, known as simulation, situated conceptualization and pattern completion inference (Barsalou, 2003, 2008, 2011, 2013; Barsalou, Niedenthal, Barbey, & Ruppert, 2003; Lebois, Wilson-Mendenhall, Simmons, Barrett & Barsalou, 2018).

According to this theory, desire develops when an internal or external cue triggers a *simulation*, or partial re-enactment of a previously rewarding experience (Barsalou, 1999, 2008). These *simulations* can motivate behaviour even when an individual is not hungry. The previously rewarding experiences become stored in memory as *situated conceptualization* (Barsalou, 2003, 2011). This construct describes the situational content surrounding the rewarding memory such as setting, emotions, people, internal states (e.g., cognitive, affective), and bodily states (e.g., taste). Once a situated conceptualization of a previous experience is present in memory, perceiving one of its components in the current situation can reactivate other components of the situated conceptualization through *pattern completion inferences* (Barsalou, 2003, 2009, 2013). Specifically, *pattern completion inference* provides relevant information about the current situation and enables situated action by retrieving information from previous experiences. For instance, the sight or smell of a tempting food can induce situated conceptualization of a previous experience and subsequently trigger appetitive desire for that food. *Pattern completion inferences* may be experienced consciously (cravings) or beyond conscious awareness, motivating behaviour and potentially leading to impulsive behaviour. Importantly, Papies and Barsalou (2015) argue that when any element of a situated conceptualization is triggered, it can serve as a cue for retrieving the rest. Thus, it seems these constructs play a key role in desire.

Indeed, research has focused heavily on ways to manage these desires, and several studies have suggested potential strategies. For example, focusing on one's long-term goals when exposed to short-term temptations (Fishbach, Friedman, & Kruglanski, 2003; Papies, Potjes, Keesman, Schwinghammer, & van Koningsbruggen, 2014), or by applying strategy techniques such as mindfulness (Jenkins & Tapper, 2014; Papies, Barsalou & Custers, 2012). In view of these potential approaches, LCS beverages may also be presented as viable strategy for individuals who find sweet tastes inherently pleasant and rewarding, by enabling these consumers to retrieve situated cues from previous LCS beverage consumption experiences that support their weight management goal (due to being very low calorie, LCS beverages can support the goal of weight control), motivating them to consume these beverages to satisfy their hedonic thoughts and cravings while preserving their weight control pursuit. In the section below, I explore the current literature applying this cognitive theory to desire for food and its relevance to LCS beverages.

1.2.1.1. Eating simulations

Within the food domain, work carried out by Papies (2013; 2016b) and Kavanagh, Andrade and May (2005) has shown that once a simulated experience of consuming something is activated (e.g., thinking about the food in terms of actually eating it), it has the potential to trigger appetitive responses to rewarding stimuli, thus motivating the individual to consume the food.

Indeed, Papies (2013) confirmed these findings using a feature-listing task (developed by Wu and Barsalou, 2009) to apply the grounded cognition theory to the representation of food. Her work further demonstrated that tempting foods (e.g., chocolate cake) were more likely to generate eating simulations compared to neutral foods (e.g., banana); specifically, hedonic and situation features were generated more often for tempting compared to neutral foods. In contrast, participants situated neutral foods quite differently, describing visual features and features relating to the production purchase and nourishment of the food. Papies argues that features of a situation associated with growing, producing, preparation or nutrition of food are not involved in eating simulations, since they are highly salient in situations that do not involve eating the food. As such, it seems that remembering a food item in terms of enjoying its taste and texture in a relaxed social situation is more likely to trigger consumption, rather than remembering how it is prepared or nutritional composition. Her results support the assumption that eating simulations are generated for hedonically pleasing foods; also, that attractive foods are generally more likely to activate eating simulations than neutral foods given the greater motivation behind the anticipated reward. These findings further suggest that the situated conceptualizations that individuals retrieve for tempting food are specific to that individual. In view of these findings, it is plausible that, in frequent consumers of LCS beverages, cues associated with these beverages could trigger eating simulations, given the strong hedonic experience that LCS beverages are thought to generate for these consumers. Additionally, the situated conceptualizations that consumers of LCS beverages retrieve may reflect the rewarding experiences that are unique to these consumers, revealing the psychological drivers behind appetitive desire for LCS beverages.

It is apparent that these situated cues (e.g., sight or smell) associated with hedonic foods and eating can trigger hedonic thoughts, cravings, and eating behaviour, which in turn can lead to desire (Locher, Yoels, Maurer & van Ells, 2005) and can facilitate overeating, particularly among participants who have difficulties regulating their eating (Fedoroff, Polivy, & Herman, 2003). Consequently, these cues may inhibit an individual's competing dieting goal which could then lead to impulsive eating behaviour (Fishbach, et al., 2003; Stroebe, Mensink, Aarts, Schut, & Kruglanski, 2008; Rogers & Hill, 1989), which poses a problem for individuals who are trying to restrict their food intake and lose weight. Notably, these effects are specific for the cued food (Fedoroff et al., 2003), suggesting that the desires triggered activate specific situated conceptualizations, rather than an overall desire to eat.

Building on the grounded cognitive theory, it is important to know the specific motivations underlying a particular goal, in order to activate an individual's necessary mechanisms for that particular goal pursuit (Papies, 2016a; Kok et al., 2015). Indeed, when an individual performs goal-directed behaviour with a certain long-term outcome in mind, this will become part of the situated representation of the behaviour (Barsalou, 2009; Papies & Barsalou, 2015). As a result, activating it in a later situation can trigger goal-directed cognition, successful self-regulation and behaviour. The specific motivation supporting goal-directed behaviour can best be activated by cues that are positive and that directly represent that motivation. Applying this principle to frequent consumers of LCS beverages, for instance, when a situated conceptualization of consuming LCS beverages on the couch while watching television becomes activated, this may activate an individual's long-term weight control goal that has often pursued in such situations, such as dieting. The activation of such strategies is more likely if an individual has successfully pursued this long-term goal in similar situations (Fishbach et al., 2003; Papies, Stroebe, & Aarts, 2008b), so that situated conceptualizations of pursuing the dieting goal in tempting situations has been stored in memory, and can easily be easily retrieved in response to tempting food cues. Therefore, if one is in a tempting situation, their memory may search for alternative ways of handling this particular situation or temptation. In this manner, situated conceptualizations of LCS beverages consumption could become activated and implemented to prevent pursuit of tempting foods. In this way, a situational cue will most likely activate the situated conceptualisation of a healthy goal-directed behaviour, leading to healthier behaviour as a result and thereby helping people to manage their tempting thoughts and food intake.

Drawing from above, this theory of grounded cognition has particular relevance to frequent consumers of LCS beverages. It is plausible that frequent consumers of LCS beverages may use these beverages as a strategy to manage their desires for sweet-tasting foods responsibly by retrieving cues and representations (e.g., eating simulations) related to their previously rewarding experiences of LCS beverage consumption. As such, determining if LCS beverages successfully activate eating simulations would enable us to determine the underlying goals and desires attached to these beverages and how they might influence behaviour. Furthermore, in determining whether LCS beverages can be effective substitutes for sugar-containing foods and beverages, it is necessary to demonstrate that LCS beverages have similar effects to sweet food and beverages on the cognitive processes that mediate desire and craving.

However, to date, research determining whether eating simulations are activated when frequent consumers perceive LCS beverages is non-existent. The current thesis addresses this gap.

1.2.2. Low-calorie sweetened beverages and potential eating regulation theories

1.2.2.1. Elaborated intrusion theory

The elaborated-intrusion (EI) theory of desire (May, Andrade, Kavanagh & Hetherington, 2012; Kavanagh et al., 2005) is another theory that focuses on the importance of imagery within the craving experience. This theory conceptualizes episodes of craving as high-level cognitive processes or elaborations recruiting mental imagery and executive (controlled) mechanisms. It suggests that cravings consist of two distinct stages whereby an initial, spontaneous craving-related thought is sufficiently intrusive and pleasant for it then to be elaborated with vivid mental imagery. In the first stage, initial thoughts appear in response to craving cues within the environment, including physiological sensations (e.g., stomach rumbling), cognitions or emotions (Andrade, Pears, May & Kavanagh, 2012). These cues can be linked to previous enjoyable experiences. Craving-related thoughts may take the form of verbal images (Kavanagh et al., 2005) and are conscious, but can be intrusive, such that they can disrupt other thoughts (Andrade et al., 2012). In the second stage, if these craving-related thoughts are intrusive enough, they can encourage the individual to elaborate the intrusion with vivid mental imagery using a number of senses, thereby creating a realistic representation of the craved target. These sensory modalities include visual, gustatory and olfactory imagery, and take up limited working memory capacity (May, Andrade, Pannabokke, & Kavanagh, 2004; Tiggemann & Kemps, 2005). Although this experience is initially pleasurable, it can become progressively negative, as the absence of the craved target becomes evident. To alleviate this discomfort or negative state, an individual can either consume the craved food or undertake some other activity (e.g., distraction or redirecting of thoughts) to break the cycle.

However, even if the cycle is broken, the same triggers and cues remain and consumption may still occur after a delay (see Tapper, 2018 review for further details).

In terms of consumption of LCS beverages, it could be suggested that frequent consumers may retrieve a range of sensory images and previous experiences of consumption of LCS beverages. This may trigger the elaboration of intrusive thoughts, and thus generate craving for LCS beverages. Furthermore, if consumers use LCS beverages to satisfy intrusive thoughts for other foods and this technique is repeatedly practiced, this behaviour will be reinforced. In this manner, one may expect that LCS beverages could help to serve as a distraction from intrusive thoughts of other appetitive foods or by interrupting these craving-related thoughts by forming alternative images (i.e., the palatability and enjoyment of LCS beverages). Indeed, Schumacher, Kemps and Tiggemann, (2017) reported that cognitive diffusion lowered intrusiveness of thoughts, vividness of imagery and craving intensity to target the initial intrusion process following chocolate cravings. Thus, in terms of strategies, it is possible that LCS beverages may help frequent consumers to focus their craving thoughts towards LCS beverages and thereby limit the frequency and duration of craving episodes.

The EI theory has some notable distinctions from the grounded cognitive theory of desire. Firstly, the grounded theory focuses on situated conceptualizations that are derived from consumptive experiences, in addition to the pattern completion inferences and simulations that result from relevant cues at a later stage. Essentially, the grounded theory not only focuses on mechanisms that underly desire, but also on the mechanisms that trigger motivated behaviour. Furthermore, in the EI theory, the focus is on sensory imagery. In contrast, the grounded theory focuses on simulations that re-enact previous experiences which include sensory states, bodily states, settings, and various internal states (i.e., goals, images). Simulation in the grounded theory takes the form of conscious imagery in addition to unconscious re-enactment of perception and various internal states. Finally, the EI theory assumes that desire is mainly the result of an elaboration of associative intrusions, while the grounded cognitive theory assumes that desire can also be derived from simulations that are not elaborated in working memory.

1.2.2.2. The boundary model

The boundary model of eating behaviour is an important biopsychological theory proposed by Herman and Polivy (1983) to explain how restrained eating can lead to unsuccessful dieting. This theory suggests that biological pressures work to maintain food intake within a certain range (zone of biological indifference) between a hunger and a satiety boundary in restrained eaters. Whereas with unrestrained eaters eating is regulated automatically within this range by internal hunger and satiety signals, restrained eaters are assumed to control their eating cognitively by imposing a diet-boundary that consists of a set of rules to limit food intake in order to maintain or achieve a desirable weight. Notably, the boundary model suggests two classes of variables that can impair the regulation of eating in restrained eaters and induce overeating, namely the experience of strong emotion distress, or perceived dietary violation of the diet boundary through either eating forbidden foods or overconsuming calories, (Polivy & Herman, 1976a, 1976b). Herman and Polivy (1983) conceptualized the tendency for restrained eaters to overeat following dietary transgressions as the so-called "what-the-hell" effect. Having violated their dietary goals, restrained eaters are thought to abandon all attempts at eating control and continue eating until they reach their satiation boundary. However, several studies have failed to find evidence for "what-the-hell" cognitions (French, 1992; Jansen, Oosterlaan, Merckelbach, & Hout, 1988) and disinhibition effects (Fedoroff et al., 2003; Rogers & Hill, 1989).

Herman and Polivy (2011) argued that exposure to tempting food cues undermines the diet by making the prospect of eating more attractive and thus overwhelming the dieter's self-regulatory inhibition. This interpretation is consistent with the assumption of the goal conflict model of eating discussed below that the smell or taste of palatable food primes the eating enjoyment goal.

Drawing from above, this theory has a particular relevance to consumers of LCS beverages, as previously discussed, they are more likely to be restrained eaters and concerned about their body weight (Appleton & Conner, 2001). As such, these individuals are likely to be particularly susceptible to tempting food, resulting in uncontrolled eating and dietary failure. Some restrained eaters may therefore use LCS beverages as a strategy to prevent disinhibited eating from occurring by satisfying their craving thoughts and desires for sweetness (in line with grounded cognition and EI theories, outlined above). In this way, these beverages may enable frequent consumers to regulate their food intake and become successful restrained eaters.

1.2.2.3. Goal conflict model

The goal conflict model is a cognitive theory accounting for the over-responsiveness of restrained eaters to external food-relevant cues (Stroebe et al., 2008; Figure 1.3.) and potential cognitive strategies that may enable people to control their diet. This theory has particular relevance to frequent consumers of LCS beverages. As previously mentioned, these consumers typically have higher dietary restraint and body weight concerns. Indeed, research has consistently shown that restrained eaters are concerned with their weight and motivated to control it by deliberately restricting their food intake, particularly energy dense foods (Lowe, Doshi, Katterman & Feig, 2013; Lowe & Thomas, 2009; Stroebe, van Koningsbruggen, Papies, Aarts, 2013; Tuschl, 1990). This is a controlled process that that requires cognitive resources. If restrained eaters are able to focus on regulation of their eating, they are capable of managing their weight. Yet, if their motivation to regulate their eating is impaired, overeating will occur. Unfortunately, many restrained eaters are not very successful in these attempts to control food intake, and their eating behaviour is characterized by cycles of food restriction and disinhibited eating (the tendency to overeat in response to a range of stimuli including palatable foods) and as a result, they are often are more susceptible to weight gain (Gorman & Allison, 1995; Lowe, 2002).

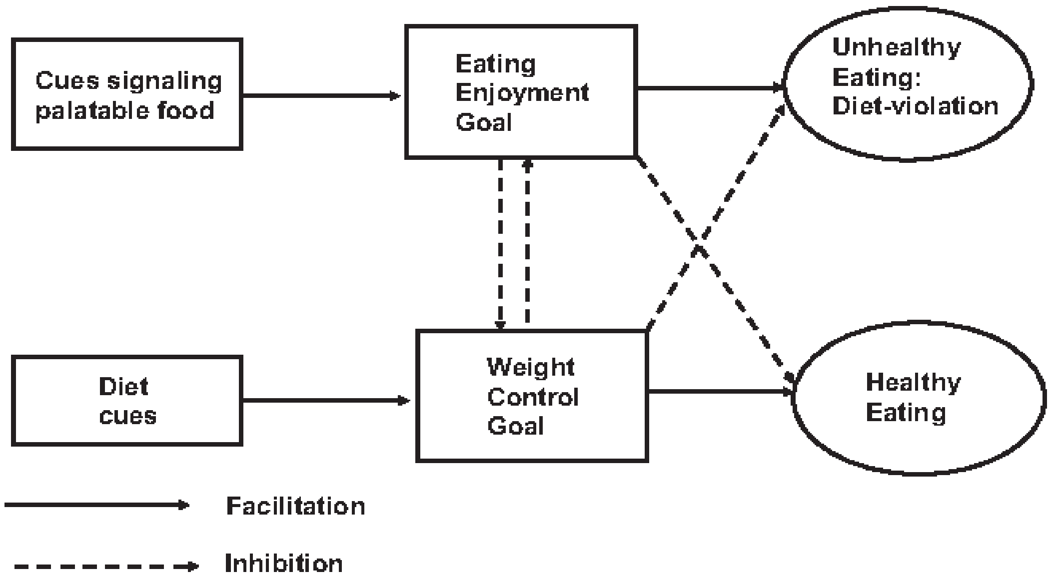

Figure 1.3. Schematic illustration of the goal conflict model of eating behaviour used to explain the eating behaviour of restrained eaters. Diet cues prime the weight control goal and lead to healthy eating by inhibiting the conflicting eating enjoyment goal and unhealthy eating responses. In contrast, palatable food cues (that are more prevalent than dieting cues in food-rich environments) prime the eating enjoyment goal and lead to unhealthy eating by inhibiting the weight control goal and healthy eating responses (Stroebe et al., 2008).

The goal conflict model (Figure 1.3.) attributes this difficulty in regulating food intake in individuals with high dietary restraint to juggling two conflicting goals regarding their food intake; namely their short-term hedonic goal of enjoyment of eating while also satisfying their long-term goal of weight control (Stroebe, et al., 2008). Importantly, this theory recognises that the anticipated pleasure of eating plays an important role in eating regulation and it is this hedonic characteristic that is the major cause of dietary failure.

There are both immediate (e.g., hedonic pleasures associated with eating a highly palatable food) and longer-term consequences (e.g., violation of weight goal and healthy eating) of eating a particular food that are considered when responding to food cues (Rangel, 2013). While both these types of consequences are considered when making food choices (Rangel & Hare, 2010), at the same time, palatable food has a strong positive incentive value (Fedoroff, Polivy & Herman, 1997). Therefore, consumption of palatable food is often a highly desirable end goal.

Priming of goals: priming the hedonic goal

Environmental cues of temptation, where highly palatable and energy dense foods are easily accessible, play a critical role in disrupting weight-regulation for restrained individuals. Thus, by activating enjoyment rather than health goals, this can easily lead to unhealthy behaviours, even outside conscious awareness (Papies, 2016b). Indeed, previous studies have shown that the exposure to attractive food cues resulted in overconsumption in restrained, compared to unrestrained eaters (Fedoroff et al., 1997, 2003; Harris, Bargh, & Bronwell, 2009). For instance, restrained eaters are more likely to overeat after exposure to temptation cues such as the sight, taste or thought of palatable foods (Fedoroff et al., 1997; Harris et al., 2009; Jansen & Van den Hout, 1991; Rogers & Hill, 1989). Fishbach et al. (2003) argue that these external cues (e.g., words, images or smells) can serve as primes that can unconsciously increase the cognitive accessibility of a goal. Goal priming refers to the activation of a mental representation of a goal by an external cue, and the prime affects behaviour by encouraging the pursuit of the primed goal (Custers & Aarts, 2005, 2010).

In support of this, several studies have consistently shown that exposure to palatable food not only primes the goal of eating enjoyment (Hofmann, Van Koningsbruggen, Stroebe, Ramanathan, & Aarts, 2010; Papies, Stroebe, & Aarts, 2007), but also inhibits the competing long-term goal of weight control in restrained eaters (Papies et al., 2008; Stroebe et al., 2008).

Papies et al. (2007) demonstrated that exposure to palatable food cues (i.e., sentences containing appetizing food words) compared to neutral food cues (i.e., sentences containing neutral food words) resulted in increased accessibility of a hedonic eating goal, as shown by faster response latencies to words representing the hedonic eating goal. Similarly, Kemps, Tiggemann and Hollitt (2014) showed that exposure to food advertisements increased the accessibility of food-related thoughts in individuals exposed to these adverts compared to individuals who were exposed to non-food advertisements. Thus, it appears that food-related primes may increase the accessibility of a hedonic eating goal, leading to difficulty in regulating one's weight, consistent with the goal-conflict model.

Priming the weight control goal

In an effort to change cognitions and unhealthy behaviours, goal-related cues that are specific to that food, can activate an individual's health goals; thereby facilitating healthier behaviour (Papies, 2016a, 2016b). By priming individuals with the health goals they strive for, it is thought to supress their thoughts about temptations that would otherwise inhibit their pursuit (Fishbach et al., 2003). Importantly, only goals that are important to that particular individual can be activated by a relevant prime (i.e., activating goal-relevant cognitions and avoiding stimuli that interfere with the goal). Indeed, several studies have shown that dieters can regulate their consumption when exposed to cues linked with their longstanding diet goals by subtly reminding themselves of these goals (Anschutz, Van Strien, & Engels, 2008; Buckland, Finlayson, Edge, & Hetherington, 2014; Papies, Potjes, Keesman, Schwinghammer, & van Koningsbruggen, 2014; Papies & Veling, 2013; Papies & Hamstra, 2010). For instance, Papies and Hamstra (2010) showed that restrained eaters consumed significantly less snacks following exposure to a poster containing health and diet words (reminded of their dieting goal) relative to restrained individuals who were not exposed to such a poster. In addition, consistent with the idea that the specific goal must be relevant to that individual, non-dieters were not affected by the prime. These findings were further replicated using healthy menu choices in a restaurant environment (Papies & Veling, 2013). Similarly, van der Laan, Papies, Hooge, and Smeets (2017) demonstrated that the presence of a diet advertisement in an online supermarket task increased the attention towards and the choice of low-calorie products. Buckland et al. (2014) also showed a reduction of a tempting snack when exposed to diet-congruent images relative to control images in dieters. These findings suggest that the behaviour in response to tempting food cues is goal-directed rather than impulsive. Together, these findings show support for the notion that exposure to health-related cues can activate health goals and trigger health-oriented behaviour.

Papies and Aarts (2016) argue that health goal primes work by activating an individual's health motivation by directing attention to healthy stimuli in their environment, at the cost of desire for unhealthy temptations. Therefore, successful dieting appears to be associated with the activation of health-related goals rather than hedonic thoughts related to food stimuli (Fishbach et al., 2003; Papies, Stroebe, & Aarts, 2008a, 2008b), which may affect how attention to food is guided by working memory. In view of this, it is possible that LCS beverages may act as a "diet prime", reminding consumers of their dieting motivations and therefore helping to regulate their eating behaviour and goal pursuit, even in situations in which short-term hedonic goals typically succeed. In addition, LCS beverages may further help prevent self-imposed dietary boundaries from being broken by satisfying food cravings and/or the hedonic desire for sweetness. Therefore, LCS beverages may remind frequent consumers of their dieting goal, while also satisfying their hedonic goal thereby realigning the previously conflicting goals in the goal-conflict model; thus controlling their eating behaviour even when surrounded by tempting cues.

Taken together, these previous findings show that priming a goal using external cues can trigger goal-directed behaviour. However, in line with the grounded cognition theory, to effectively prime a health goal, it is important that the primed goal is motivationally desirable to that individual, whilst also activating the specific reasons to pursue the goal with effective cues that attract attention towards the specific goal (Custers & Aarts, 2005, Aarts 2007; Fishbach & Trope, 2005; Aarts, Custers, & Veltkamp, 2008; van Koningsbruggen, Stroebe & Aarts, 2011; Papies et al., 2008a Papies, 2016b). Finally, by being repeatedly primed and continuously performing the primed behaviour, this may lead to the formation of healthy habits (Lally & Gardner, 2013) and long-term beneficial health effects. These theoretical perspectives can be applied to understanding the impact of LCS beverages in the context of appetite and weight control. Specifically, LCS beverages may be a potential psychological strategy to satisfy frequent consumers' hedonic eating goals while simultaneously preserving their weight control goal (i.e. realigning previously conflicting goals). LCS beverages thereby offer great potential for individuals who struggle with their weight. In satisfying consumers' innate desire for sweetness, LCS beverages could facilitate self-regulation in the face of high-calorie food temptation, without the accompanying caloric intake and guilt. It is therefore important to consider and explore this eating regulation model as a potential psychological mechanism which may underlie motivation for consumption of LCS beverages.

1.2.3. The consequences of low-calorie sweetened beverage consumption

Finally, it is important to consider the ways in which beliefs about consumption of LCS beverages may influence food intake and behaviours in frequent consumers. From one perspective, by believing these beverages are a viable strategy in complying with weight management goals, consumers may feel more in control (i.e., self-efficacy) over their food choice and overall intake, ultimately helping them to stay motivated in their pursuit of their weight control goal, leading to healthier food choices. Indeed, self-control beliefs have an important influence in the maintenance of healthy behaviours such as weight control (Bernier & Avard, 1986; Hagger, Wood, Stiff & Chatzisarantis, 2009). Both motivation and self-efficacy beliefs have been highlighted as key determinants of a healthy diet (de Ridder, Kroese, Evers, Adriaanse & Gillebaart, 2017). In support of this, Hagger et al. (2013) found that reduced feelings of self-control over food led to difficulties in regulating eating and subsequently increased food intake among restrained eaters. Therefore, these reduced feelings of self-control over food may lead to unhealthy choices and long-term weight gain (Wills, Isasi, Mendoza & Ainette, 2007). Furthermore, the long-term inhibition of eating behaviour has been shown to leave individuals with high restraint with diminished self-control resources and vulnerable to subsequent self-regulatory failure when presented with tempting foods (Vohs & Heatherton, 2000). In view of this, LCS beverages may help remind consumers of their dieting motivations and feel more in control in regulating their eating behaviour and make healthier food decisions.

However, another possibility is that some individuals, who over-consume on other foods such as chocolate, do so because they believe LCS beverages are healthy. It may be that people who drink LCS beverages believe they have saved enough calories, therefore they feel entitled to then indulge in tempting foods. Indeed, it has been argued that LCS beverages consumption may lead to inadvertent shifts in food patterns and selection; this in turn may encourage not only increased energy intake but also to a decrease in diet quality (Sylvetsky, 2018; Sylvetsky & Dietz, 2014). In consideration of this, a clearer picture of the role of LCS beverages in the diet may emerge if we have a better understanding of consumers' motivations for choosing these beverages.

A further possibility is that these beverages may not be capable of protecting people from over-consumption following a craving experience, leading to periods of increased food intake and facilitating self-regulatory failures. In other words, these consumers may feel overwhelmed with food-related thoughts when exposed to many temptations, that these thoughts likely trigger a salient and potent desire to eat and these beverages may not be enough to completely satisfy this desire and prevent consumption of the desired food.

Finally, LCS beverage consumption may reduce eating-related guilt; specifically, consumers may feel that by consuming these beverages they are making positive food choices and refraining from choosing forbidden (i.e., unhealthy) foods. Frequent consumers perhaps believe that by consuming LCS beverages they are supporting their goal of reducing their energy intake, leading to feelings of greater-self-control over food temptations. This is an important consideration, since previous research indicates that eating-related guilt has the potential to hinder healthy behaviours, because individuals might experience helplessness and feel unable to change their behaviours (Dewberry & Ussher 2001; Kuijer &. Boyce, 2014). Additionally, experiencing eating-related guilt can lead to negative outcomes including selection of indulgent foods, increased food consumption and long-term weight gain (Kuijer & Boyce, 2014; Kuijer, Boyce, & Marshall, 2015). LCS beverages may therefore be a help to consumers in exercising self-control over foods choices and weight control.

Drawing on the above, it remains unclear what the fundamental attitudes and beliefs associated with consumption of LCS are and whether these beverages have a beneficial or counterproductive effect on psychological processes that control eating behaviour. This is an important consideration given the growing popularity of LCS beverages (Gibson et al., 2016), and yields important implications for consumers who frequently consume these beverages in terms of determining their capabilities as a useful tool in managing their appetitive desires and control over their weight.

1.3. The current thesis

As discussed, there is currently a lack of scientific evidence regarding the antecedents of LCS beverage consumption and the psychological mechanisms underpinning the effect of their consumption on eating motivation and behaviour. Indeed, it has been argued that LCS beverages may encourage compensatory overeating of sweet foods or foods lower in nutrients (Gardner et al., 2012). Do individuals who frequently consume these beverages feel justified in consuming more energy dense foods, negating the calorie savings? Specifically, by consuming LCS beverages, it is possible that consumers believe they are making healthy food choices and deserve to treat themselves by consuming other tempting foods; consequently having a negative effect on overall diet quality. Or on the other hand, do LCS beverages help people to deal with desire and cravings, by providing a sweetness reward whilst helping regulation of food intake and preservation of their weight control goal, even in tempting environments? To address these overarching questions, the first aim of the current thesis was to identify the beliefs and attitudes towards LCS beverages which motivate those who frequently consume LCS beverages. Thus, by establishing the core beliefs towards LCS beverages, the current thesis aims to provide insight into perceptions, cognitive representations and desire for LCS beverages, which are likely drivers of consumption of these beverages. The specific aims of this research were as follows:

Aim 1. To establish the psychological predictors of low-calorie sweetened beverage consumption (Chapters 2-3).

Chapter 2

Chapter 2 presents the development of a novel tool to quantify the specific driving factors associated with consumption of LCS beverages (i.e. attitude and beliefs towards LCS beverages questionnaire). This novel questionnaire quantifies the salient beliefs and attitudes that are associated with consumption of LCS beverages. A further aim of this study was to use this questionnaire to examine contrasting attitudes and beliefs surrounding LCS beverages in frequent and non-consumers of LCS beverages. A final aim was to determine whether frequent consumption of LCS beverages was associated with high BMI, body weight concerns and dietary restraint.

Chapter 3

Drawing upon findings from Chapter 2, Chapter 3 presents a study that empirically explored the cognitive representations of LCS beverages. Specifically, and in line with the theory of grounded cognition, it aimed to determine whether eating simulations (i.e., partial re-enactments of previous hedonic experiences surrounding LCS beverage consumption) play a role in the representation of LCS beverages in frequent compared to non-consumers (using a feature-listing task adapted from previous studies). It was predicted that frequent LCS consumers (but not non-consumers) would generate higher number of eating simulations when describing LCS beverages compared to neutral foods. Furthermore, it was hypothesised that frequent consumers would generate a similar number of eating simulations for both LCS beverages and tempting foods, while non-consumers would generate more eating simulations for tempting foods compared to neutral foods and LCS beverages. Finally, a further aim was to determine whether frequent consumers associate LCS beverages with healthy attributes (in line with the goal-conflict model).

Aim 2. To examine the psychological mechanisms and consequences associated with low-calorie sweetened beverage consumption (Chapter 4-5).

Drawing upon potential psychological mechanisms associated with LCS beverage consumption (discussed in section 1.2.2.), a second aim of the current thesis was to examine the consequences of consumption of LCS beverages on eating motivations and behaviours. This was addressed in Chapters 4 and 5.

Chapter 4

Chapter 4 presents two experimental studies which aimed to establish the psychological mechanisms underpinning the effect of LCS beverages on eating behaviour; specifically, these studies aimed to determine whether LCS beverages are helpful or counterproductive for controlling food cravings and eating behaviour in frequent consumers. A craving manipulation was implemented to activate the hedonic eating goal, which would be likely to lead to over-consumption. However, it was expected that LCS beverages would satisfy hedonic desires and subsequently prevent over-consumption from occurring. As such, study 3 hypothesised that energy intake would be greater following the craving manipulation, relative to the control manipulation in non-consumers. It was predicted that frequent consumers, however, would be protected from this effect due to the availability of LCS beverages in the *ad libitum* eating context. In line with the goal-conflict model, LCS beverages may act as a highly salient hedonic cue due to their association with a rewarding hedonic experience. As a result of this, and also in line with incentive-motivational models (Field et al., 2016), it was also predicted that frequent consumers, but not non-consumers, would show an attentional bias towards LCS beverage stimuli and that this bias would be amplified when frequent consumers were in a state of craving.

Study 4 aimed to replicate the effects of study 3 in frequent consumers. In addition, the availability of LCS beverages was manipulated to determine whether the effects found in study 3 were due to LCS beverages being available for consumption (and thereby satisfying hedonic eating motives). It was predicted that in the LCS unavailable condition, participants would show a greater energy intake, and also report higher guilt, lower meal enjoyment and lower perceived control in the craving condition relative to the control condition. However, in the LCS available condition, it predicted there would be no difference between the craving and control conditions in terms of energy intake, guilt, meal enjoyment and perceived control.

Chapter 5

Chapter 5 further explored the longer-term impact of LCS deprivation in frequent consumers. In depriving individuals of LCS beverages, their hedonic motives may override their weight management goal, and result in subsequent loss of control over food intake. To investigate this, participants assigned to the deprived condition were deprived of LCS beverages for a 7-day period, while participants in the non-deprived condition consumed LCS beverages as normal. Habitual self-reported measures of mood and intake were used in order to capture a change in these behaviours in the natural environment. Drawing upon the findings from Chapter 4, it was hypothesised that (1) self-reported food cravings (in both the free-living and controlled laboratory settings) would be higher in the LCS-deprived condition than in the non-deprived control condition. (2) Energy intake (in both the free-living and controlled laboratory settings) would be higher in the LCS-deprived condition than in the non-deprived control condition. As a result of this increase in energy intake, (3) it was predicted that negative mood and guilt (in both the free-living and controlled laboratory settings) would be greater in the LCS-deprived condition than in the non-deprived control condition.

To summarise, the current thesis encompassed two primary aims: 1) to establish the psychological predictors behind consumption of LCS beverage (i.e. what predicts their consumption?) and 2) to examine the psychological mechanisms and consequences associated with LCS beverage consumption with regard to eating behaviour (i.e. are LCS beverages helpful or counter-productive?). See Figure 1.4. for an overview of the structure and aims of the thesis.

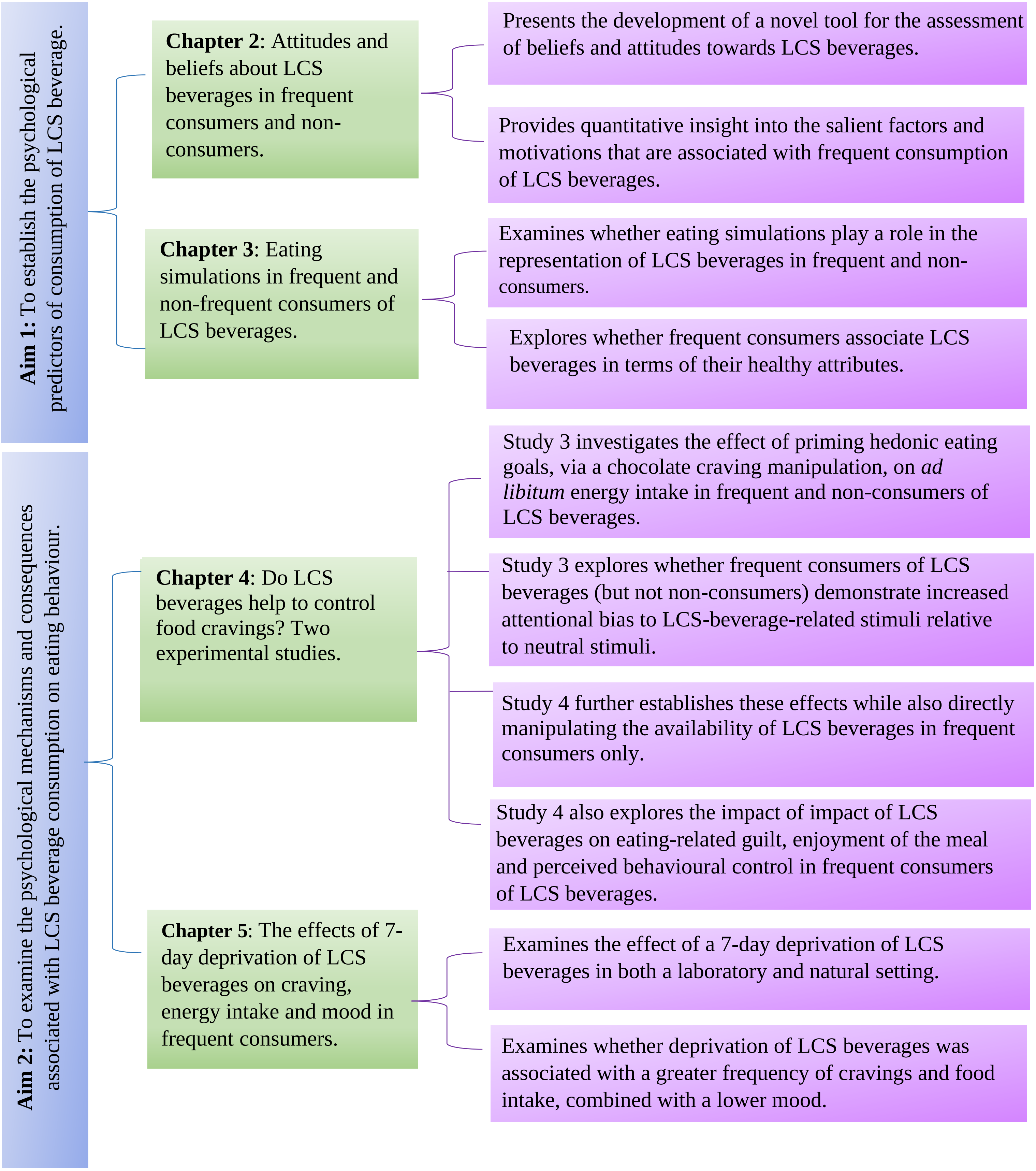

Figure 1.4. Thesis overview. Thesis aims are presented in the blue boxes, chapter headings are in green boxes, and the individual aims of each chapter are presented in the purple boxes.

Chapter 2: Attitudes and beliefs about low-calorie sweetened beverages in frequent consumers and non-consumers: Development of a new measurement tool

2.1. Abstract

LCS beverages represent an alternative to sugar-sweetened beverages (SSB) due to their sweet taste without the addition of calories. Despite LCS beverages becoming increasingly popular, the psychological factors which influence their consumption are unclear and valid and reliable measurement tools are lacking. To address this, the current study developed a novel questionnaire designed to measure beliefs and attitudes towards LCS beverages. Differences between frequent consumers and non-consumers of LCS beverages on beliefs and attitudes, BMI, and eating styles were then examined. The questionnaire was developed through principal component analysis of responses from 340 participants (mean age 26 ± 8.83 years; BMI 24.73 ± 4.22 kg/m^2; 69% female), who completed an online questionnaire which included a pool of items designed to measure attitudes and beliefs towards LCS beverages. The analysis initially identified a three-factor structure; however, following a confirmatory factor analysis on a separate sample of participants (N=289), a two-factor structure was generated. Factor one consisted of items that referred to positive beliefs about LCS beverages aiding weight management and satisfying cravings. Factor two referred to palatability and enjoyment of LCS beverages. Participants also completed questionnaire measures of dietary restraint, body weight concerns, and their habitual intake of beverages (LCS beverages, SSBs, and water). Results indicated that frequent consumers of LCS beverages had significantly higher beliefs that LCS beverages are palatable and effective in controlling appetite and weight relative to non-consumers. The questionnaire had good overall psychometric properties indicating that it provides a valid and reliable means of quantifying

beliefs about LCS beverages. This will facilitate further study of consumer behaviour towards these products with regard to key psychological drivers of consumption.

2.2. Introduction

LCS beverages have become extremely popular with consumers (Sylvetsky, Welsh, Brown, & Vos, 2012; Gibson et al., 2016). LCS beverages are often marketed as "healthy" alternatives to SSBs due to the absence of calories and ability to mimic the sensory properties of SSB (Bellisle & Drewnowski, 2007; Mattes & Popkin, 2009). As such, LCS beverages have emerged as a potential health strategy to satisfy both thirst and an innate desire for sweetness, whilst reducing sugar intake, total energy intake and promoting weight loss (Ventura & Mennella, 2011; Drewnowski & Rehm, 2016). Despite this, their role in weight management and health remains a topic of continued controversy (Azad et al., 2017; Toews et al., 2019; Lohner, Toews & Meerpoh, 2017; Sylvetsky, Swithers & Rother, 2015; Schernhammer et al., 2012).

As outlined in Chapter 1, there is concern that consumption of LCS beverages may stimulate energy intake, weaken appetite control and promote a preference for hedonically pleasing food (Piernas et al., 2013). This is primarily based on animal and observational studies (Duffey, Steffen, Van Horn, Jacobs & Popkin, 2012; Fowler et al., 2008; Swithers, Sample & Katz, 2013; Swithers, Laboy, Clark, Cooper & Davidson, 2012) which have raised public awareness and created a negative opinion towards LCS beverages (Sylvetsky & Rother, 2016), potentially deterring their consumption. However, contrary to this, a systematic review and meta-analysis indicated that LCS consumption as a substitute for sugar leads to *reduced* energy intake and body weight (Rogers et al., 2016). Relatedly, Leahy et al. (2017) utilized data (N=25,817) from the National Health and Nutrition Examination Survey (NHANES) in men and women. They reported that LCS beverage consumers drink these products to help control total calorie intake and do not compensate for sugar or energy deficits by consuming more sugary food. In accordance with these findings, Bellisle (2015) and Gibson et al. (2016) argue that LCS beverages may be a practical beverage choice in helping to regulate sugar and carbohydrate intake. These findings suggest that some people are consuming LCS beverages to at least reduce total calorie intake and potentially achieve weight loss.

Furthermore, several studies have demonstrated that LCS beverages intake is particularly high among successful maintainers of weight loss. For instance, Phelan et al. (2009) compared the dietary strategies and use of beverages between a weight loss maintainer group (WLM) and a normal weight group (NW). They found that the WLM group reported consuming three times more daily servings of LCS beverages, more daily servings of water and consuming a diet that was lower in fat compared to the NW group. Similarly, Miller and Perez (2014) found that approximately 66% of individuals who had successfully maintained weight loss for > 1 year consumed a LCS-containing beverage on a weekly basis. Drawing on these findings, it seems plausible that the use of LCS beverages may assist some individuals in maintaining a reduced calorie diet and maintaining weight loss over time. Thus, the regulation of weight/weight loss could be a motivating factor that is driving LCS consumption. However, no attempt has been made to explicitly measure the fundamental factors that motivate LCS beverage consumption.

Consumption of LCS beverages has also been shown to be higher among adults who are overweight or have obesity, compared to adults of healthy weight (Mattes & Popkin, 2009). One possible explanation for this association is that overweight and obese individuals may turn to LCS beverages in response to their excess adiposity and/or weight gain (Pereira, 2013). Indeed, Drewnowski and Rehm (2016) reported an association between intent to lose weight and LCS beverage use. They found that past weight fluctuations were a predictor of LCS beverage consumption. Consistent with this idea, frequent use of LCS beverages has been associated with a higher BMI and weight gain (Stellman & Garfinkel, 1986), but also with weight concerns and a high dietary restraint (Appleton & Conner, 2001; Elfhag, et al., 2007). Limited studies from the US have shown that individuals who had obesity and were female, were more likely to consume LCS beverages compared to individuals who were of a healthy weight and male (Sylvetsky & Rother 2016; Paulsen et al., 2016; Pollard et al., 2016). Notably, Paulsen et al. found that consumption of LCS beverages was primarily consumed as a snack, suggesting that consumers are using them to alleviate food cravings without the additional calories. Individuals with high body weights and concerns surrounding their weight may therefore use LCS beverages as a strategy to control and/or lose weight (Stellman & Garfinkel, 1986). Specifically, frequent consumers may believe that LCS beverages enable them to feel satiated, satisfy cravings and ultimately achieve their weight goals.

To the authors' knowledge, only one qualitative study has investigated consumer perceptions towards LCS beverages. Zoellner Estabrooks, Davy, Chen and You (2012) found that taste, low energy/sugar and positive health benefits were the most important determinants of LCS beverage consumption in a sample of 54 participants. However, their focus was on SSB consumers and did not explicitly recruit frequent and non-consumers of LCS beverages which may reveal other drivers of consumption or non-consumption. Surprisingly, little is known about the consumer profiles and determinants of LCS beverages. Given these limitations, examining the cognitions underlying LCS beverage consumption, particularly attitudes and beliefs towards these beverages are important in understanding LCS beverage consumers' motivations and behaviours. Attitudes account for a significant portion of variance in behavioural outcomes (Ajzen, 2011) and favourable attitudes towards a product often translate into a greater propensity of the consumer to purchase it (Steinman, 2009). Essentially, individual attitudes, both implicit and explicit, have been identified as one of the multiple drivers of consumer behaviours, including food-related ones (Cervellon, Dubé, & Knäuper, 2007). Studying the determinants of LCS beverage consumption may therefore allow the specific drivers and barriers of consumption to be identified. Despite this, we know very little about the attitudes individuals hold towards LCS beverages, and this is partly due to the lack of a suitable measurement tools. As such, our understanding of this area is limited. Thus, the development of an attitudes and beliefs towards LCS beverages measure constitutes an important step toward this end.

Presently, most of the existing questionnaires surrounding LCS beverage consumption have either been developed from a marketing perspective, or subject surveys, while other questionnaires (De Cock et al., 2016) focus more on overall beverage consumption itself. For instance, a survey conducted by the International Food Information Council Foundation (IFICF) found that 77% of the individuals reported trying to limit/avoid sugar. In order to limit their sugar intake, 60% of individuals consume more water instead of calorie beverages, while 29% of individuals use LCS. In addition to limiting sugar intake, LCS consumers reported diabetes management, reduction in calorie intake and maintenance/loss in weight as important motivators behind consumption (IFICF, 2018). A survey conducted by Mintel indicated that 64% of respondents were increasingly concerned surrounding the safety of “artificial” sweeteners. In addition, 81% of respondents agreed with the statement that “sugar-free foods do not taste as good as those made with real sugar” (Pereira, 2006). Sylvetsky, Greenberg, Zhao and Rother (2014) did measure attitudes towards LCS in both food and beverages. They reported that some individuals believed they were unsafe for consumption and actively tried to avoid consuming them. However, they focused on the topic of providing LCS beverages to children and did not specifically recruit frequent or non-consumers of LCS beverages. These findings further suggest that consumption of LCS beverages is tied to consumer efforts to decrease their intake of calories and caloric sweeteners. To date, current questionnaires can inform us about the type of consumer who may purchase these beverages and consumer trends.

Nonetheless, none of these questionnaires are able to inform on beliefs and attitudes towards LCS beverage specifically.

Drawing on the above, there is a need for a framework to identify those factors which influence regular LCS beverage consumption. Thus, the main aim of the present study was to develop a validated measure to quantify the specific driving factors (such as beliefs about appetite control, credibility and appropriateness) behind LCS beverage consumption. The secondary aim was to use the questionnaire to examine differences in attitudes and beliefs about LCS beverages in frequent relative to non-consumers of LCS beverages. We also investigated whether frequent consumption of LCS beverages is associated with high BMI, body weight concerns and dietary restraint.

2.3. Method

2.3.1. Participants

Participants were recruited via public advertisements that were shared on various social media platforms (i.e., Facebook, Twitter and University of Liverpool webpages), and in public places such as community centres, university noticeboards, and retailers in the Merseyside area of the UK. To be eligible to take part, participants could not have any existing medical conditions or be taking any medication that could influence appetite, mood or intestinal habits. All participants were between 18-60 years old and fluent in English. All participants read an information sheet and signed a consent form prior to taking part. The sample size was based on recommendations that there should be between 5 and 10 observations for each item included in the factor analysis (Comrey & Lee, 1992). In exchange for taking part, participants were offered the chance to be entered into a prize draw where they could win, £50 or one of two £25 vouchers. Alternatively, first year Psychology students were allocated course credits. The study received ethical approval from the University of Liverpool Research Ethics Committee.

The participants were in one of two groups (group 1 or group 2). Initial exploratory factor analysis was performed using responses from group 1 (N=340). Responses from group 2 (N=289) were used to confirm the factor structure. Finally, test-retest reliability was performed using a subset of participants from group 1 (N=90).

2.3.2. Measures

2.3.2.1. Development of the attitudes and beliefs questionnaire items

An initial set of 49 question items was generated based on discussions within the research team, pilot work and reviewing the literature (the 49-item questionnaire is available in Appendix A). To ensure that items adequately captured a range of beliefs behind LCS beverage use, we included at least five items to capture each 'theme'. Specifically, items referred to either: taste, health, reducing cravings, sweetness, weight management and palatability in relation to LCS beverages. For each item, participants were asked to rate their level of agreement with each item using a 7-point likert scale. Questionnaire items were assigned a value of 1 to 7 (1= Strongly disagree, 2= disagree, 3= Somewhat disagree, 4= Neutral, 5= Somewhat agree, 6= Agree, 7= Strongly agree). The higher score indicated stronger beliefs in relation to each of the themes (i.e., stronger beliefs that LCS beverages reduce cravings). There were also 2 open ended questions at the end of the questionnaire to which the respondent could add any additional themes that were not asked about within the questionnaire.

2.3.2.2. Frequent and non-frequent consumers of Low-Calorie Sweetened Beverages

A Food Frequency Questionnaire (FFQ) developed by Appleton and Conner (2001) was used to assess consumption of a range of beverages (water, regular squash, sweetened carbonated beverages, LCS carbonated drinks, unsweetened tea/coffee, tea/coffee sweetened with sugar, tea/coffee sweetened with LCS, hot chocolate, milkshakes and fruit juices). Participants indicated the number of times per day or per week that they consumed a glass, can or cup of the relevant beverage (e.g. bottled water, regular squash, low/reduced sugar squash).

The absolute quantity of LCS beverages consumed per day was calculated based on the sum of the reported quantities of ``diet/reduced-sugar/sugar-free squash", ``diet carbonated drinks" and ``tea/coffee sweetened with artificial sweeteners". For example, if a participant reported drinking 4 glasses of Pepsi max every day (this would equate to 4 x200ml/per day), and 3 mugs of tea with sweetener per week (3 x 350ml/per week; 150 mls/per day), on average, this participant drinks 950 ml/day of diet drinks per day (please see Appendix B for the FFQ developed by Appleton and Conner).

Following Appleton and Conner's questionnaire, participants were defined as frequent consumers (*N*=108) if they reported consuming ≥825 ml LCS beverages/day. Participants who reported consumption of 0 ml of LCS beverages/day in addition to ≥825 ml/day of SSB and/or ≥ 825 ml/day of water were defined as non-consumers (*N*=103). This sub-sample of participants (i.e. frequent consumers *N*=108, non-consumers *N*=103) from group 1 were included in stratified analyses to address the secondary aims of the study (i.e. to examine differences in attitudes and beliefs about LCS beverages in frequent relative to non-consumers of LCS beverages). Respondents who completed the original questionnaire but were not classified as a frequent or non-consumer (*N*=129) were excluded from these secondary analyses. This classification was based on Appleton and Conner's (2001) study in which values of 825 ml/day and 0 ml beverages/day represented the top and bottom tenths of consumption levels of LCS, respectively, within their sample. The top 10th percentile of LCS beverage consumption equated to either 2.5 cans of LCS beverages; 4 glasses of sugar free squash or 3.5 cups of tea/coffee sweetened with LCS per day.

2.3.2.3. Eating styles

Eating behaviour: Dietary restraint, emotional and external eating were assessed using the Dutch Eating Behaviour Scale (DEBQ; Van Strien, Frijters, Gerard & Bergers, 1986). The restraint sub-scale comprises of 10 items such as “Do you try to eat less at mealtimes than you would like to eat?". The emotional eating sub-scale consists of 13 items such as " Do you have the desire to eat when you are irritated?" and the external eating sub-scale consists of 10 items such as "Do you eat more than usual when you see others eating?". Participants were asked how frequently each of the statements applies to them. All responses were scored on a 5-point Likert scale (Never/seldom=1 to Very often=5), with higher scores indicating greater tendency to exhibit the sub-scale behaviour. Participants' level of restraint was determined by the mean score of the individual items. The Cronbach's Alpha for restrained, emotional and external eating in the current study were .80, .90 and .79 respectively.

Weight concerns: Weight concerns were measured using the Eating Disordered Inventory (EDI; Garner & Olmstead, 1984). Participants completed drive for thinness (7 items), bulimia (7 items), body dissatisfaction (9 items) and perfectionism (6 items) sub-scales, measuring eating attitudes and behaviours. Participants had to respond to each question on a 6-point Likert scale ranging from "Never" to "Always". Sub-scale scores were determined by the mean score of the relevant items. The Cronbach Alphas for the Drive for thinness, Body dissatisfaction, Bulimia and Perfectionism sub-scales in the current study were .81, .82, .79 and .73 respectively.

2.3.3. Procedure

All of the measures previously described were compiled into an online survey hosted by Qualtrics. Participants were instructed to complete the questionnaire in their own time. After providing informed consent, participants provided demographic information including their age, gender, weight (in kilograms, pounds or stones), height (in centimetres, or feet and inches) and dieting status ("are you currently dieting?" Yes/no response). Questionnaires were then completed in the following order: Beverage FFQ, EDI, DEBQ, and the novel attitudes and beliefs towards LCS beverages questionnaire. Finally, participants who wished to be entered into the prize draw provided their e-mail address.

In total, 340 participants completed the online questionnaires in full (Group 1). A subset of these participants (*N*=150) were notified by email to complete the attitude and beliefs questionnaire for a second time, of which 90 completed the questionnaire, two weeks apart to assess the test-retest reliability of the questionnaire. Following principal component analysis, the updated attitudes and belief questionnaire was then sent out to a new cohort of participants (Group 2; *N*=289) to confirm the factor structure. To ensure this was a new group of participants, participants were informed that they could not take part if they completed the original questionnaire. Email addresses were compared to ensure no participants completed both questionnaires. As in Group 1, participants in Group 2 were also asked to complete the FFQ for LCS beverages and the DEBQ. They were also asked to provide their age, gender and whether they were currently dieting, and they were fully debriefed at the end of the study.

2.3.4. Data analysis

2.3.4.1. Pre-analysis checks and data preparation

Prior to analysis, participants' responses on each of the attitudes and beliefs associated with LCS beverage consumption questionnaire's items were assigned a value of 1 to 7. The higher score indicated greater positive beliefs in relation to each of the themes, some items were reverse scored so that inter-correlations with other items remained positive. The items were assessed for skewness and kurtosis, and sampling adequacy was checked using the Kaiser–Meyer– Olkin (KMO) statistic. Bartlett's test of sphericity was used to assess whether correlations between items were sufficiently large for principle components analysis (PCA) (values of $P<.05$ indicate sufficient inter-item correlations). Development of the final version of the attitude and beliefs beverage questionnaire is discussed in further detail in the Results section.

2.3.4.2. Questionnaire development and validity

Initial exploratory factor analysis and internal reliability analyses were performed using responses from the main data set (Group 1; N=340). Responses from the separate sample of participants (Group 2; N=289) were used to confirm the factor structure. Internal reliability was performed using responses from group 1 and 2. A subset of participants from group 1 (N=90) who completed the initial questionnaire were emailed and completed the updated version of the attitudes and belief questionnaire to assess the test-retest reliability of the questionnaire.

2.3.4.3. Exploratory factor analysis (Group 1; N=340)

In the initial questionnaire, participants were asked to rate their level of agreement towards each statement regarding LCS beverages using a 7-point Likert scale. Exploratory factor analysis (EFA) was subsequently conducted on the beliefs and attitudes questionnaire to identify subscales on the questionnaire by detecting inter-relationships between the various items. Both parallel analysis (using the Monte Carlo simulation method, Glorfeld, 1995) and a scree-plot (Catell, 1966) were used to identify an initial factor solution and identify the emerging themes. The structure of the scale was explored using principal component analysis using oblique rotation (as factors were expected to correlate with each other, Vogt, 1993). Items were removed if they failed to meet the loading criteria of >.40 (Osbourne & Costello, 2009), or had loadings of > 0.35 on more than one factor. Items that had low item-total correlation (<0.40), were conceptually similar items or did not share a conceptual meaning with the remaining items within that factor (O'Rourke & Hatcher, 2013) were also removed following reliability analysis (Cronbach's alpha).

2.3.4.4. Confirmatory factor analysis (CFA) (Group 2; N=289)

Confirmatory factor analysis (CFA) was conducted to verify the salient factors identified in the EFA. CFA using structural equation modelling [IBM AMOS V24 (Arbuckle, 2016)], was performed on the solution with best fit. Items were free to load onto their corresponding latent factors, and latent factors were free to correlate with each other. Model specifications included correlated factors, uncorrelated error variances, and the variance of the first item on each factor fixed to one. Good model fit was assessed by examining the following indices: normed $\chi2$ statistic ($\chi2$/df) (Ullman, 2001), Goodness of Fit Index (GFI; Bentler, 1990), Comparative Fit Index (Kelloway, 1998), the Root Mean Square Error of Approximation [RMSEA (MacCallum, Browne & Sugawara, 1996)] and Standardized Root Mean Square Residual [SRMR (Hu & Bentler, 1999)]. Normed $\chi2$/df ratios of <2, and GFI and CFI values of above .90, are deemed acceptable (Bentler, 1990; Kelloway, 1998). RMSEA values indicate either good fit (<.05), fair fit (>.05, <.08), mediocre fit (>.08, <.10) or poor fit (>0.10) (MacCallum, Browne and Sugawara, 1996), and SRMR values of <.08 are considered good fit (Hu & Bentler, 1999). Residuals, item–factor loadings, factor variance, item variance, and modification indices (for consideration of potential error co-variances) were also considered when evaluating model fit. Where appropriate, model fit was modified to improve fit by adding covariance pathways between error terms. These were determined following inspection of the modification indices.

2.3.4.5. Internal consistency (Groups 1 and 2)

Cronbach's alpha was used to assess the internal consistency of each subscale. Nunnally and Bernstein (1994) suggests α=.70 as a lower acceptable bound for alpha. Total and subscale scores were computed based on the mean scores for each subscale. All analyses were conducted for groups 1(*N*=340) and 2 (*N*=289) separately.

2.3.4.5 Test–retest reliability (Group 1 subset; N=90)

Using data from group 1 (a subset of participants from group 1 completed the questionnaire twice, 2 weeks apart) test–retest reliability was assessed by examining the intra-class correlation between the questionnaire's total and subscale scores obtained at the initial time of testing and 2-week interval. Scores of .60 or more indicate good test–retest reliability (Cicchetti, 1994).

2.3.4.6 Frequent vs. non-consumers analysis (Group 1 subset; N=211)

As indicated in section 2.3.2.2. participants from group 1 were classified as either frequent consumers (*N*=108) or non-consumers (*N*=103), and all other respondents (*N*=129) were excluded from the sub-analyses pertaining to comparison of frequent versus non-frequent consumers. Differences between frequent and non-frequent consumers of LCS beverages on attitudes and beliefs as well as BMI, body-weight concerns and eating behaviour traits were examined using independent samples t-tests.

2.4. Results

2.4.1. Pre-analysis checks and participant characteristics

Prior to the EFA, skewness values and kurtosis in Group 1 ranged between the desired levels of −2 and 2, thus data did not need to be transformed (Lewis-Beck, Bryman, & Liao, 2004). The Kaiser– Meyer–Olkin statistic for the model was above the acceptable level of .05 (KMO=.94) and Bartlett's test of sphericity was significant (p<.001). Descriptive characteristics of the demographic characteristics for Group 1(N = 340) and Group 2 (N = 289) are presented in Table 2.1.

__Table 2.1.__ Participant Characteristics for Group 1 and Group 2. Values are means with standard deviations in parentheses.

Measure		**Group 1** *Mean (SD)*	**Group 2** *Mean (SD)*
N		340	289
Body weight	BMI (kg/m^2)	24.73(4.22)	25.03(3.99)
Demographics	Age (y)	26.17(8.83)	26.92(9.72)
	Gender (%)	31M 69F	30M 70F
	Smoking (Y/N) %	11Y 89N	11Y 89N
	Dieting (Y/N) %	16Y 84N	22Y 78N
Eating Style	DEBQ-Restraint	3.21(1.05)	2.60 (0.91)
	DEBQ-Emotional Eating	2.78(1.07)	2.49 (0.96)
	DEBQ-External Eating	3.52(0.95)	3.21(0.62)

DEBQ= Dutch Eating Behaviour Questionnaire. Group 1 vs. Group 2. Group 1 completed the initial pool of items designed to measure attitudes and beliefs towards LCS beverages and Group 2 completed the condensed version of the questionnaire for CFA.

2.4.2. Exploratory factor analysis (Group 1; *N*=340)

The parallel analysis and scree-plot initially identified a four-factor solution. However, numerous subsequent PCA with oblique (oblimin) rotations revealed the 4-factor solution was weak (i.e. items had low item-total correlation <.40). A number of items were subsequently removed (as previously described in the data analysis section) identified as unclear or irrelevant, generating a three-factor solution from the remaining 23 items (out of the original 49 items). Factor one comprised of 9 items that referred to positive beliefs surrounding appetite (hunger, cravings) and weight management, e.g. “I believe LCS beverages help me to manage my cravings for sweet foods” and accounted for 55.86% of the total variance. Factor two comprised 6 items that referred to neutral beliefs surrounding LCS beverages having no impact on appetite and weight management, e.g. “I believe LCS beverages have no impact on appetite” and accounted for 16.14%, of the total variance. Factor three comprised of 8 items and referred to palatability, e.g. "I believe LCS beverages taste as good as their sugar alternatives" and accounted for 11.06% of the total variance. Cronbach's alpha revealed high internal consistency for positive beliefs (α=.95), neutral beliefs (α=.85) and palatability and enjoyment scales (α=.94). Factors one, two and three were moderately positively correlated with each other (r=.415, p<.001). Item-factor loadings are available in Appendix C.

A higher score indicated greater beliefs that LCS beverages are beneficial for weight managements, sweetness cravings and palatability in Factors one and three. Higher scores for Factor two indicated stronger beliefs that LCS beverages increased a preference for sweetness, cravings and weight gain. Three items in factor three were reverse scored so that inter-correlations with other items remained positive.

2.4.3. Confirmatory factor analysis (Group 2; *N*=289)

Confirmatory factor analysis was conducted on Group 2 participants to determine how well the data fit the specified three-factor model. Eleven items were free to load onto the latent factor positive beliefs, 6 items were free to load onto the latent factor neutral beliefs, and 8 items were free to load onto the latent factor palatability and enjoyment. The initial model showed poor fit in the sample: (normed $\chi 2$ (χ^2/df) = 5.97 was outside the acceptable range, values of RMSEA (90% CI) = .096 (.089-.104), GFI=.611, CFI=.772, SRMR=.1038 were all outside desirable levels. Therefore, in an attempt to improve model fit, seven error co-variances were added based on examination of modification indices (Figure 2.1.), items with the lowest factor loadings were removed and fit indices were re-examined. Removing low loading items resulted in the neutral beliefs factor being removed. Following its removal, a two-factor model emerged; Factor one (appetite concerns and weight management; 7 items) and Factor two (palatability and enjoyment; 7 items) provided an overall good fit to the data, with the fit criteria falling within the acceptable to desirable range (normed $\chi 2$ ($\chi 2$/df)=1.48, GFI=.952, RMSEA (90% CI)=.041 (.023–.057), CFI=.991, SRMR=.044). Standardized factor loadings indicated that all items appropriately reflected their underlying latent variable (p<.001). The full 14-item questionnaire and scoring instructions are provided in Appendix D.

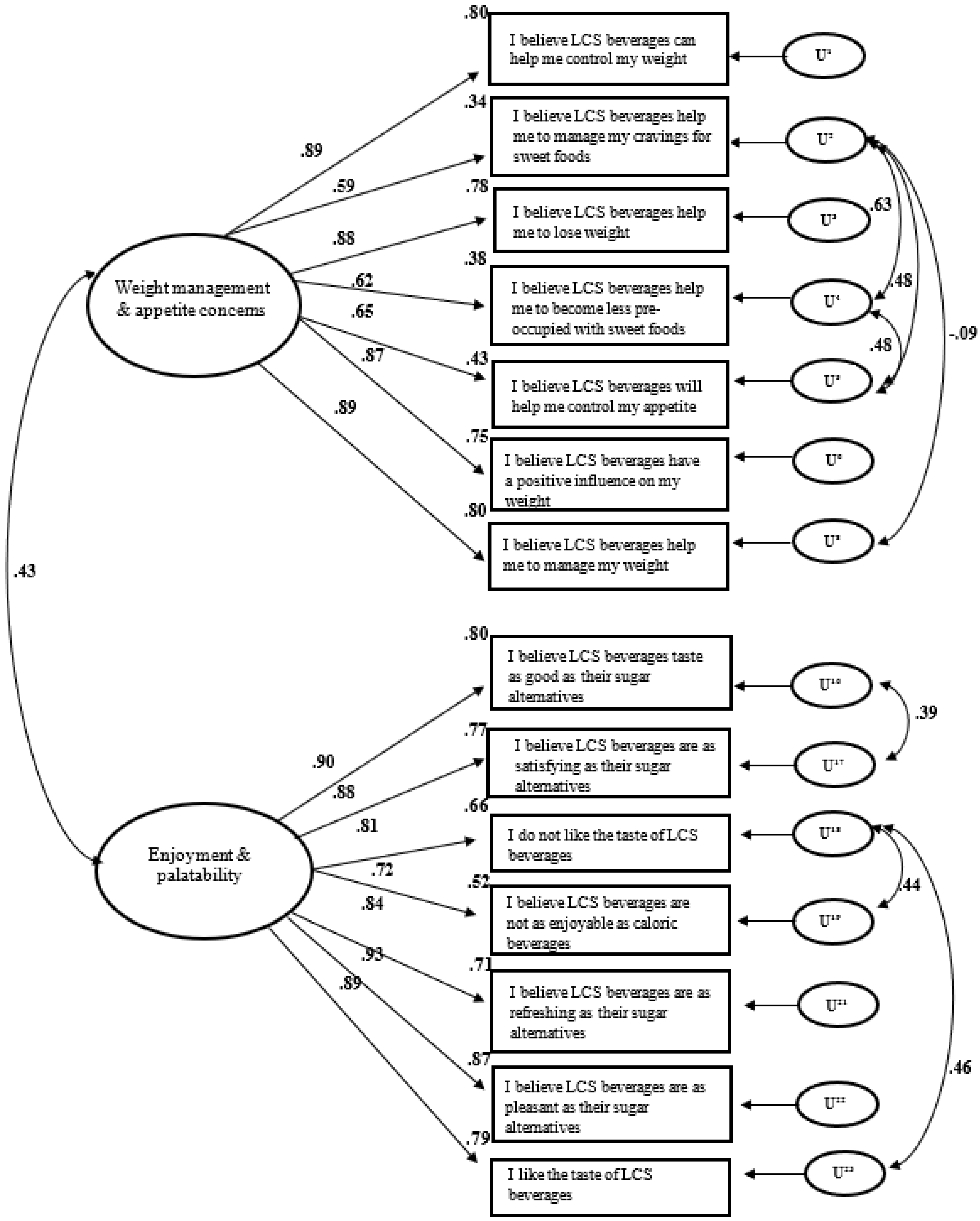

Figure 2.1. Factor model of questionnaire with standardized factor loadings (i.e. values corresponding to one-way arrows), error terms (circled values), and covariance's (values corresponding to two-way arrows).

2.4.4. Internal consistency (Group 1 and 2)

Cronbach's alpha was used to assess the internal consistency of each subscale. For group 1, both subscales had high internal reliability: weight management and appetite (α=.96) and enjoyment and palatability scales (α=.95). Similarly, for group 2, reliability estimates revealed high internal consistency for weight management and appetite (α=.92) and enjoyment and palatability scales (α=.95).

2.4.5. Re-test reliability (*N*=90)

Mean scores for group 3 at time 1 (that is, initial testing) and time 2 (following a 2-week interval) are displayed in Table 2.2. The intra-class correlation coefficient revealed good test–retest reliability for the overall questionnaire scores (r = 0.83) and the two subscales (weight management and appetite: r = 0.77; enjoyment and palatability: r = 0.75).

Table 2.2. *Questionnaire total and subscale scores.*

	Group 1 (t^1)	**Group 1 (t^2)**
Overall Questionnaire	4.01 (1.05)	3.75 (0.99)
Weight management and appetite	3.90 (1.37)	3.60 (1.28)
Enjoyment and palatability	4.14 (1.06)	3.90 (1.06)

Subset from Group 1 (*N*=90); t^1 refers to scores obtained at the initial time of testing; t2 refers to scores obtained following a 2-week interval in the group 1 subset. Mean scores range from 1 (minimum) to7 (maximum) for the overall questionnaire, weight management and appetite subscale and enjoyment and palatability subscale. Values are Means (SD).

2.4.6. Comparison of frequent vs. non-consumers of LCS beverages (Group 1 subset; *N*=211)

Participant characteristics for the two groups are provided in Table 2.3. Frequent consumers of LCS beverages had a significantly higher BMI and self-reported dieting status compared to the non-consumers (please see Appendix E for frequent and non-consumers' beverage volume intake of LCS beverages, SSB, and water). Chi-square tests revealed there was no significant relationship between LCS beverage use and gender and smoking status, (*ps*>.083). However, there was a significant difference in dieting status between the groups, with frequent consumers containing significantly more dieters $x^2(1) = 21.29$, $p=.001$ compared to non-consumers. Independent t-tests revealed that frequent consumers had significantly higher dietary restraint, drive for thinness and body dissatisfaction compared to non-consumers. Non-consumers had significant higher levels of external eating ($p<.001$) relative to frequent consumers. Non-consumers also scored significantly higher on the EDI perfectionism scale ($p=.008$) compared to frequent consumers, however this was no longer significant following Bonferroni adjustments (see Table 2.3.).

Frequent consumers had significantly higher beliefs that LCS beverages were beneficial for weight management and appetite concerns compared to non-consumers ($p<.001$). Frequent consumers also had significantly greater beliefs that LCS beverages were palatable and enjoyable compared to non-consumers ($p<.001$) (see Appendix F for qualitative results). All *p*-values were corrected for Bonferroni adjustments.

Table 2.3. *Descriptive characteristics, eating styles and weight concerns for frequent and non-consumers of LCS beverages respectively. Values are Mean and SDs.*

Measure		**Frequent consumers of LCS Beverages** *Mean (SD)*	**Non-consumers of LCS Beverages** *Mean (SD)*	***p***
N		108	103	
Body weight	BMI (kg/m^2)	28.07(4.27)	23.19(3.12)	.001
Demographics	Age (y)	26.69(7.59)	26.85(10.47)	.899
Chi-square	Gender %	24M 76F	35M 65F	.083
	Smoking (Y/N) %	8Y 92N	6Y 94N	.479
	Dieting (Y/N) %	35Y 65N	8Y 91N	.001
Eating Style	DEBQ-Restraint	3.52(0.82)	2.91(1.17)	.001
	DEBQ-Emotional Eating	2.66(1.14)	2.79(1.07)	.413
	DEBQ-External Eating	3.00(1.04)	3.78(0.78)	.001
Body Weight Concerns	EDI- Drive for thinness	4.03(1.17)	2.38(0.97)	.001
	EDI-Body Dissatisfaction	4.35(1.02)	3.64(0.92)	.001
	EDI-Bulimia	1.41(0.56)	1.34(0.52)	.373
	EDI Perfectionism	2.68(0.49)	2.87(0.54)	.008
Attitudes & Beliefs towards LCSB	Weight management & Appetite	5.53(0.87)	2.84(1.18)	.001
	Enjoyment & palatability	4.24(0.79)	3.60(0.67)	.001

DEBQ= Dutch Eating Behaviour Questionnaire. EDI= Eating Disordered Inventory *p<.001, **p<.05 frequent consumers vs. non-consumers.

2.5. Discussion

The primary purpose of the present study was to develop a novel psychometric instrument for assessing LCS beverage consumption motives. The scale comprised of a two-factor scale structure, which was confirmed by a confirmatory factor analysis. Items in factor

1 referred to positive beliefs about LCS beverages on weight management and appetite, whereas factor 2 referred to the enjoyment and palatability of LCS beverages. These subscales demonstrated good internal consistency and good test–retest reliability over a 2-week interval. The subscales provide a unique contribution to explaining the role of attitudes towards LCS beverages in understanding consumer behaviour.

Notably, the two-factor structure of the questionnaire is consistent with the goal-conflict theory of eating (Stroebe et al., 2008), which describes individuals with high dietary restraint struggle with the hedonic enjoyment of eating and their long-term goal of dieting. In line with this theory, the goal of enjoying hedonic foods is reflected by the 'palatability and enjoyment' subscale. This subscale contains items related to the taste and rewarding experience of LCS beverages. In turn, the weight management goal is reflected by the 'appetite and weight concerns' subscale, because it contains items related to control over food cravings and weight. The emergence of these two subscales suggests that weight management along with palatability serve as important motives in determining LCS beverage consumption. We speculated that participants who frequently consume LCS beverages might believe these beverages help satisfy their hedonic desire for sweetness and that this might result in aiding weight management/loss. Drawing on this theory, LCS beverages may thereby provide a way for individuals to reconcile these conflicting goals. Indeed, several items of the questionnaire reflect this (i.e., 'I believe LCS beverages help me to manage my weight' and 'I believe LCS beverages are as satisfying as their sugar alternatives), suggesting that two-factor structure adequately captures both of these goals.

In line with this theory, our results highlight the contrasting differences in beliefs surrounding LCS beverages between frequent and non-consumers. Frequent consumers had higher beliefs that LCS beverages are significantly more palatable and effective in controlling appetite and weight management in comparison to non-consumers of LCS beverages.

Certainly, attitudes and beliefs serve as a fundamental component in predicting behaviour among frequent consumers of LCS beverages (Glasman & Albarracín, 2006; Ajzen & Fishbein, 2005; Kruglanski, & Stroebe, 2005) as predicted by the Theory of Planned Behaviour (Ajzen, 2011). As such, the emergence of these beliefs suggests that weight management in addition to hedonic enjoyment serve as important motives in determining LCS beverage consumption. Thus, from this theoretical perspective, our study increases understanding of the underlying beliefs that are associated with greater LCS consumption. However, additional studies are required to further elucidate the causal role beliefs may play in LCS beverage consumption.

Frequent consumers reported having significantly higher BMI, dietary restraint and significantly higher tendencies towards body dissatisfaction and drive for thinness compared to non-frequent consumers. In contrast, non-consumers reported significantly higher levels of external eating. As previously reported within the literature, high levels of BMI have been associated with frequent consumption of LCS beverages and products (Stellman & Garfinkel, 1986; Parham & Parham, 1980; Appleton & Conner, 2001). Consistent with Appleton and Conner, frequent consumers also had significantly higher dietary restraint, strong concerns about weight and weight-related issues (see also Schoeller, Shay & Kushner, 1997 and Alexander & Tepper, 1995). It therefore seems plausible that some individuals with high BMIs may employ LCS beverages as a way to manage their weight and eating behaviour. Collectively, these findings suggest that LCS beverages may offer a versatile strategy for weight control in individuals who are vulnerable to temptation and struggle with their weight and concerns about their body.

In comparison to other questionnaires used to understand beverage consumption, this novel questionnaire offers a more comprehensive insight into the motives specifically behind LCS beverage consumption. To our knowledge, this research provides the only questionnaire specifically developed to measure attitudes towards LCS beverage intake. Data derived from this tool could potentially contribute to future policies implementing health strategies to reducing sugar consumption.

The results of the present study must nevertheless be interpreted within its limitations. This study applied theory-driven validation techniques of CFA to extend earlier work where the original factor structure was generated using PCA (a data-driven method). The present sample size was sufficient and was based on the frequently cited recommendations that there should be between 5 and 10 observations for each item included in the factor analysis and at least 200 participants in total (Comrey & Lee., 1992; Streiner, 1994). However, the majority of the participants were University educated. Thus, the representativeness of the sample is in somewhat limited and it remains speculative whether we would see similar results in lower sociodemographic groups. A second limitation is that the current study used a cross-sectional design, and thus we were unable to draw conclusions about the causal relationship between scores on the attitudes and beliefs questionnaire, consumption of LCS beverages and BMI. As such, the extent to which the scale is predictive of consumption and prospective weight gain and weight-loss success is an important avenue for future research.

The analyses demonstrated the polarised views that frequent consumers and non-consumers of LCS beverage hold. It is important however, to mention that the sample was predominantly female which could result in some biases. Given that males and females may differ with regards to their motivations behind LCS beverage consumption, further validation of the scale is required within a male population. It is also important to note that measures of height and weight were obtained via self-report. This may have limited the accuracy of the BMI data as individuals tend to overestimate their height and underestimate their weight (Pursey, Burrows, Stanwell & Collins, 2014). Despite this, self-reported height and weight have been found to correlate strongly with measurements obtained by a researcher (Olfert et al., 2018) and thus are thought to provide valid estimates of anthropometric data.

2.6. Conclusion

The present study developed a novel tool to quantify attitudes and beliefs towards LCS beverages with good overall psychometric properties. A two-factor measure was generated - Factor one consisted of items that referred to positive beliefs about LCS beverages with regard to aiding weight management and satisfying cravings, and Factor two referred to palatability and enjoyment of LCS beverages. Frequent consumers of LCS beverages scored significantly higher than non-consumers on both factors. Frequent consumers had higher BMI and also reported higher levels of dietary restraint, drive for thinness and body dissatisfaction. Overall, the findings from the current study demonstrate that hedonic enjoyment and managing cravings and weight concerns are considered to be important factors influencing LCS beverage consumption in frequent consumers. The results provide valuable insight for future marketing and policy strategies aimed at promoting lower consumption of added sugar in the diet.

Chapter 3: Eating simulations in frequent and non-frequent consumers of low-calorie sweetened beverages

3.1. Abstract

Previous studies indicate that an individual's cognitive representation of food plays an important role in motivated behaviour. Specifically, when encountering cues related to attractive foods, individuals simulate the experience of eating these foods (i.e. "eating simulations"). However, understanding how LCS beverages are represented in frequent consumers of these beverages is yet to be empirically investigated. Accordingly, the present study aimed to determine whether eating simulations play a role in the representation of LCS beverages in frequent and non-consumers. It was hypothesised that frequent consumers (but not non-consumers) would generate higher number of eating simulations when describing LCS beverages compared to neutral foods. Furthermore, it was predicted that frequent consumers would generate a similar number of eating simulations for both LCS beverages and tempting foods, while non-consumers would generate more eating simulations for tempting foods compared to neutral foods and LCS beverages. Finally, we explored whether frequent consumers would associate LCS beverages with healthful attributes. A feature-listing task designed to activate eating simulations was used, and responses of participants who were frequent (N=30) and non-consumers (N=30) of LCS beverages were compared. Participants listed as many adjectives they could think of for words relating to tempting foods (e.g. cookies), neutral foods (e.g. rice) and LCS beverages (e.g. Pepsi max). Each of these features was then categorised using a previously developed coding scheme. As predicted, results indicated that frequent consumers produced significantly more eating simulations for LCS beverages compared to neutral foods, but a similar number compared to tempting foods. In contrast, for non-consumers, only tempting foods were strongly represented in terms of eating simulations compared to neutral foods and LCS beverages which were similar to each other. In addition,

LCS beverages were strongly associated with positive health features for frequent consumers but not for non-consumers. These findings suggest that sensory and hedonic experiences and positive health consequences are highly salient factors which may drive consumption of LCS beverages for frequent consumers.

3.2. Introduction

Popularity of LCS beverages is often attributed to their ability to satisfy both thirst and a desire for sweetness without the additional calories (Ventura & Mennella, 2011; Bellisle & Drewnowski, 2007). Consistent with this, findings from Chapter 2 have shown that frequent consumers believe that LCS beverages are both palatable and effective in aiding weight management and satisfying cravings. Despite this, little is known about the psychological processes that motivate these individuals to consume LCS beverages. To understand motivated behaviour for LCS beverages, it is necessary to determine how LCS beverages are represented conceptually (Barsalou, 2008). As discussed in Chapter 1 section 1.2.1, when an individual encounters an image related to a food that they deem attractive, they draw on previous experiences and simulate the experience of eating it and how rewarding it would be to consume (Papies & Barsalou, 2015; Papies, 2013; Stroebe et al., 2013; Kavanagh, et al., 2005). According to the grounded cognition theory, these "eating simulations" are derived from previous perceptual experiences relevant to that object (Barsalou, 2008). As such, if an eating simulation is generated for a particular food item, it reveals the properties most salient to that individual and in this way, uncovers their goals and desire attached to the food. Therefore, understanding how LCS beverages are represented conceptually is likely to provide new insight into eating motivations and behaviour.

Previous research has shown that eating simulations play an important role in theories of goal-directed behaviour (Custers & Aarts, 2010; Papies & Aarts, 2016). Specifically, simulations are generally produced for hedonic food experiences, motivating the individual to consume the food (Papies, & Aarts, 2016; Locher et al., 2005; Lowe & Butryn, 2007). On this basis, we would expect that when frequent consumers encounter LCS beverages, this should act as a cue for retrieving relevant LCS beverage consumptive memories and trigger simulations of previously rewarding experiences, thereby influencing them to consumer LCS beverages. Presently, research on eating simulations and LCS beverages is non-existent. In light of this knowledge gap, applying the grounded cognition theory in terms of LCS beverage consumption would help to understand how frequent consumers classify these beverages and whether they support their eating enjoyment and weight management goals.

To explore eating simulations, a feature-listing task has been shown to be effective in capturing a rich representation of foods (Papies, 2013), which are specific to that individual. Feature-listing is an established and reliable psychological technique used to quantify representations for a range of stimuli (Wu & Barsalou, 2009; Santos Chaigneau, Simmons, & Barsalou, 2011; Yap, Tan, Pexman & Hargreaves, 2011; McRae, Cree, Seidenberg & McNorgan, 2005). Furthermore, because participants are not aware of the construct being measured, it is argued to be an implicit measure (De Houwer & Moors, 2007). Papies (2013) applied this approach to the representation of food. She demonstrated that both hedonic (e.g. delicious) and situation features (e.g. eaten during the summer) were listed more often for tempting foods (e.g. vanilla ice-cream.) compared to neutral foods (e.g. apple). Importantly, features describing the pleasure (i.e., hedonic experience), the background in which the food is eaten (ie., eating situation) in addition to sensory experience (i.e., taste, texture temperature) are all thought to reflect aspects of an eating simulation (Wu & Barsalou, 2009). In contrast, Papies (2013) found that participants situated neutral foods quite differently, describing visual features and features related to the production, and purchase of the food. In addition, Papies (2013) showed that chronic dieters listed fewer eating simulation features towards tempting foods compared to non-dieters. These findings further support the possibility that eating simulations are highly dependent on the eating goals of the individual.

Drawing on the above, the present study explored whether eating simulations play a role in the representation of LCS beverages using a similar approach to Papies (2013). It was hypothesised that frequent consumers (but not non-consumers) would generate a higher number of eating simulations when describing LCS beverages compared to neutral foods (hypothesis 1). Furthermore, it was predicted that frequent consumers would generate a similar number of eating simulations for both LCS beverages and tempting foods, while non-consumers would generate more eating simulations for tempting foods compared to neutral foods and LCS beverages (hypothesis 2). Finally, in contrast to much of the research suggesting that eating simulations are generated for foods categorised as tempting but unhealthy (Papies, 2013; Veling, Aarts & Stroebe, 2012), a further aim was to determine whether frequent consumers associate LCS beverages with healthy attributes.

3.3 Method

3.3.1. Participants

Sixty university staff and students (Mean age 28.43 ± 10.51y) were recruited from the University of Liverpool via poster and online advertisements. Prior to attending the laboratory session, participants were identified and classified as frequent and non-consumers of LCS beverages according to a self-reported online Food Frequency Questionnaire (FFQ) assessing consumption of a range of beverages developed by Appleton and Conner (2001) (see Chapter 2 for details). In addition to being either frequent or non-consumers of LCS beverages, inclusion criteria required that participants were non-smokers, had never been diagnosed with an eating disorder, and were not on any medication known to affect appetite. All participants completed the online screening questionnaire prior to testing to ensure that they meet all inclusion criteria. One-hundred and thirteen participants completed the screening questionnaire, of which seventy-two were eligible to take part. Those respondents who met the study's criteria were invited by e-mail to participate in the study. Sixty-four participants responded, informing us that they were happy to take part. Four participants subsequently withdrew prior to attending the laboratory session.

On the basis of their responses to the screening questionnaire, suitable participants were subsequently classified as frequent (N=30) and non-consumers (N=30) of LCS beverages in a between-subjects design. Ethical approval was granted by the University Research Ethics Committee. All participants attended one laboratory session and gave written consent prior to taking part. The experiment was performed on desktop computers in individual cubicles in the Ingestive Behaviour Laboratory. In exchange for taking part, participants were given a reimbursement of £5 voucher for their time. Alternatively, first year Psychology students were allocated course credits.

3.3.2. Measures

3.3.2.1. Feature-listing task

Following Papies (2013) protocol, participants were asked to list features in relation to 24 words. The critical words consisted of four attractive but unhealthy foods (vanilla ice cream, cookies, crisps and Victoria sponge cake), four neutral, healthy foods (cucumber, banana, apple and rice) and four LCS beverages (Sprite Zero, Diet Coke, Pepsi Max, and Seven-Up free). Words relevant to twelve natural and household objects (butterfly, phone, mattress, gate, bird, elephant, keys, ladybird, window, lamp, spider, and leaves) were also included. The natural/household objects served as fillers to disguise the food-related nature of the task. Each word was presented individually on the computer screen. Participants were given the instructions “In this task you are asked to describe properties that are generally true for that object. Please write at least 5 properties for the object (there is room to add up to 15 properties). Please remember there is no time limit. You can use single words or phrases when listing properties of the object. Before you begin there will be two examples shown”. The first example was the word "*stone*" with the features "heavy, round, cold, grey, can be thrown"; the second example was sponge with the features "yellow, light, rough, handy for doing the dishes" provided. Participants were requested to type their responses into a text box below the word being presented. They were encouraged to respond spontaneously, and to generate features that initially came to mind and are typically true for each word. The order of presentation of the word stimuli was randomised for each participant (see Appendix G for details of feature-listing task).

3.3.2.2. Feature coding scheme

A coding system based on work of Papies (2013) and Wu and Barsalou (2009) was used to code the features that participants generated in the feature-listing task. The features were subsequently divided into specific categories, as described below, see Figure 3.1.

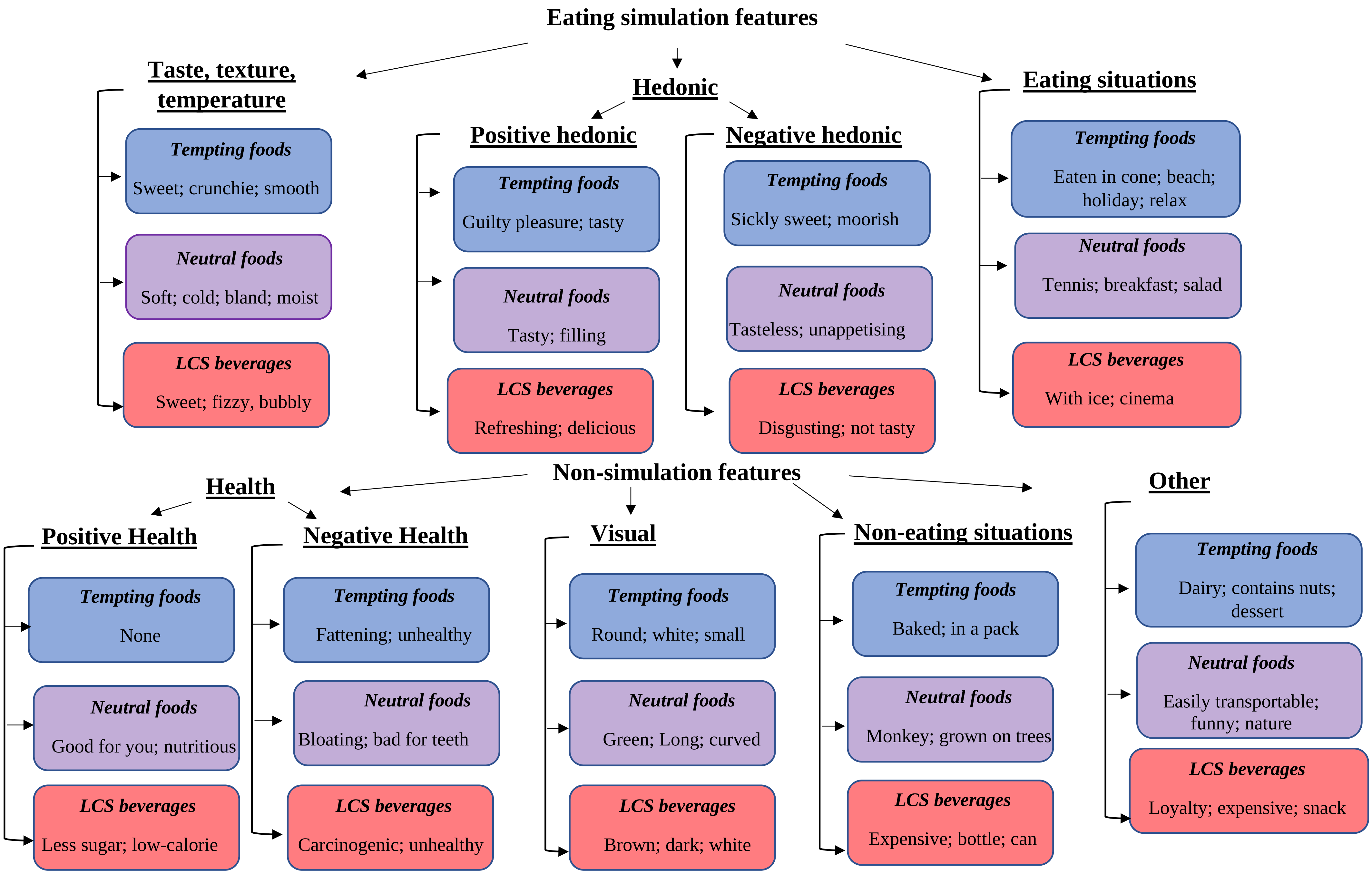

Figure 3.1. Coding scheme and examples of eating and non-simulation features for tempting foods, neutral foods and LCS beverages.

3.3.2.2.1. Eating simulation features

Taste, texture and temperature: Features were coded as taste, texture and temperature, if they referred to food as sweet, crunchy or hot when eating the food (taste, texture and temperature, respectively).

Eating Situations: A feature was coded as a situation feature if it described an aspect of a situation that involves eating the food. Examples include a specific time (e.g., “afternoon”), place (e.g., “couch”), or event (e.g., “dinner party”) where the food is eaten; a specific action (e.g., “chewing”) or manner of eating (e.g., “on a stick,” “from the bag”); an object or utensil used in an eating situation (e.g., “cup,” “bowl”); another food that you eat with the critical food (e.g., “goes well with chicken”); a specific form that the food can take (e.g., “apple tart”); a prepared dish in which you typically find the food (e.g., “lasagne,” “salad”); or a person in an eating situation (e.g., “kids”). To sum up, features were coded as a situation features if they refer to when, where, and how one consumes the food, what accompanies it when eaten and who eats it.

Hedonic features: Features were coded as “hedonic” if they described the pleasurable or unpleasant eating sensations they experienced when eating the food item (e.g., “tasty,” “delicious,” “disgusting”). This category included both positive and negative features. Within the hedonic category, features were coded in two subcategories as either hedonic positive or hedonic negative.

3.3.2.2.2. Non-simulation features

Positive and negative health features: A feature was coded as a health feature if it referred to the health implications of eating a food, or to the food generally being healthy or unhealthy. Examples of features coded for healthy are “healthy,” “nutritious,” or “vitamins.” Examples of features coded for unhealthy are “unhealthy,” or “bad for your skin.” This enabled us to determine if LCS beverages differed between groups in their perceived healthiness.

Visual features: A feature was coded in this category if it referred to a visible aspect of a food object. This included the colour of the food (e.g., "orange"), the form it comes in (e.g., "grains"), the shape of an individual item (e.g., "round"), visible parts on the outside (e.g., "peel"), or visible parts on the inside (e.g., "seeds") of a food.

Non-eating situations: A feature was coded in this category if it referred to a situation that did not involve eating a food. These features referred to how the food is produced (e.g., "from the oven"), how it is grown ("from a tree"), where it is purchased (e.g., "butchers"), how it is stored ("jar," "tin"), as well as necessary procedures or ingredients prior to eating the food ("baking"). A feature was also coded into this category if it referred to a non-human agent eating the food (e.g., "monkey" for banana). Features that refer to the temperature or the texture of a food but that are not experienced when eating the food, but that are experienced on other occasions (e.g., during storage or transport) was also coded as non-eating situation features (e.g., "break easily").

Other features: All other features were coded to this category. These included category words (e.g., "vegetables," "fruit"), ingredients that the food contains (e.g., "eggs"), products that can be derived from the food (e.g., "juice"), or other features that could not otherwise be categorised (e.g., "snow white").

3.3.2.2.3. Calculating proportions of feature type

The proportion of features that a participant produced in a specific coding category for a given food was determined by dividing the number of features in the coding category by the total number of features for the food (e.g., if a participant described crisps using 7 features in total and 3 of these were hedonic; to determine the proportion of hedonic features, we would divide 3 by 7 (=.4285) and multiply this by 100 to get a percentage). These proportions were then averaged across the four tempting and the four neutral foods, and four LCS beverages separately, for each participant. This procedure was followed for all feature types. The proportion of eating simulation features was calculated per participant by adding the proportions of taste, texture, and temperature features, eating situation features, and hedonic features. The proportion of other features was similarly calculated by summing the proportions of the remaining four feature types (visual, non-eating situations, health, and other).

3.3.2.3. Appetite ratings

Levels of hunger were assessed using 100mm Visual Analogue Scales (VAS). Each scale was anchored by ‘Not at all’ on the left and ‘Extremely’ on the right.

Desire to eat. Current desire to eat for each of the sixteen critical food items (used in the feature-listing task) in addition to 25 other foods fillers were measured. For example, participants were asked “Would you like to have a slice of Victoria sponge cake right now?” and indicated their response by ticking “Yes or “No”. The total number of foods they currently desire to eat within each food group were then combined (ie., tempting, neutral and LCS beverages).

3.3.2.4. Questionnaires

The following questionnaires were used to provide descriptive information between the two groups.

The Dutch Eating Behaviour Questionnaire: (DEBQ; van Strien et al., 1986) was used to measure restraint, emotional and external eating (as previously described in Chapter 2). The Cronbach’s Alphas for restrained eating, emotional and external eating in the current study were .86, .81 and .78 respectively.

The Perceived self-regulatory success in dieting questionnaire: (PSRS; Fishbach et al., 2003) was administered to measure dieting success in order to determine whether frequent consumers were more successful at managing their weight relative to the non-consumers. Participants rated how successful they are in watching their weight or losing weight and how difficult it is for them to stay in shape using the perceived self-regulatory success in dieting questionnaire on 7-point scales. The Cronbach's Alpha for dieting success was .78.

3.3.3. Procedure

Testing took place in the Department of Psychological Sciences on the University of Liverpool campus. Participants attended one session, 30 minutes long; all sessions were conducted between 12-6pm. Informed consent was obtained upon arrival and participants completed their first Visual analogue scale (VAS) measure for hunger (to control for hunger). Participants then completed the feature-listing task (following the protocol of Papies, 2013). Following this, participants completed a second VAS measure of hunger, current desire to eat (including critical food items from the task) in response to a selection of foods, in addition to the behavioural questionnaires (DEBQ, PSRS). To ensure the absence of demand characteristics, participants were asked to indicate what they thought the aims of the study were. Participants' height and weight was taken before being debriefed.

3.3.4. Data analysis

Main analyses were conducted on proportions of features generated for the relevant feature type, and mean percentages for ease of interpretation.

3.3.4.1. Critical analysis

3.3.4.1.1. Eating simulation features (Hypotheses 1 & 2)

Our first hypothesis predicted that frequent consumers (but not non-consumers) would generate a higher number of eating simulations when describing LCS beverages compared to neutral foods. For our second hypothesis, it was predicted that frequent consumers would generate a similar number of eating simulations for both LCS beverages and tempting foods, while non-consumers would generate more eating simulations for tempting foods compared to both neutral foods and LCS beverages. To determine the differences in proportions of eating simulations generated between consumers groups and within each group, a two-way mixed

ANOVA was conducted on proportions of eating simulation features as the dependent variable, with group (frequent consumers vs. non-consumers) as the between-subjects factor and food type (LCS beverages vs. tempting vs. neutral) as the within-subjects factor.

3.3.4.1.2. Non-simulation features

To explore the individual and group differences in proportions of non-simulation features, a two-way mixed ANOVA was conducted on proportions of non-simulation features with group (frequent consumers vs. non-consumers) as the between-subjects factor and food type (LCS beverages vs. tempting vs. neutral) as the within-subjects factor.

3.3.4.2. Additional analysis

3.3.4.2.1. Eating simulation feature type

To further explore differences for individual eating simulation feature-types, a three-way mixed ANOVA was carried out with consumer group (frequent consumers vs. non-consumers) as the between-subjects factor, and food type (LCS beverages vs. hedonic vs. neutral) and feature-type (taste/texture/temperature vs. eating situation vs. hedonic) as the within-subjects factors. The dependent factor was the proportion of features generated. A significant 3-way interaction was followed up with contrasts for each feature-type separately.

3.3.4.2.2. Health Features

A further aim of the study was to investigate the effect of consumer groups and, within each group, whether there were any differences on the number of positive and negative health features generated for tempting, neutral and LCS beverages. To determine this, a 3-way mixed ANOVA was conducted with group (frequent consumers vs. non-consumers) as the between-subjects factor, food type and health feature type (i.e. positive vs. negative) as within-subjects factors and proportion of health feature types as the dependent factor.

3.3.4.3. Supplementary analysis

3.3.4.2.3. Hunger

Hunger ratings were analysed using 2 x 2 mixed design factorial ANOVA. Time (before and after the feature-listing task) was the within-subjects factor, and consumer group (frequent consumers vs. non-consumers) was the between-subjects factor.

Desire to eat. To explore whether frequent consumers and non-consumers differed in terms of the number of food and beverages they currently desire to eat, the total number of foods they currently desire to eat within each food group were combined (i.e., tempting, neutral and LCS beverages). A two-way mixed ANOVA was conducted with consumer group (frequent vs. non-consumer) as the between-subjects factor and food type (tempting vs. LCS beverages vs. neutral foods) as the within-subjects factor and number of foods they desire to eat as the dependent factor.

3.4. Results

3.4.1. Participant characteristics

Participant characteristics of both groups are presented in Table 3.1. Independent samples t-tests confirmed that frequent consumers had significantly higher BMI, higher restraint, and lower dieting success relative to non-consumers. There were no significant differences between consumer groups on remaining characteristics, (*ps*>. 085). A chi-squared test showed that there were no significant differences in the number of males and females between groups, $\chi^2(1) = .480$, $p=.488$.

Table 3.1. *Descriptive statistics of each group. Values are means with standard deviations in parentheses.*

Variable	Frequent consumers of LCS beverages (n=30)	Non-consumers of LCS beverages (n=30)
Age (y)	30.07 (12.30)	26.80(8.26)
BMI(kg/m^2)	27.16(3.72)	22.87(2.77)*
DEBQ		
Restraint	3.46(.56)	2.85(.75)**
Emotional	2.91(.77)	2.61(.66)
External	3.13(.37)	3.31(.42)
PSRS		
Dieting success	3.90(1.32)	4.61(1.07)**
Chi-square		
Gender %	13M 87F	20M 80F

DEBQ= Dutch Eating Behaviour Questionnaire. PSRS= Perceived self-regulatory success in dieting questionnaire. *p<.001, **p<.05. Frequent consumers vs. non-consumers.

3.4.2. Overall number of features generated

Participants produced on average 5.40 (SE =0.10) features per food word, this is slightly more than Papies' (2013) 5.16 features. To determine whether frequent consumers differed from non-consumers in terms of the overall number of features generated for foods, a two-way mixed ANOVA was conducted with group as the between-subjects factor and food-type (tempting, LCS beverages and neutral foods) as the within-subjects factor and number of features as the dependent factor. There was no group x food-type interaction, $F(2,116)=1.51$, $p=.225$, $\eta_p^2=.03$ and no main effect of group, $F(1,58)=.42$, $p=.518$, $\eta_p^2<.01$. There was, however a main effect of food-type, $F(2,116)=5.94$, $p=.003$, $\eta_p^2=.09$, participants produced more features for neutral foods (5.60; SE =1.15) compared to tempting foods $t(59)=2.16$, $p=.035$, $d=$ 0.28 (5.38; SE =0.56) and LCS beverages $t(59)=2.84$, $p=.006$, $d=$ 0.37(5.33; SE =0.56). There was no difference in the number of features produced between tempting foods and LCS beverages (p=.224). This analysis thus indicates that frequent and non-consumers generated a similar number of features for tempting foods, LCS beverages and neutral foods.

3.4.3. Critical analysis

3.4.4. Eating simulation features

The two-way mixed ANOVA revealed a main effect of consumer group, $F(1,58)=22.81$, $p<.001$, $\eta_p^2=.28$ and a main effect of food type on the proportion of eating simulation features, $F(2,116)=78.35$, $p<.001$, $\eta_p^2=.58$. There was also a consumer group x food type interaction, $F(2,116)=18.92$, $p<.001$, $\eta_p^2=.25$. Post hoc independent t-tests confirmed that there was no difference between frequent and non-consumers on proportion of eating simulations for tempting foods (freq. consumers: M=62%, SD=3%; non-consumers M=56%, SD=3%) or for neutral foods (freq. consumers: M=29%, SD=3%; non-consumers M=27%, SD=2%), both *Fs* < 1.426, both *ps*>.159. However, frequent consumers generated significantly more eating simulations for LCS beverages (M=55%, SD=3%) compared to non-consumers (M=24%, SD=3%), $t(58)= 7.44$, $p<.001$, $d=1.88$, see Figure 3.2.

Paired-t-tests showed that, consistent with our first hypothesis, frequent consumers generated a significantly higher proportion of eating simulation features for LCS beverages (M=55%, SE=3%) compared to neutral foods (M = 29%, SE = 3%), $t(29)= 6.31$, $p<.001$, $d= 1.15$. Consistent with our second hypothesis, frequent consumers generated a similar amount of eating simulations for LCS beverages (M = 55%, SE = 3%) and tempting foods, (M = 62%, SE = 3%), $t(29)=1.91$, $p=.066$, $d=0.35$. Frequent consumers also generated a significantly higher proportion of eating simulations for tempting foods (M = 62%, SE = 3%) relative to neutral foods (M = 29%, SE = 3%), $t(29)=11.29$, $p<.001$, $d=1.82$.

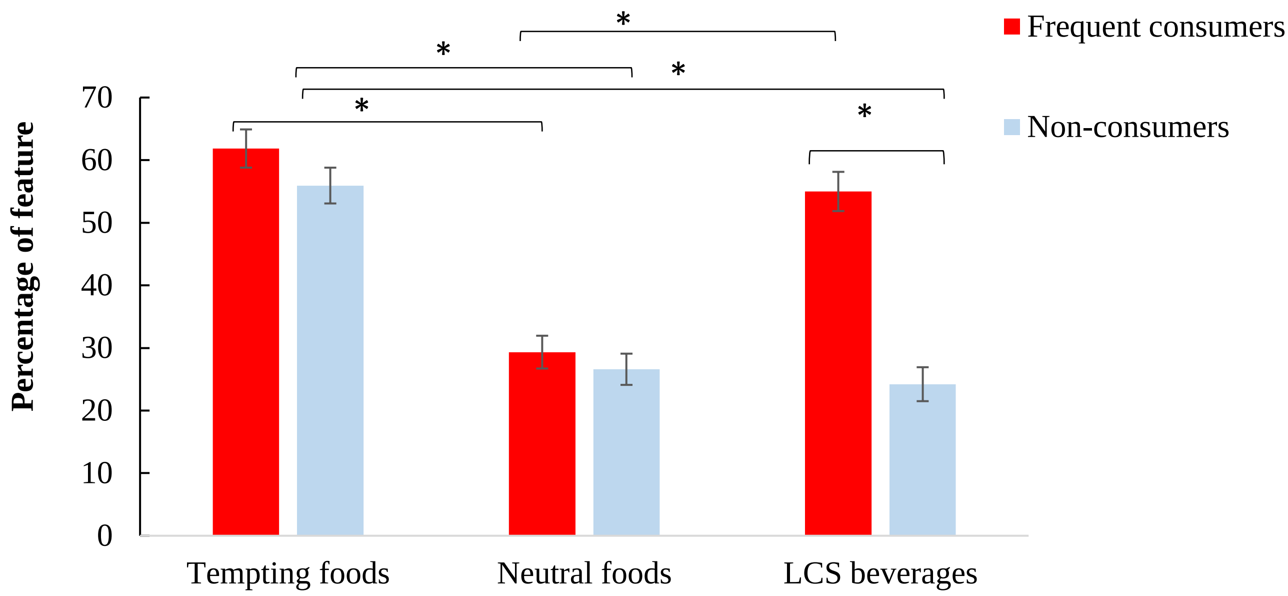

Figure 3.2. Percentages of eating simulations generated for tempting, neutral foods and LCS beverages for frequent and non-consumers. Values are means and standard errors of the mean. *p<.001.

In contrast, paired t-tests revealed that non-consumers produced a similar proportion of eating simulations for both LCS beverages (M= 24%, SE= 3%) and neutral foods (M= 27%, SE= 2%), $t(29)=1.91$, $p=.510$, $d= 0.12$, see Figure 3.2. Additionally, non-consumers generated significantly more proportions of eating simulations for tempting foods (M=56%, SE= 3%) relative to both LCS beverages (M=24%, SE=3%), $t(29)=9.38$, $p<.001$, $d=1.71$ and neutral foods (M =27%, SE= 2%), $t(29)= 8.13$, $p<.001$, $d=1.45$.

3.4.5. Non-simulation features

Analysis revealed a main effect of consumer group, $F(1,58)=22.13$, $p<.001$, $\eta_p^2=.28$, main effect of food type, $F(2,116)=80.34$, $p<.001$, $\eta_p^2 =.58$ and a consumer group x food type interaction on the proportion of non-simulation features, $F(2,116)=19.96$, $p<.001$, $\eta_p^2=.26$. Post-hoc independent t-tests revealed that non-consumers generated a higher proportion of non-simulation features for LCS beverages (M = 76%, SE = 3%) see Figure 3.3, compared to frequent consumers (M = 45%, SE = 3%), $t(29)=7.23$, $p<.001$, $d=1.86$. However, there was no difference between frequent and non-consumers on the proportion of non-simulation features generated for tempting (freq. consumers: M=38%, SD=3%; non-consumers: M=44%, SD=3%) or neutral foods (freq. consumers: M=71%, SD=2%; non-consumers: M=73%, SD=2%), both $Fs<1.44$, both $ps>.154$.

Paired t-tests revealed that frequent consumers generated a significantly higher proportion of non-simulation features for neutral foods (M=71%, SE = 3%) compared to tempting foods (M = 38%, SE = 3%), $t(29)= 12.05$, $p<.001$, $d=2.20$ and LCS beverages, (M =45%, SE=3%), $t(29)=7.16$, $p<.001$, $d=1.31$. There was no difference in the proportion of non-simulation features generated for tempting (M= 38%, SE = 3%) and LCS beverages (M = 45%, SE = 3%) for frequent consumers, $t(29)=7.16$, $p=.054$, $d=0.34$.

For non-consumers, paired t-tests revealed a similar proportion of non-simulation features for LCS beverages (M= 76%, SE= 3%) and neutral foods (M=73%, SE=2%), $t(29)=.826$, $p=.416$, $d= 0.17$. They generated a higher proportion of non-simulations for LCS beverages, $t(29)=9.12$, $p<.001$, $d=1.66$ and neutral foods, $t(29)=8.05$, $p<.001$, $d=1.45$ compared to tempting foods (M = 44%, SE = 3%), see Figure 3.3.

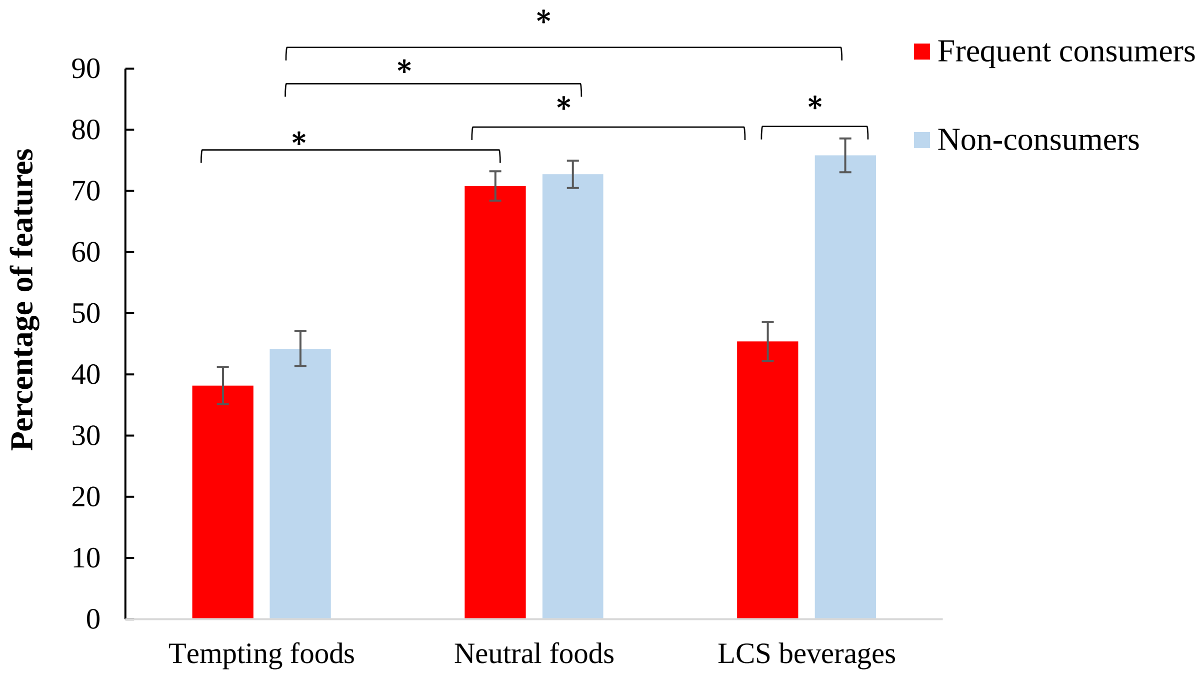

Figure 3.3. Percentages of non-simulations generated for tempting, neutral foods and LCS beverages for frequent and non-consumers. Values are means and standard errors of the mean. *p<.001.

3.4.4. Additional analysis

3.4.4.1. Eating simulation feature type (see Figure 3.4.)

To look at eating simulations in more detail (i.e., taste/texture/temperature vs. eating situation vs. hedonic), a three-way mixed ANOVA was conducted to look at the proportion of specific eating simulations features generated for each food type between frequent and non-consumers. Analysis revealed a main effect of feature type, $F(2,116)=30.41$, $p<.001$, $\eta_p^2=.34$, but no consumer group x feature type interaction, $F(2,116)=.915$, $p=.404$, $\eta_p^2=.02$. There was, however, a food type x feature type interaction. $F(4,232)=21.86$, $p<.001$, $\eta_p^2=.27$ and a consumer group x food type x feature type interaction, $F(4,232)=8.20$, $p<.001$, $\eta_p^2=.12$.

To further decompose this interaction, two-way mixed ANOVAs were conducted for frequent and non-consumers separately, each with food type (LCS beverages vs. tempting vs. neutral) and specific feature type (taste/texture/temperature vs. eating situation vs. hedonic) as the within-subjects factors. For frequent consumers, there was a main effect of food type,

$F(2,58)=46.61$, $p<.001$, $\eta_p^2=.62$, a main effect of feature type, $F(2,58)=14.75$, $p<.001$, $\eta_p^2=.34$ and a food type x feature type interaction, $F(4,116)=7.38$, $p<.001$, $\eta_p^2=.20$. Similarly, for non-consumers, there was a main effect of food type, $F(2,58)=50.71$, $p<.001$, $\eta_p^2=.64$, feature type, $F(2,58)=17.10$, $p<.001$, $\eta_p^2=.37$ and a food type x feature type interaction, $F(4,116)=26.48$, $p<.001$, $\eta_p^2=.48$.

In light of this, the effect of food type was analysed in a series of repeated measures ANOVAs for each specific eating simulation feature (i.e., taste/texture/temp, eating situation and hedonic) separately, first in frequent consumers and then in non-consumers.

3.4.4.1.1. Taste/texture/Temperature

In frequent consumers, there was a main effect of food type for the proportion of taste/texture/temp features, $F(2,58)=30.13$, $p<.001$, $\eta_p^2=.51$. Paired t-tests revealed that frequent consumers were more likely to describe both tempting foods, $t(29)=7.84$, $p<.001$, $d=1.57$ and LCS beverages, $t(29)=6.14$, $p<.001$, $d=1.25$ using taste/texture/temp features compared to neutral foods. There was no significance difference in the proportion of taste/texture/temp features between tempting food and LCS beverages, $t(29)=.762$, $p=.452$, $d=0.12$ (see Figure 3.4., panel A).

In non-consumers, there was also a main effect of food type, $F(2,58)=63.76$, $p<.001$, $\eta_p^2=.69$. However, in contrast to frequent consumers, non-consumers were more likely to describe tempting foods using taste/texture/temp features compared to both LCS beverages and neutral foods, $t(29)=9.77$, $p<.001$, $d=2.14$ and $t(29)=9.07$, $p<.001$, $d=2.37$, respectively (see Figure 3.4., panel B). Additionally, there was no difference in the proportion of taste/texture/temp features between LCS beverages and neutral foods, $t(29)=1.11$, $p=.278$, $d=0.31$.

3.4.4.1.2. Eating situations

There was no main effect of food type for the proportions of eating situation features for frequent consumers; they generated a similar number of eating situations features for LCS beverages, tempting and neutral foods $F(2,58)=1.66$, $p=.198$, $\eta_p^2=.05$, (see Figure 3.4., panel A).

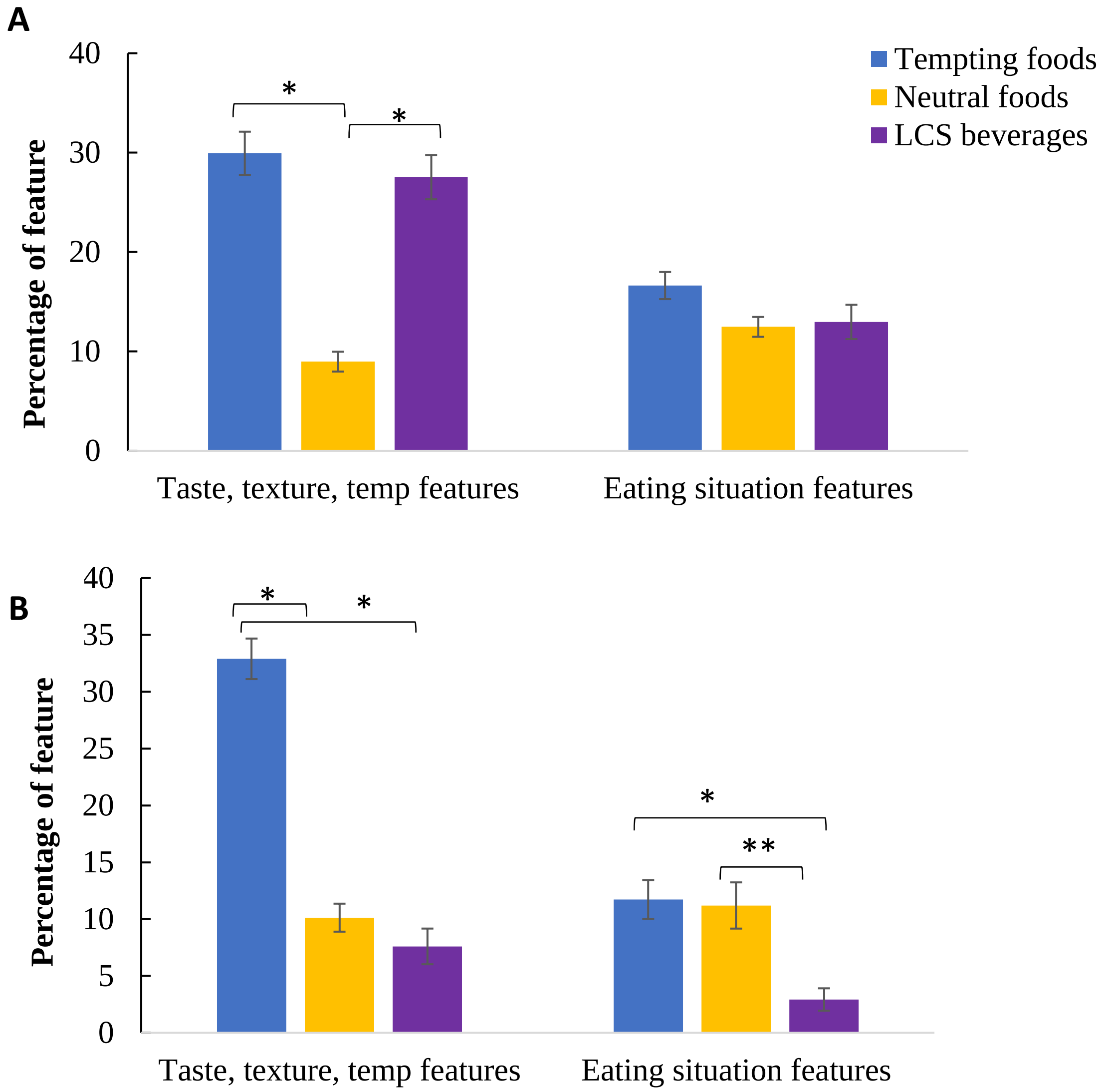

Figure 3.4. Percentages of taste, texture, temperature and eating situation features generated for tempting, neutral foods and LCS beverages for frequent (Panel A) and non-consumers (Panel B). Values are means and standard errors of the mean. *$p<.001$, **$p<.05$.

In contrast, for non-consumers, there was a main effect of food type, $F(2,58)=12.42$, $p<.001$, $\eta_p^2=.30$. Non-consumers were more likely to describe tempting foods and neutral foods using an eating situation feature compared to LCS beverages, $t(29)=5.47$, $p<.001$, $d=1.02$ and $t(29)=3.78$, $p=.001$, $d=0.68$, respectively, (see Figure 3.4., panel B). There was no difference between neutral and tempting foods $t(29)=.255$, $p=.801$, $d= 0.05$.

3.4.4.1.3. Hedonic features

There was a main effect of food type for the proportion of hedonic features, $F(2,58)=7.73$, $p<.001$, $\eta_p^2 =.21$. Frequent consumers generated a higher proportion of hedonic features for both tempting foods $t(29)=4.25$, $p<.001$, $d=0.58$ and LCS beverages $t(29)= 3.24$, $p=.003$, $d=0.57$ compared to neutral foods. There was no difference between LCS beverages and tempting foods types, $t(29)=.184$, $p=.855$, $d=0.03$.

For non-consumers there was a main effect of food type, $F(2,58)=8.91$, $p<.001$, $\eta_p^2 =.24$. Non-consumers were more likely to describe tempting foods using hedonic features compared to neutral foods, $t(29)=3.72$, $p=.001$, $d=0.52$. They also generated more hedonic features for LCS beverages compared to neutral foods, $t(29)=4.19$, $p<.001$, $d=0.65$. There was no difference in the proportion of hedonic features for tempting and LCS beverages, $t(29)=.975$, $p=.338$, $d=0.17$.

Hedonic positive and negative features. To explore the hedonic features further, they were split into positive and negative hedonic features. For frequent and non-consumers separately, a two-way repeated measures ANOVA was conducted, with hedonic feature (positive and negative) and food type (tempting vs. LCS beverages vs. neutral) as the within-subject factors.

For frequent consumers, analysis revealed a main effect of food type for the proportion of hedonic features, $F(2,58)=7.73$, $p=.001$, $\eta_p^2=.21$, main effect of hedonic feature $F(2,58)=90.69$, $p<.001$, $\eta_p^2 =.76$ and food type x hedonic feature interaction, $F(2,58)=7.19$, $p=.002$, $\eta_p^2 =.20$. Paired t-tests revealed that frequent consumers generated a higher proportion of positive hedonic features for both tempting foods $t(29)=4.14$, $p<.001$, $d=0.76$ and LCS beverages $t(29)=3.14$, $p=.004$, $d=0.58$ compared to neutral foods. There was no difference in proportion of positive features generated for tempting foods and beverages, $t(29)=.429$, $p=.671$, $d=0.08$, see Figure 3.5., panel A. There was no difference in the proportion of negative hedonic features for tempting, neutral and LCS beverages, all $Fs<. 1.295$, all $ps>.205$.

For non-consumers there was a main effect of food type, $F(2,58)=8.91$, $p<.001$, $\eta_p^2=.24$, but no main effect of hedonic feature ($p=.093$).There was a food type x hedonic feature interaction, $F(2,58)=31.29$, $p<.001$, $\eta_p^2=.51$. Non-consumers were more likely to describe tempting foods using positive hedonic features compared to neutral foods, $t(29)=3.32$, $p=.002$, $d=0.61$ and LCS beverages $t(29)=5.10$, $p<.001$, $d=0.93$. Furthermore, they generated a higher number of proportions of positive hedonic features for neutral food compared to LCS beverages, $t(29)=3.33$, $p=.002$, $d=0.61$ see Figure 3.5., panel B. They also generated a higher proportion of negative hedonic features for LCS beverages compared to neutral foods, $t(29)=5.32$, $p<.001$, $d=0.53$ and tempting foods, $t(29)=5.26$, $p<.001$, $d=0.51$.There was no difference in the proportion of negative hedonic features between tempting and neutral foods, ($p=.161$).

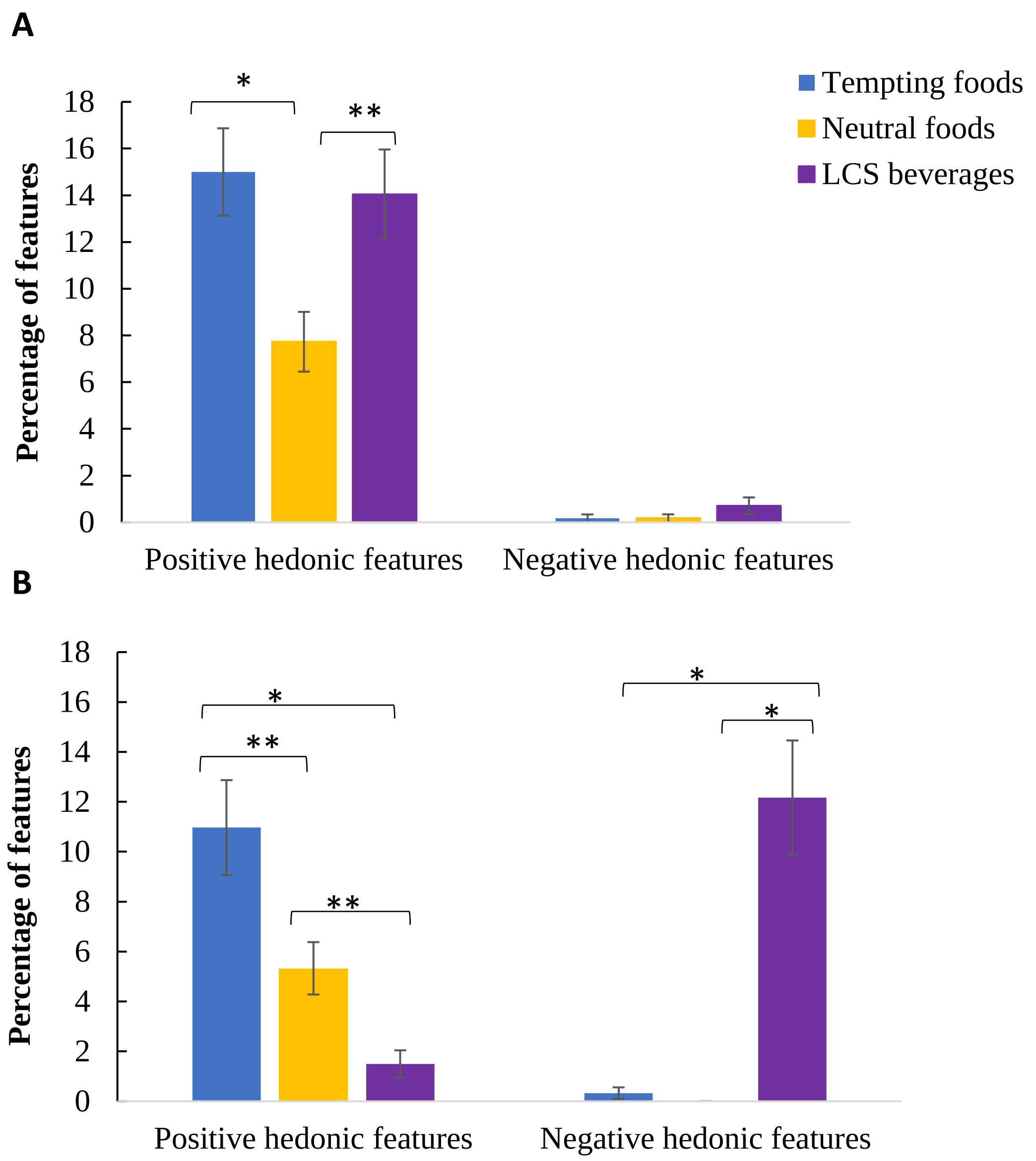

Figure 3.5. Percentages of positive and negative hedonic features generated for tempting, neutral food and LCS beverages between frequent (Panel A) and non-consumers (Panel B). Values are means and standard errors of the mean. **p*<.001, ***p*<.05.

3.4.4.2. Positive and negative health features

Health features were stratified as positive and negative features and the number of positive and negative health features generated for the different food groups was compared between frequent and non-frequent consumers in a 3-way mixed ANOVA (with consumer group as the between-subjects factor, and food type and health feature type (i.e. positive vs. negative) as within-subjects factors). There was no main effect of group or health feature type (*ps*>.319). There was however, a main effect of food type, $F(2,116)=30.08$, $p=.001$, $\eta_p^2=.34$, a food type x group interaction, $F(2,116)=4.07$, $p=.022$, $\eta_p^2=.06$, a food type x health feature interaction, $F(1.74,100.66)=61.63$, $p=.001$, $\eta_p^2=.52$ and a consumer group x food type x health feature interaction, $F(1.74,100.66)=35.72$, $p<.001$, $\eta_p^2=.38$.

Exploring this further, a repeated measures ANOVA was conducted, separately for frequent and non-consumers, to look at the effect of health feature type (positive and negative) on the different food types (LCS beverages vs. hedonic vs. neutral). For frequent consumers, analysis revealed a main effect of health feature type, $F(2,58)=40.32$, $p<.001$, $\eta_p^2=.58$, a main effect of food type, $F(1,29)=13.17$, $p<.001$, $\eta_p^2=.31$, and a health feature x food type interaction, $F(2,58)=34.34$, $p<.001$, $\eta_p^2=.54$. Similarly, for non-consumers, there was a main effect of health feature type, $F(1,29)=27.68$, $p<.001$, $\eta_p^2=.49$ and food type, $F(2,58)=20.10$, $p<.001$, $\eta_p^2=.41$, and a health feature x food type interaction, $F(2,58)=66.28$, $p<.001$, $\eta_p^2=.70$.

To explore this further, the effect of food type (i.e., tempting, neutral and LCS beverages) was analysed for positive and negative health features separately, first in frequent consumers and then in non-consumers.

In frequent consumers, a repeated measures ANOVA revealed a main effect of food type for proportions of positive health features, $F(2,58)=35.54$, $p<.001$, $\eta_p^2=.55$. Paired t-tests showed that frequent consumers generated a higher proportion of positive health features for LCS beverages (M = 16%, SE = 1%), $t(29)=7.28$, $p<.001$, $d=1.82$ and neutral foods (M = 15%, SE = 1%), $t(29)=9.99$, $p<.001$, $d=0.76$, compared to tempting foods (M=0%, SE=0%). Furthermore, there was no difference in the amount of positive health features generated for LCS beverages and neutral foods for frequent consumers, $t(29)=.442$, $p=.661$, $d=0.05$. For negative health features, there was also a main effect of food type, $F(2,58)=8.39$, $p=.001$, $\eta_p^2=.22$. Paired t-tests revealed that frequent consumers generated more negative health features for tempting foods (M = 7%, SE = 1%) compared to neutral $t(29)=4.58$, $p<.001$, $d=0.84$ and

LCS beverages, $t(29)=2.22$, $p=.034$, $d=0.37$ but had similar proportions of negative health features for both neutral foods (M = 0.17%, SE = 0.2%), and LCS beverages (M = 3%, SE = 0.2%), $t(29)=1.84$, $p=.076$, $d= 0.41$ (see Figure 3.6., Panel A).

For non-consumers, analysis revealed a main effect of food type for proportion of positive health features, $F(2,58)=32.64$, $p<.001$, $\eta_p^2=.53$. Non-consumers generated a higher proportion of positive health features for neutral foods, (M =11%, SE =1%), compared to LCS beverages, (M=3.3%, SE =0.9%) $t(29)=4.21$, $p<.001$, $d=1.07$, and tempting foods, (M=0%, SE = 0%), $t(29)=8.99$, $p<.001$, $d=1.64$. Non-consumers also generated a higher proportion of positive health features for LCS beverages relative to temping foods, $t(29)=3.28$, $p=.003$, $d= 0.60$. Additionally, there was a main effect of food type for proportion of negative health features, $F(2,58)=44.79$, $p<.001$, $\eta_p^2=.61$. Paired t-tests revealed a higher proportion of negative health features were generated for LCS beverages (M = 22%, SE = 2%) $t(29)=9.71$, $p<.001$, $d=1.77$ and tempting foods (M = 10%, SE = 1%), $t(29)=4.76$, $p<.001$, $d=0.87$, compared to neutral foods (M = 0.3%, SE = 0.2%). Non-consumers also generated a higher proportion of negative health features for LCS beverages compared to tempting foods, $t(29)=4.68$, $p<.001$, $d=0.85$ (see Figure 3.6., Panel B).

To see analyses conducted for specific non-simulation features (i.e., visual vs. non-eating situations vs. other), see Appendix H.

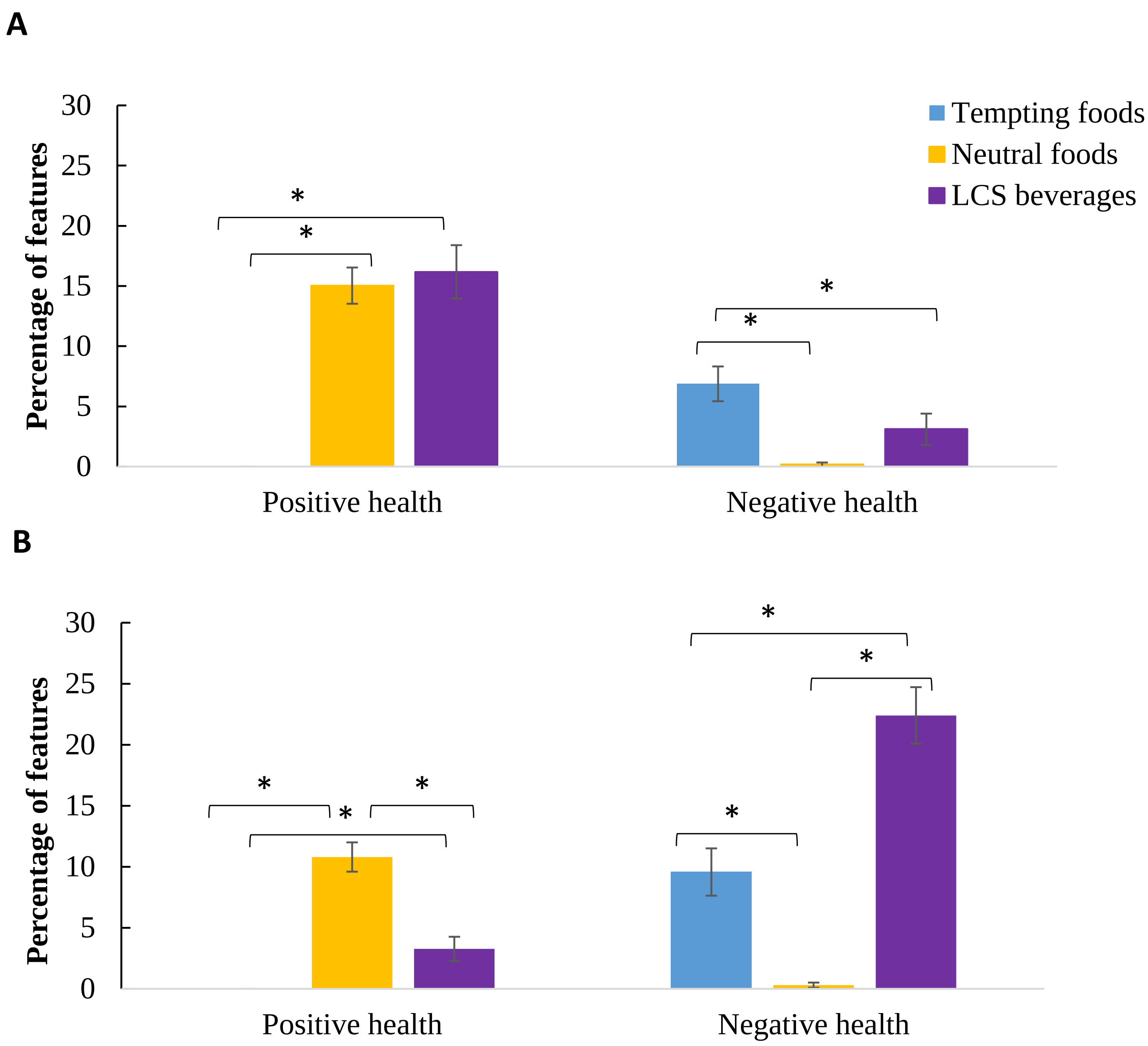

Figure 3.6. Percentages of positive and negative health features generated for tempting, neutral food and LCS beverages between frequent (Panel A) and non-consumers (Panel B). Values are means and standard errors of the mean. **p*<.001.

3.4.4.3. Hunger

There was no main effect of group or group x time interaction on hunger ratings, both *Fs*<.780, *ps*>.381. There was a main effect of time on hunger ratings, $F(1,58)=4.59$, $p=.036$, $\eta_p^2=.07$. Specifically, following the feature-listing task (M=55.29 mm, ± 28.63), hunger ratings were significantly greater than before the task (M=53.66 mm, ± 27.55).

Desire to eat. To determine whether frequent consumers differed from non-consumers in terms of the number of food and beverages they currently desired to eat, the total number of foods they would desire to eat within each food group were combined (i.e., tempting, neutral and LCS beverages). A two-way mixed ANOVA was conducted with group as the between-subjects factor and food type (tempting, LCS beverages and neutral foods) as the within-subjects factor and number of foods they desire to eat as the dependent factor. Analysis revealed a main effect of group, $F(1,58)=8.30$, $p=.006$, $\eta_p^2=.13$, main effect of food type $F(2,116)=84.41$, $p<.001$, $\eta_p^2=.59$ and consumer group x food type $F(2,116)=28.73$, $p<.001$, $\eta_p^2=.33$. Post-hoc independent t-tests revealed that there was no difference in the number of foods that frequent and non-consumers wanted to eat for tempting and neutral foods, (both $ps>.154$). However, frequent consumers ($p<.001$; M=1.67, ±0.76) reported wanting to consume more LCS beverages compared to non-consumers (M=0.00, ±0.00).

3.5. Discussion

The present study used a feature-listing task to investigate whether eating simulations play a role in the representation of LCS beverages in frequent consumers and non-consumers. Consistent with hypothesis 1, frequent LCS consumers generated a higher proportion of eating simulations when describing LCS beverages relative to neutral foods. Furthermore, as predicted, frequent consumers generated a similar numbers of eating simulations for both LCS beverages and tempting foods, in contrast non-consumers generated more eating simulations for tempting foods compared to neutral foods and LCS beverages (hypothesis 2). This is in line with previous research (Keesman et al., 2018; Papies 2013), in which perceiving an attractive food words triggers more eating simulations compared to neutral foods.

Examining the representation of food and LCS beverages in more detail revealed that tempting foods were largely represented by the taste, texture and temperature features for both consumer groups. This pattern was mirrored for LCS beverages in frequent consumers. As such, this sensory feature seems to be particularly salient for food and beverages that are deemed rewarding. Indeed, Papies (2013) argues that the taste, texture and temperature feature might be so salient that they can be retrieved from memory via word associations and are not dependent on an actual eating simulation. Furthermore, consistent with Papies findings, neutral foods were comparatively less represented by eating simulations, instead non-simulation features dominated the feature list for neutral foods in both frequent and non-consumers. These findings further suggest that rewarding foods are more likely to initiate eating simulations through gustatory sensations.

The hedonic experience is another important factor in how food and beverages are represented. LCS beverages and tempting foods were represented more in terms of their positive hedonic features relative to neutral foods for frequent consumers. This was not surprising with research showing that tempting foods that are experienced as rewarding (Drewnowski, 1995; Pinel, Assanand & Lehman, 2000) are more likely to trigger simulations of previous rewarding hedonic experiences (Papies 2013; Stroebe, et al., 2008; Locher et al., 2005; Fishbach et al., 2003). Interestingly, the current study also found that non-consumers described both LCS beverages and tempting foods more in terms of hedonic features compared to neutral foods. However, closer inspection revealed that while tempting foods were largely described in terms of their positive hedonic experiences, LCS beverages were heavily represented in terms of their negative hedonic experience compared to tempting and neutral foods for non-consumers. This suggests that aspects of the hedonic experience are influential in motivating an individual to consume LCS beverages, and that simulating them in response to appetitive cues affects motivational processes. For instance, frequent consumers responses made much use of positive hedonic features such as “tasty,” “refreshing,” “tastes the same as coke” and “delicious” for LCS beverages, suggesting that the positive hedonic experience associated with consuming LCS beverages is an important aspect of how frequent consumers represent them. In view of this finding, it is plausible that, in frequent consumers, the positive hedonic experience that LCS beverages appears to generate, is most likely a motivating factor behind consumption. This contrasts with non-consumers, who associated LCS beverages with more negative hedonic features such as "disgusting" and "unpleasant". Together, these findings suggest that the eating simulations frequent consumers retrieve, reflect the rewarding experiences that are specific to that consumer. LCS beverages may therefore support frequent consumers goal-directed action, such that, these beverages spontaneously trigger embodied simulations of consuming LCS beverage.

Examining eating situations in more detail, there was no difference between tempting, neutral foods and LCS beverages in terms of eating situations generated for frequent consumers. On the other hand, LCS beverages were comparatively less represented in terms of eating situations than both tempting and neutral foods for non-consumers. This is not surprising given that non-consumers do not consume these beverages, as such, they are less likely to draw on previous eating situations involving LCS beverage consumption and enjoyment of them. It further reflects the negative connotations LCS beverages hold for non-consumers. Moreover, our findings are in contrast to Papies (2013) findings and several behavioural (Keller & van der Horst, 2013; Blake, Bisogni, Sobal, Devine, & Jastrane, 2007; Locher et al., 2005) studies, that demonstrated that representations of desirable foods are more likely to be situated as these foods tend to have stronger links with memories of previous rewarding eating experiences. A possible explanation for this contrasting finding could be that the sensory and hedonic experiences from previously rewarding eating experiences are more salient factors in the representation of tempting and LCS beverages.

A further aim of the current study was to determine whether frequent consumers would generate a higher number of positive health features for LCS beverages relative to non-consumers. This follows on from our previous findings (Chapter 2, of the current thesis), where frequent consumers believed that LCS beverages were beneficial in managing their weight and cravings compared to non-consumers. Notably, the representation in terms of positive health features was more pronounced for LCS beverages (16%) and neutral foods (15%) compared to tempting foods (0%) in frequent consumers. They described LCS beverages as "healthier alternative," "low calorie," "healthier than regular coke," and "less sugar". Contrastingly, for non-consumers, negative health features dominated the representation of LCS beverages. They generated more negative health features for LCS beverages (22%), followed by tempting foods (10%) compared to neutral foods (0.3%). They chose features such as "unhealthy" "chemicals added," "carcinogenic," "not good for your teeth," and "bad for the brain". This is an interesting finding, and while health features are not directly involved in the simulations of a food, the present findings suggest they are still an important element of the representation for LCS beverages. Furthermore, it suggests that frequent consumers associate LCS beverages as beneficial in pursuing their long-term goal of weight control. This disparity between consumer groups reveals the importance of the individual's goals and desire attached to the food. It further suggests that health-related aspects are salient drivers behind consumption of LCS beverages. This in in contrast to much of the current research (Papies; 2013; Siep et al., 2009; Wang et al., 2004) which typically finds that eating simulations are generally only generated for foods that are considered attractive but unhealthy. However, LCS beverage consumption has been associated with reductions in energy intake and body weight (Rogers et al., 2016) and greater fruit and vegetable intake (Drewnowski & Rehm, 2016), it therefore seems that LCS beverages are being implemented in an effort to lead a healthier lifestyle. Thus, the present findings suggest that theses health-related beliefs are fundamental in motivating consumption of LCS beverages.

Drawing from above, the difference in simulations generated for LCS beverages between the groups suggests that beliefs surrounding health and hedonic experiences are salient in influencing their food choices and experiences. Similarly, Keesman et al. (2018) reported that alcoholic beverages were strongly represented in terms of their positive sensory experiences and outcomes (using a comparable feature-listing task) in habitual consumers. These positive experiences were the motivating factors behind consumers alcohol consumption. Furthermore, LCS beverages may have a beneficial impact on consumers' motivated behaviour by reminding them of their long-term weight management goal. For instance, when consumers' are exposed to tempting cues, LCS beverages may satisfy their short-term hedonic goal to indulge, by providing an alternative source of immediate pleasure, whilst subtly reminding consumers of their valued long-term weight control goal. Indeed, research has shown that priming a health goal (Papies, 2016b) can have a positive influence on health behaviour (among individuals where the primed goal holds significance) by activating health and weight related thoughts whilst inhibiting competing thoughts about tempting foods that interfere with their goal pursuit (Papies & Aarts, 2016; Papies & Barsalou, 2015; Papies & Veling, 2013; Stroebe et al., 2013; Custers & Aarts, 2005, 2010; Fishbach et al., 2003).

To our knowledge, this is the first study to explicitly compare frequent and non-consumers of LCS beverages and how these beverages are represented conceptually. From a grounded cognition perspective, the difference in simulations generated for LCS beverages between the groups suggests that beliefs surrounding health and hedonic experiences are salient in motivating their food choices and experiences. A strength of the study is that we used a similar inductive approach to Papies (2013), which was adopted in order to build on and extend her findings to frequent consumers of LCS beverages. More research is needed, however, to confirm whether consumption simulations induce such appetitive responses in other groups. Furthermore, because people conveyed their conceptual knowledge using a linguistic method, some types of information are captured more clearly than others. As such, it is possible that some information surrounding LCS beverages may be more difficult to verbalise and capture.

Future work should consider methods to examine more complex representation of LCS beverages.

3.6. Conclusion

The present study demonstrated that both LCS beverages and hedonically pleasing foods were represented more in terms of eating simulations compared to neutral foods for frequent consumers. In contrast, for non-consumers only tempting foods were strongly represented in terms of eating simulations, while LCS beverages and neutral foods were comparatively less represented in terms of eating simulations but instead non-simulations. LCS beverages were represented more in terms of their positive hedonic experiences and health-related consequences for frequent consumers. In comparison, negative hedonic experiences and negative health consequences seem to be important factors for how these beverages are represented for non-consumers. Taken together, the contrasting findings for frequent and non-consumers suggest that beliefs surrounding the health and hedonic experiences of LCS beverages are salient in influencing their food choices and experiences. The present study provides new insight into desire and motivated behaviour for LCS beverages, and subsequently increases our understanding of how desire arises and may affect frequent consumers' behaviour.

Chapter 4: Do low-calorie sweetened beverages help to control food cravings? Two experimental studies

The study reported in this chapter has been published in Physiology & Behavior as:

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4.1. Abstract

LCS beverages may help consumers to satisfy hedonic food cravings without violating dieting goals, however this remains unexplored. The present research investigated the effect of priming hedonic eating motivations on *ad libitum* energy intake in frequent and non-consumers of LCS beverages. It was hypothesised that energy intake would be greater after the hedonic eating prime relative to a control prime in non-consumers, but that frequent LCS beverage consumers would be protected from this effect. In **Study 3** (*N*=120), frequent and non-consumers were exposed to either chocolate or neutral cues (craving vs. control condition) and then completed a beverage-related visual probe task with concurrent eye-tracking. *Ad libitum* energy intake from sweet and savoury snacks and beverages (including LCS) was then assessed. **Study 4** followed a similar protocol, but included only frequent consumers (*N*=172) and manipulated the availability of LCS beverages in the *ad libitum* eating context (available vs. unavailable). Measures of guilt and perceived behavioural control were also included. In **Study 3**, as hypothesised, non-consumers showed greater energy intake in the craving condition relative to the control condition, but frequent consumers had similar energy intake in both conditions. Frequent consumers (but not non-consumers) also demonstrated an attentional bias for LCS beverage stimuli compared to both sugar and water stimuli. In contrast, in **Study 4** frequent consumers showed greater energy intake in the craving condition relative to the

control condition; however, overall energy intake was significantly greater when LCS beverages were unavailable compared to when they were available. Ratings of guilt were higher and perceived control was lower in the LCS-unavailable condition relative to the LCS-available condition. **Conclusions**: LCS beverages did not consistently protect consumers from craving-induced increases in energy intake. However, frequent consumers consumed fewer calories overall when LCS beverages were available (relative to unavailable), as well as perceiving more control over their food intake and feeling less guilty.

4.2. Introduction

LCS beverages have emerged as a strategy to reduce total energy intake, providing sweet taste without additional calories and thereby potentially assisting in weight loss (Panahi, et al. 2013; Mattes et al., 2011). Despite their popularity, the influence of LCS beverages on energy intake and weight maintenance has been a contentious issue. Some argue that LCS beverages encourage a preference for hedonically pleasing food and increase the risk for weight gain and obesity (Swithers, 2013; Swithers, 2010; Nettleton et al., 2009; Fowler et al., 2008), although this may be a non-causative association. Indeed, a recent systematic review found that consumption of LCS beverages, when used as a substitute for sugar, is associated with *reductions* in energy intake and body weight (Rogers et al., 2016). Given this controversy, understanding the motivations behind consumption of LCS beverages is of importance. However, as mentioned in Chapter 1, we know very little about the underlying psychological drivers behind frequent consumption of LCS beverages and how these psychological factors impact on eating behaviour.

As previously discussed in Chapter 1, Appleton and Conner (2001) addressed this research gap by investigating the characteristics associated with frequent consumption of LCS beverages. They found that frequent consumers of these beverages are typically overweight but also have high dietary restraint and body weight concerns relative to non-consumers of LCS beverages. In view of these findings, these consumers, whilst motivated to control their weight, are also vulnerable to periods of food restriction and disinhibited eating (Lowe, 2002; Gorman & Allison, 1995). This is in line with the goal conflict model, which proposes that dietary restraint is difficult because these individuals are attempting to juggle two conflicting goals; their hedonic goal of enjoyment of eating while also satisfying their long-term goal of weight maintenance (Stroebe, et al., 2008). This is a challenge for dieters because low-energy, "diet" foods are often less hedonically pleasing than foods with higher calorie contents (Drewnowski, 2003).

Drawing on the above, it is plausible that LCS beverages may benefit some individuals because these products are able to satisfy food cravings and/or hedonic desire for sweetness while also enabling maintenance of dieting goals (thereby realigning previously conflicting goals). However systematic investigation of this has yet to be conducted and the mechanisms for how LCS beverages might influence energy intake are unclear. In view of this, the secondary aim of the present thesis was to address this issue by examining the psychological mechanisms associated LCS beverage consumption and this aim provided the focus for this chapter.

One possibility is that LCS beverages may act as a "diet prime", reminding consumers of their dieting motivations and thereby helping to regulate their eating behaviour. While this has not been investigated specifically for LCS beverages, several studies have demonstrated that exposing participants to cues linked with their longstanding diet goals can trigger goal-directed behaviour (Buckland et al., 2014; Buckland, Finlayson, & Hetherington, 2013; Fishbach et al., 2003). For example, restrained eaters do not overeat following pre-exposure to palatable food cues when they are reminded of their dieting goal (Papies & Hamstra, 2010; see also Anschutz Van Strien & Engels, 2008, for comparable findings). However, it is important that the primed goal is motivationally relevant to that individual, in that given situation (Custers

& Aarts, 2005, Aarts 2007; Fishbach & Trope, 2005; van Koningsbruggen, Stroebe & Aarts, 2011; Papies et al., 2008b). Given this link, it is plausible that exposure to LCS beverages may similarly act as a diet prime for frequent consumers of these beverages and thereby enable them to pursue their long-term weight maintenance goals even in situations in which short-term hedonic goals typically prevail. As a result, individuals may feel more in control and less guilty over their eating. Given that negative affect is often associated with increased consumption or emotional eating (Cuijpers, Steunenberg, & Van Straten, 2007; Epel et al., 2001; Greeno & Wing, 1994), determining whether consumption of LCS beverages reduces feelings of guilt and increases perceived behavioural control would also be meaningful.

In line with the goal-conflict model, Chapter 1 discussed another possibility where the presence and availability of LCS beverages acts as a highly salient hedonic cue due to their association with a rewarding experience (i.e. sweet taste). According to incentive-motivational models, repeated exposure to stimuli associated with food reward results in biased attention towards these and any other relevant stimuli (see Field et al., 2016). As a result of this, we would expect frequent consumers of LCS beverages to exhibit a bias in attention towards LCS beverages, and this bias may be further amplified under conditions when hedonic eating motivations are activated. Consistent with this idea, Kemps and Tiggeman (2009) found that participants who were experimentally induced into a temporary state of food craving showed increased attentional bias to chocolate-related pictures, relative to the control condition (see also Smeets, Roefs & Jansen, 2009, and van Dillen & Andrade, 2016, for similar findings). Thus, if LCS beverages are associated with hedonic eating motivations in frequent consumers, we would expect to see an amplified attentional bias towards cues associated with LCS beverage stimuli, particularly when hedonic motivations (i.e. food cravings) are primed.

The overarching focus of this chapter was to address the secondary aim of the present thesis, namely, to determine the psychological mechanisms underpinning the effect of LCS beverages on eating behaviour. Specifically, we investigated the effect of priming hedonic eating goals, via a chocolate craving manipulation, on *ad libitum* energy intake in frequent and non-consumers of LCS beverages. It is well-established that food cue exposure and craving increase food intake (Boswell & Kober, 2016), therefore in Study 3, we hypothesised that energy intake would be greater after the craving manipulation relative to the control manipulation in non-consumers. However, we predicted that frequent consumers would be protected from this effect due to the availability of LCS beverages in the *ad libitum* eating context (Hypothesis 1). We also examined attentional bias towards LCS beverage-related stimuli following the craving or control manipulation. We predicted that frequent consumers, but not non-consumers, would show an attentional bias to LCS beverage stimuli and that this bias would be amplified when frequent consumers were in a state of craving (Hypothesis 2).

4.3. Study 3 Method

4.3.1. Participants

One hundred and twenty university staff and students (mean age 31.44 ±8.54 years) were recruited to take part in a study investigating the relationship between beverage consumption and behaviour. Prior to attending the laboratory session, participants were identified and classified as frequent and non-consumers of LCS beverages according to a self-reported online Food Frequency Questionnaire (FFQ) by Appleton and Conner (2001) assessing consumption of a range of beverages (see Chapter 2, section 2.3.2.2. for further details). Participants were classified as frequent consumers if they reported consuming ≥825 ml LCS beverages/day. Non-consumers of LCS beverages were defined by a consumption of 0ml of LCS beverages in addition to ≥825 ml/d of SSB and/or ≥825 ml/d of water, to ensure effects of high consumption of beverages were controlled for. In addition to being either frequent or non-consumers of LCS beverages, inclusion criteria required that participants were non-smokers, had no food allergies or intolerances, had never been diagnosed with an eating disorder, and were not on any medication known to affect appetite. Finally, due to the eye-tracking technique used, glasses wearers were unable to take part. All participants completed an online screening questionnaire prior to testing to ensure that they meet all inclusion criteria.

On the basis of their responses to the screening questionnaire, frequent (*N*=60) and non-consumers (*N*=60) of LCS beverages were randomly allocated to either the craving or control condition, in a 2 x 2 between-subjects design. Ethical approval was granted by the University Research Ethics Committee and all participants gave written informed consent before participation.

4.3.2. Measures

4.3.2.1. *Craving condition: exposure*

The craving manipulation was adapted from Kemps and Tiggemann (2009). Participants were requested to pick their favourite chocolate bar from a selection of eight brands of "fun-size" wrapped chocolate bar. They were instructed to unwrap and intensively smell and touch their chosen chocolate bar without tasting it for 2 minutes, to attempt to invoke the sensation of craving. Participants were instructed to write down the name of the chocolate bar and indicate how much they liked it on a 100-mm visual analogue scale (VAS) ranging from "not at all" to "very much". They were then asked to indicate their craving for chocolate at that very moment using a VAS. Participants completed the craving exposure on two occasions, first for two minutes before the Visual Probe Task (VPT) and for a second time (craving booster) for 1 minute, halfway through the VPT (please see below section for detailed description of the VPT).

4.3.2.2. Non-craving condition: control

Participants assigned to the 'control condition' completed a similar protocol to the craving exposure, to ensure that all participants took part in comparable activities. However, instead of being exposed to chocolate, participants were given a basket of eight different coloured wooden blocks, resembling the shape and size of the chocolate bars. The remaining instructions were the same as the craving manipulation; selecting their preferred block, sensualising the block and completing VAS scales for craving chocolate and how much they liked their chosen colour.

4.3.2.3. Ad libitum snack intake

Participants were provided with a variety of snack foods, presented in bowls and invited to eat *ad libitum* for 15 minutes. The food items consisted of the following items: a 150g bowl of Tesco mini flapjacks (Per 100g: 458 Kcals, 21.9g fat), a 115g bowl of Tesco mini brownies (Per 100g: 394 kcals, 15g fat), 44g bowl of two packets of salt and vinegar Snack-a-Jacks (Per bag: 89 kcals, 1.6g fat), 1 x cheese and onion sandwich (Tesco Cheese and Onion, Per pack: 505kcals, 28.4g fat), 2 x Tesco cheese and onion rolls (Per 60g roll: 176 kcals, 9.6g fat) and 115g of Tesco millionaire bites (Per 100g: 500 kcals, 28.0g fat). Participants were also offered a 1-litre bottle of sugar sweetened beverage (SSB), of either Coke (Per 100ml: 42kcal, 0g fat) or Sprite (Per 100ml: 14.0g kcal, 0.0g fat), a 1-litre bottle of LCS beverage of either Diet Coke (Per 100ml: 0.4kcal, 0.0g fat) or Sprite Zero (Per 100ml: 1kcal, 0.0g fat) and a 1-litre bottle of still water (0.0kcal, 0.0g fat). The beverages given were previously decided on based on each participant's screening questionnaire in which they indicated their preferred beverage. Plates, bowls and beverages were covertly weighed before and after consumption to determine food intake.

4.3.2.4. Attentional bias; visual probe task (VPT)

All stimuli were presented using Inquisit version 3 (Millisecond software, 2012). The VPT tasks used images of three different beverage types - LCS, SSB and water - and depicted a range of beverage-related scenes and bottle varieties (e.g., 1 litre bottle of diet coke, a can of coke being poured into a glass). These three beverage types were used to generate three categories of image pairs: (1) LCS beverages vs. water images, (2) LCS beverages vs. SSB images, and (3) Water vs. SSB images. Within each image pair category, there were eight image pairs, which each appeared eight times (see Figure 4.1.). The task thus consisted of 192 trials (in line with Christiansen, Mansfield, Duckworth, Field & Jones, 2015). Images were 125mm high x 125 mm wide. Within each pair, images consisted only of the beverages and they were matched as closely as possible for colour, complexity, brightness, shape, and size. Prior to attending the laboratory, frequent consumers indicated their preferred LCS beverage and similarly, non-consumers indicated their preferred SSB. Participants viewed their chosen beverage during the task (i.e., if participants opted for Sprite Zero, the LCS beverage images viewed in the task were all Sprite Zero). Using personalised stimuli has been shown to significantly improve the internal reliability of the VPT (i.e. Christiansen et al., 2015). We decided to include both SSB and water as controls to determine if frequent consumers of LCS beverages were distracted more by LCS beverage stimuli even when sugar beverages were also present. Eight additional images pairs depicting stationery items and household items were used for the practice trials. The order of trials was randomised for each participant.

Each trial began with a white fixation cross presented in the centre of the screen for 500ms. This was followed by a pair of images presented for 2000ms, one picture on the left of the screen and the other on the right, 60 mm apart. Immediately after this, one of the images was replaced by a probe (a white arrow on a black background, pointing up or down). Participants were instructed to respond as quickly as possible to the orientation of the probe by pressing the corresponding key, to indicate the location of the probe. The inter-trial interval was 500ms. Participants first completed 8 practice trials in which neutral image pairs (stationery and household images) were presented. The task lasted approximately 25 minutes. The complete task was divided into two blocks of 96 critical trials each, with a break in the middle to maintain craving (i.e., craving booster). Reaction time to probes was measured on each trial.

4.3.2.5. Eye-movement measurements

Eye-tracker: Participants were seated approximately 23 inches away from the computer screen with their chin on a chin-rest. A 9-point calibration with a validation procedure was carried out prior to the visual probe paradigm. Participants gaze was measured using the attention allocation process. This attention was defined as a period that is not a blink or saccade and will last at least 100 ms for each trial (Christiansen et al., 2015; Jones et al., 2012). Participants did not make any fixations on the pictures on 11.2% of trials in the task. Eye-movements were recorded during the VPT using an Eye-Trac D6 desktop mounted camera (Applied Science Laboratories, Bedford, MA).

Both a direct and indirect measure of attentional bias were therefore measured, one based on reaction times and the other based on eye-movements**.**

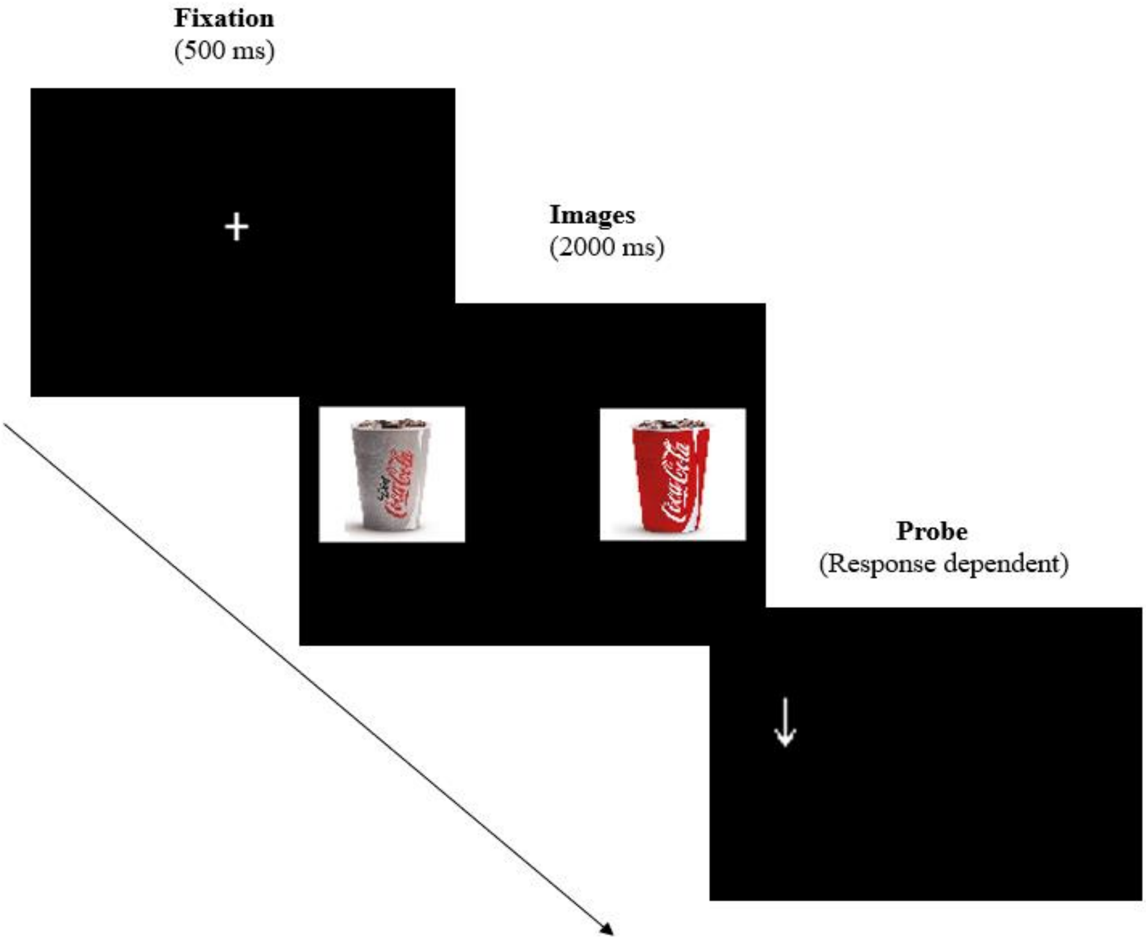


Figure 4.1. Example of the sequence and duration of screen presentation in the eye-tracking task during a single trial. The task consisted of 192 trials and each trial type (i.e. LCS beverage vs. water, LCS beverage vs. sugar beverage and sugar beverage vs. water) was presented 64 times. Each trial displayed the fixation cross (500 ms), followed by the paired images (2000 ms), and then the visual probe (until response).

4.3.2.6. Additional measures and trait eating questionnaires

Attitudes and beliefs towards LCS beverages: Attitudes towards LCS beverages were assessed using the novel questionnaire previously developed in Chapter 2, containing two subscales: appetite and weight management (7 items) and palatability and enjoyment of LCS beverages (7 items). Participants indicated the extent to which they agreed with each statement (e.g. "I believe LCS beverages help me to manage my cravings for sweet foods") on a 7-point Likert scale which ranged from "Strongly disagree to "Strongly agree". Subscale scores were determined by the mean score of the relevant items. Both scales had high internal reliability: appetite and weight management (α=.96), and palatability and enjoyment (α=.95).

Trait chocolate craving: The Attitudes to Chocolate Questionnaire (ACQ; Benton, Greenfield & Morgan, 1998) was used to assess trait craving for chocolate and eating chocolate for emotional reasons (craving), negative feelings associated with eating chocolate (guilt), and eating chocolate for functional reasons (functional) on a 24-item scale. Responses were recorded on a 100mm VAS ranging from "Not at all like" to "Very much like me".

In addition, The Dutch Eating Behaviour Questionnaire (DEBQ; van Strein, Frijters, Gerard & Bergers, 1986) and Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985) were used to provide descriptive information about the sample (see Chapter 2 section 2.3.2.3. for a full description of these measures).

4.3.2.7. Appetite ratings

Levels of craving for chocolate, hunger, fullness, and thirst were assessed using 100mm-VAS. Each scale was anchored by 'Not at all' on the left and 'Extremely' on the right. Appetite VAS measures have been shown to have good validity and reliability (Blundell et al., 2010).

4.3.3. Procedure

Testing took place in the Department of Psychological Sciences on the University of Liverpool campus. Each participant attended one 60-min session. All sessions were conducted between 12pm and 6pm. Upon arrival, participants provided written informed consent and confirmed that they had not eaten for at least 3 hours prior to the study. Additionally, frequent consumers were asked to refrain from consuming any LCS beverages 24 hours in advance. Upon arrival, participants indicated their current appetite ratings (of hunger, fullness, thirst and craving for chocolate) using VAS (Time 1). Following this, participants completed the respective craving or control conditions for 2 minutes. A second measure of appetite was taken

(T2). Participants then performed the VPT and concurrent eye-tracking task. There was an interval in the middle of the task and participants were once again subjected to the craving or control exposure for 1 minute (i.e. craving booster) to ensure that participants assigned to the craving condition maintained their increased levels of craving. They were asked to smell and touch the chocolate (or wooden block) for 1 minute in the middle of the task and indicate the level of craving on a VAS. Subsequent appetite ratings were also assessed (T3). Participants then completed the second half of the VPT and eye-tracking task. Following this, participants completed appetite ratings again (T4). Subsequently, participants were given a selection of sweet and savoury foods and beverages which they could consume *ad libitum* for 15 minutes. As part of the cover story participants were given the selection of foods under the pretence that, because they were asked to refrain from consuming food for 3 hours, we offered everyone some food before they could leave. Participants were invited to consume as much or as little as they wanted. Food and beverage intake were measured by covertly weighing the bowls and drinks before and after consumption. Following this, participants' ratings of appetite were measured again (T5). Participants then filled in the DEBQ, TFEQ, attitudes and beliefs towards LCS beverages questionnaire and the ACQ and measures of height and weight were taken to calculate BMI. To ensure the absence of demand characteristics, participants were asked to indicate what they thought the aims of the study were. Finally, participants were debriefed and thanked for their time.

4.3.4. Data analysis

4.3.4.1. Craving manipulation

A 2 (condition: craving exposure/control) x 2(consumer group: Frequent/non-consumers) x 5 (time) mixed design ANOVA was conducted with condition and consumer group as the between-subjects factors, time as the within-subjects factor and craving (VAS) as the dependent variable.

4.3.4.1. Energy intake

The amount (in g) of food consumed was converted into calories. A 2(condition; craving, control) x 2(consumer group; frequent consumers, non-consumers) ANOVA on energy intake was conducted (Hypothesis 1), with condition and consumer group as the between-subjects factors and *ad libitum* energy intake as the dependent variable. We also conducted exploratory analyses to examine the effects of condition and consumer group on intake of specific food-types (i.e. sweet foods, savoury foods, beverages).

4.3.4.2. Attentional bias scores

Eye-movement data: For eye-movement data, gaze dwell time was measured. Gaze dwell time was determined as the total amount of time in milliseconds that participants spent fixating on each image over the 2000ms of each trial. In accordance with previous research (e.g., Christiansen et al., 2015), fixations were defined as a stable eye-movement within one degree of visual angle for 100ms or longer. Attentional bias scores for LCS beverages relative to water were determined by subtracting mean gaze dwell time on water images from mean gaze dwell time on LCS beverage images. Similarly, the attentional bias score for LCS beverages relative to SSB was determined by subtracting the mean gaze dwell time on SSB images from mean gaze dwell time on LCS beverage images. A positive score indicated an increased attention towards LCS beverages, while a negative score indicated an attentional bias towards the control (i.e. water or sugar beverages) images.

Manual response to latencies probes: Data from practice and filler trials were discarded. Reaction times faster than 200ms, slower than 2000ms and then three standard deviations above the individual mean were removed prior to analysis (see Schoenmakers, Wiers & Field, 2008). Attentional bias scores were determined by computing mean reaction times to congruent probes (those that appeared in the same location as LCS beverage images) and incongruent probes [those that appeared in the same location as control (water or SSB) images] before subtracting the congruent from incongruent reaction times. Two separate bias scores were computed for LCS beverages compared to water, and for LCS beverages compared to SSB. A positive score indicated increased attention towards LCS beverages, while a negative score indicated an attentional bias towards the control (i.e. water or SSB) images.

The following analyses were conducted to test Hypothesis 2:

Gaze dwell times bias: A 2 (condition; craving vs. control) x 2 (consumer group; freq. vs. non-consumers) ANOVA was conducted with condition and consumer group as between-subjects factors and gaze dwell time bias for LCS beverages relative to water as the dependent variable. The analysis was then repeated with gaze dwell time bias for LCS beverages relative to SSB as the dependent variable.

Reaction time bias: A 2 (condition; craving vs. control) x 2 (consumer group; freq. vs. non-consumers) ANOVA was conducted with condition and consumer group as between-subjects factors and response latency bias for LCS beverages relative to water as the dependent variable. The analysis was then repeated with response latency bias for LCS beverages relative to SSB as the dependent variable.

4.4. Study 3 Results

4.4.1. Participant characteristics

Due to technical problems with the eye-tracker, data from 5 participants were lost. Four participants had excessive missing data from the VPT (>25% reaction times missing) and were also excluded; the remainder had <5% of data missing. Nine additional participants were therefore recruited to replace the lost data. Participant characteristics of the final sample are provided in Table 4.1. Independent samples t-tests confirmed that frequent consumers had significantly higher BMI, restraint, disinhibition and trait guilt associated with chocolate consumption relative to non-consumers. Additionally, frequent consumers had significantly higher beliefs that LCS beverages were palatable and effective in controlling appetite and weight relative to non-consumers. There were no significant differences between consumer groups on remaining characteristics, (*ps*>. 226). A chi-squared test showed that there was no significant differences in the number of males and females between consumer groups, $\chi^2(1) =.051$, $p=.822$. Importantly, independent t-tests confirmed that participants did not differ between the craving and control conditions with regard to any of these characteristics (*ps*>.131).

Table 4.1. *Descriptive statistics stratified by consumer group. Values are means with standard deviations in parentheses.*

Characteristics	**Frequent consumers of LCS beverages (n=60)**	**Non-consumers of LCS beverages (n=60)**
Age (y)	30.45 (9.17)	32.43(7.81)
BMI (kg/m^2)	26.29(4.26)	22.80(3.48)*
TFEQ		
Disinhibition	8.35(2.62)	6.33(2.77)*
DEBQ		
Restraint	3.24(1.07)	2.63(1.10)**
Emotional	2.96(.90)	3.01(.89)
External	3.25(.47)	3.30(.53)
Attitudes & Beliefs		
Appetite & Weight management	5.61(6.07)	2.58(1.16)*
Palatability & Enjoyment	5.10(1.25)	3.31(1.43)*
ACQ		
Trait Functional	34.66(14.60)	35.53(15.50)
Trait Guilt	44.56(16.66)	31.91(19.04)*
Trait Craving	51.62(18.27)	47.07(22.46)

TFEQ= Three Factor Eating Behaviour. DEBQ= Dutch Eating Behaviour Questionnaire. ACQ= Attitudes to Chocolate Questionnaire. *p<.001, **p<.05 frequent consumers vs. non-consumers.

4.4.2. Craving manipulation

The ANOVA revealed a significant main effect of condition on craving for chocolate, $F(1,116)=44.12$, $p<.001$ $\eta_p^2=.28$, and a condition x time interaction, $F(2.24,260.15)=47.44$, $p<.001$ $\eta_p^2 =.29$ (see Figure 4.2.). Planned comparisons using t-tests revealed participants in the craving condition reported significantly higher craving for chocolate at time-points T2 ($p<.001$; following craving exposure), T3 ($p<.001$; following craving booster) and T4 (p<.001;

end of VPT) relative to the control condition. Importantly, there was no difference between conditions at T1 or T5 (*ps*>.264). There was no main effect of consumer group, *F(*1,116)=1.03, *p*=.313*,* η_p^2=.01, and no interaction between condition x time x group, indicating that the effect of condition over time was consistent in frequent and non-consumers, *F(*2.24,260.15)=.913, *p*=.412, n_p^2=.01. Full analysis for ratings of hunger, fullness and thirst are available in Appendix I.

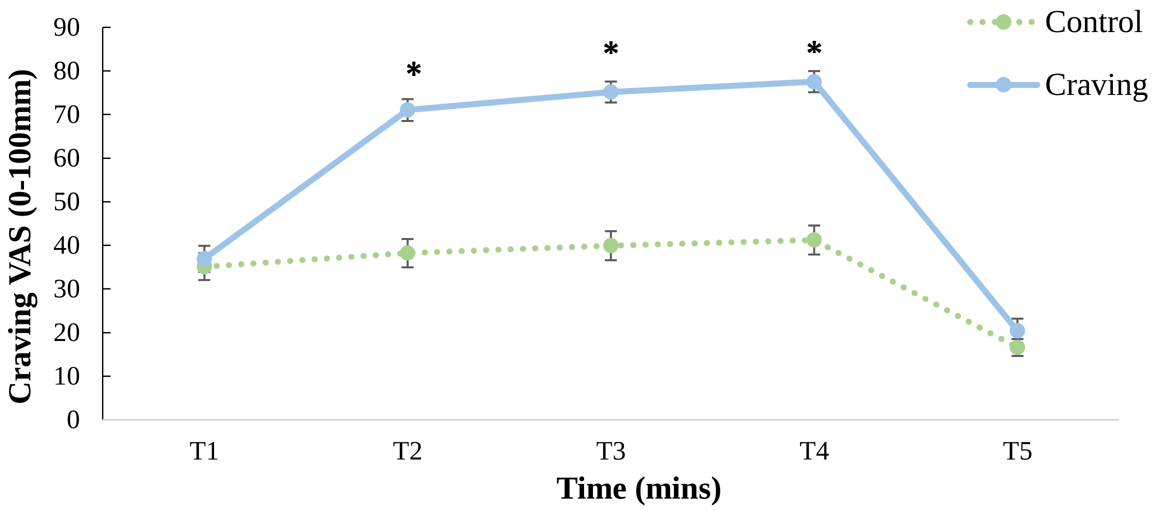


Figure 4.2. Ratings of craving for chocolate at each time-point in the craving and control condition conditions (collapsed across frequent and non-consumers). Values are means and standard errors of the mean. **p*<.001.

4.4.3. Energy intake

There was a significant condition x consumer-group interaction on energy intake, *F*(1,116)=5.30, *p*=.023, η_p^2=.04 (Figure 4.3.). Planned comparisons showed that, consistent with our first hypothesis, frequent consumers consumed similar amounts in both the craving and control conditions *t*(58)=1.11, *p*=.270, *d*=0.29 whereas non-consumers consumed significantly more in the craving (M=562.19 kcal; ±405.33), relative to the control (M=374.74 kcal; ±255.70) condition, *t*(48.93)=-2.14, *p*=.037, *d*=0.55. There were no main effects of consumer group, *F*(1,116)=0.60, *p*=.441, η_p^2=.01, or condition *F*(1,116)=0.53, *p*=.467, η_p^2 =.01.

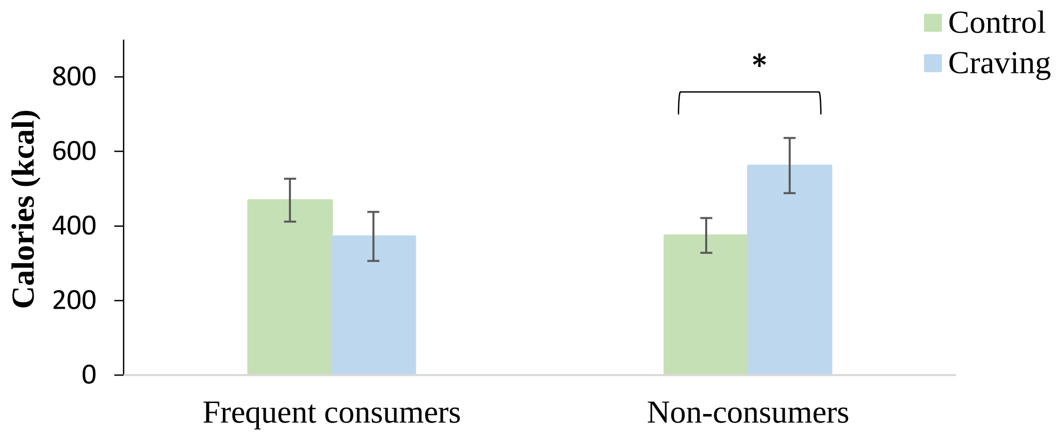


Figure 4.3. Mean energy intake following craving and control conditions in frequent and non-consumers (**p*=.037). Error bars represent standard error of the mean.

Correlational analyses revealed that there was a significant positive association between craving and energy intake in non-consumers (r=.402, p<.001) but not in frequent consumers, (r=.005, p=.968).

4.4.3.1. Exploratory analyses on energy intake

To further explore the interaction between condition and consumer group on energy intake, a mixed 3-way ANOVA was conducted, with condition (craving vs. control) and consumer group (freq. vs. non-consumer) as the between-subjects variables and food type (sweet, savoury and beverages) as the within-subjects variable and intake reported in kcal as the dependent variable. There was no interaction between condition x consumer group x food type, $F(1.74, 202.06)=1.58$, $p=.211$, $\eta_p^2=.01$. This indicates that the interactive effect of condition and consumer group on total energy intake, was not driven solely by calories from sweet, or savoury foods, or beverages.

To further explore potential differences in the volumes of beverages consumed, we conducted a mixed-ANOVA, with condition and consumer group as between-subjects variables, beverage type (LCS beverage, SSB, water) as the within-subjects variable, and intake reported in ml as the dependent variable. There were main effects of beverage type, F(1.6, 190.16)=34.20, $p<.001$, $\eta_p^2=.23$ and consumer group, $F(1,116)=13.41$, $p<.001$, $\eta_p^2=.10$. There was also an interaction between consumer group x beverage type, $F(1.6,190.16)=160.21$, $p<.001$, $\eta_p^2=.58$. Post-hoc t-tests revealed that frequent consumers drank significantly more LCS beverages ($p<.001$; M=364.58ml; ±142.50) relative to non-consumers (M=0.00ml ±0.00). Contrastingly, non-consumers drank significantly more SSB ($p<.001$; M= 99.43 ml ±145.38), and water ($p<.001$; M=185.29.ml; ±176.74) relative to frequent consumers (M=0.00ml; ±0.00, and M=19.57ml; ±67.28, respectively). Furthermore, frequent consumers drank significantly more overall (M=384.15ml; ±160.17) relative to non-consumers (M=284.72ml; ±138.69), $t(118)=3.64$, $p<.001$, $d=0.66$. There were no interactions between condition and beverage type, or between condition, consumer group and beverage type (*ps*>.146). This indicates that the amount of the different beverages consumed in the two consumer groups was not influenced by whether participants were in the craving or control condition.

4.4.4. Attentional bias

Gaze dwell time bias: Results showed a main effect of consumer group on dwell time bias for LCS beverage-related images relative to water images, $F(1,116)=8.10$, $p=.005$, $\eta_p^2=.07$, such that frequent consumers exhibited an increased attentional bias compared to non-consumers (Figure 4.4., panel A). There was no main effect of condition, $F(1,116)=0.68$, $p=.410$, $\eta_p^2<.01$ and contrary to Hypothesis 2, no condition x consumer group interaction on gaze dwell bias for LCS beverage-related images relative to water images, $F(1,116)=2.89$, $p=.592$, $\eta_p^2<.01$.

The same pattern of results was found when dwell time bias for LCS beverages images relative to SSB-related images was the dependent variable (Figure 4.4., panel B). There was a main effect of consumer group, $F(1,116)=11.63$, $p<.001$, $\eta_p^2=.09$ such that frequent consumers exhibited a greater attentional bias than non-consumers. There was no main effect of condition,

$F(1,116)=.01$, $p=.904$, $\eta_p^2<.01$, and no interaction between condition and consumer-group, $F(1,116)=.18$, $p=.677$, $\eta_p^2<.01$.

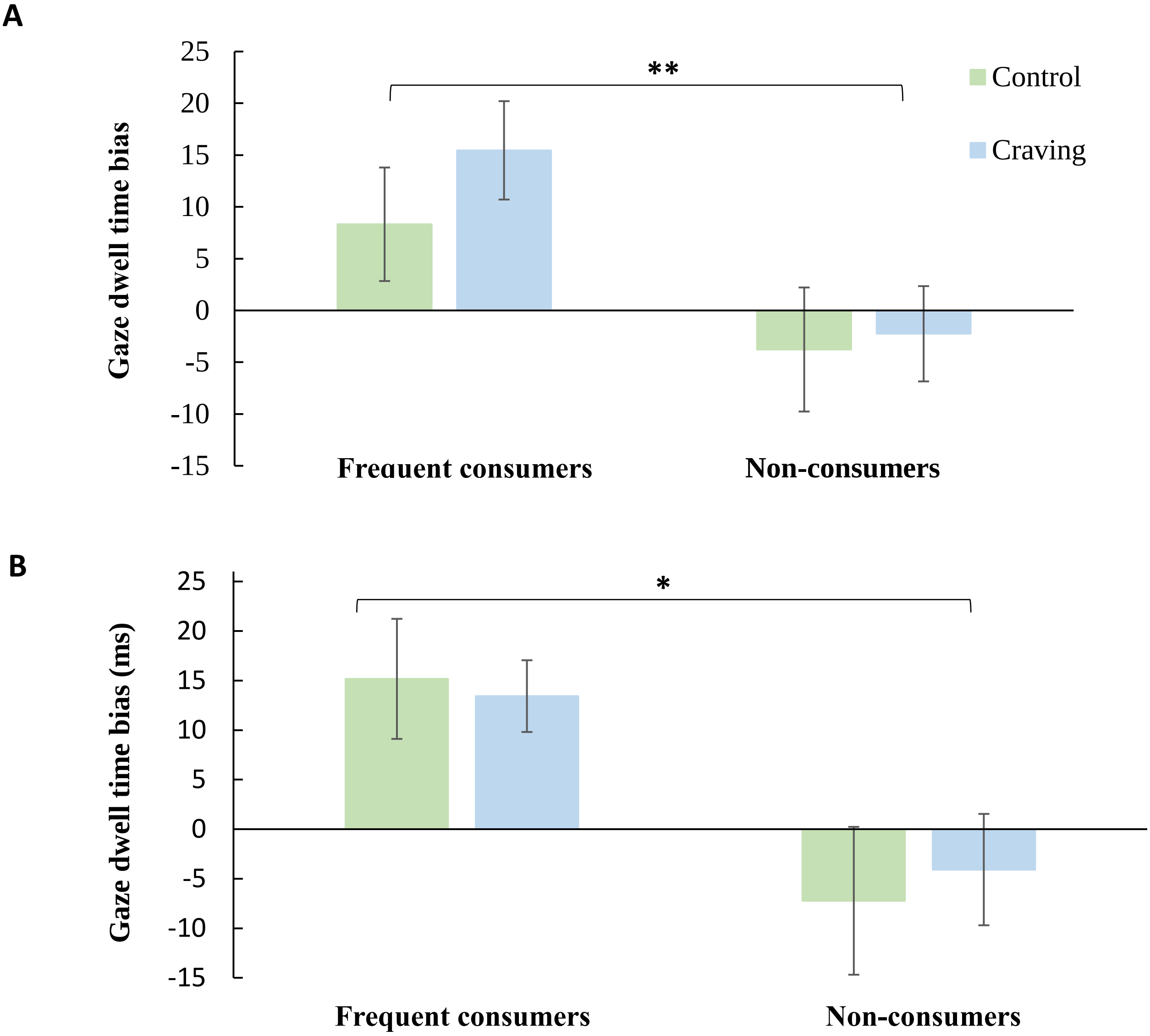


Figure 4.4. Mean gaze dwell bias (in milliseconds with standard error bars) for LCS beverages relative to Water (Panel A), Mean gaze dwell bias for LCS beverages relative SSB (Panel B). *p<.001, p**<.05. A positive score indicates an increased attentional bias for LCS beverages, relative to water or SSB.

Reaction times: Inconsistent with Hypothesis 2, there were no main effects of consumer group or condition, and no condition x consumer-group interaction on response latency bias for LCS beverage-related images relative to water-related images, all *Fs* < 1.553, all *ps*>.215.

Similarly, there were no main effects of consumer group or condition, and no condition x consumer-group interaction on response latency bias for LCS beverage-related images relative to SSB-related images, all *Fs* < 2.169, all *ps* >.143.

4.5. Interim Discussion

Study 3 found that frequent consumers of LCS beverages did not show greater energy intake following the craving exposure relative to the control exposure, despite reporting significant increases in chocolate craving (indicating activation of hedonic eating motivations). It is well-established that cue-induced craving is associated with subsequent increased eating (Belfort-DeAguiar & Seo, 2018; Boswell & Kober, 2016), and therefore it is meaningful that frequent consumers of LCS beverages did not exhibit this behavioural response in our study. Contrastingly, non-consumers consumed more calories in the craving condition relative to the control condition. Moreover, they showed a significant positive association between craving and energy intake while there was no evidence for this link in frequent consumers.

There were some notable differences between frequent and non-consumers; frequent consumers had significantly higher BMI, dietary restraint, body weight concerns and disinhibition relative to non-consumers. Given the strong relationship between disinhibited eating behaviours and exposure to palatable foods (Bryant, King & Blundell, 2008; Bellisle et al., 2004), we might expect that frequent consumers would be *more* susceptible to hedonic eating cues following the craving manipulation, However, this was not the case possibly because frequent consumers were able to satisfy their hedonic eating goal by consuming LCS beverages, whilst also pursuing their more long-term goal of weight management. However, against this idea, there was no effect of being in the craving-condition on LCS beverage intake in frequent consumers (i.e., we might expect them to consume *more* LCS beverages in the craving condition, relative to the control condition, if these beverages were being used to satisfy food cravings, but this was not the case).

A further novel finding was that frequent consumers showed an overall attentional bias towards images of LCS beverages, whereas non-consumers showed no evidence of this bias. Overall, these results suggest that frequent consumers are drawn towards LCS beverages over other beverages including SSB. In light of the recent controversy surrounding LCS beverages and whether they encourage a preference for sweet foods and beverages in the diet (Casperson et al., 2017; Sylvetsky & Dietz, 2014; Swithers & Davidson, 2008), our findings suggest that this attentional bias is specific to LCS beverages, rather than reflecting a more general bias towards sweet-tasting products.

In Study 4, we aimed to replicate the effect of the craving manipulation on energy intake in frequent consumers. We also aimed to determine whether this effect was due to LCS beverages being available for consumption (and thereby satisfying hedonic eating motives). In order to do this, we manipulated the availability of LCS beverages (available vs. unavailable) in the *ad libitum* eating context. We predicted that in the LCS unavailable condition, participants would show greater energy intake when in a state of craving relative to the non-craving control condition (i.e., mirroring the result found in non-consumers in Study 3). However, in the LCS available condition, we predicted that there would be no difference in food consumption between the craving and non-craving control condition (Hypothesis 1). We also explored the impact of LCS beverages on eating-related guilt, enjoyment of the meal, and perceived behavioural control. We predicted that, due to greater food consumption, in the LCS unavailable condition, participants would report higher guilt, lower meal enjoyment and lower perceived control in the craving condition relative to the control condition. However, in the LCS available condition, we predicted there would be no difference between the craving and control conditions (Hypothesis 2).

4.6. Study 4 Method

4.6.1. Participants

Participants (*N*=172) were a new group of frequent consumers of LCS beverages, as determined using the Appleton and Conner (2001) FFQ which was completed during an online pre-study screening questionnaire. In a 2 x 2 between-subjects design, participants were randomly allocated either to the craving or control condition, and the LCS available or LCS unavailable condition, generating four independent groups. We powered the study (80% power) using GPOWER 3.1 to detect a medium-large effect size (*f*=.35, on the basis of Study 1) at an alpha level of *p*=.05 and recruited the required sample (*N*=172) to detect a significant interaction between LCS availability and craving exposure in relation to food intake.

4.6.2. Measures and procedure

The overall method was the same as in Study 3, with the following changes.

1. As we were specifically interested in the effect of craving exposure and LCS availability on food intake in frequent consumers, we only recruited frequent consumers.
2. To investigate the effect of LCS availability on food intake in response to the craving manipulation (vs. control), LCS beverage availability was experimentally manipulated. During the *ad libitum* buffet, LCS beverages were either available with the snack food (available condition) or they were unavailable (non-available condition). Participants were offered one type of SSB (their preferred choice from Coke, Pepsi and Seven-up) and water in the unavailable condition, while in the LCS-available condition they had all three beverage types available (SSB, water and LCS beverages).
3. We did not have a specific hypothesis regarding attentional bias, however in order to maintain consistency between the two studies, participants completed the same VPT

with images of LCS, SSB and water beverages. The eye-tracking element was removed for ease of completion and only responses based on reaction times were collected. Results are provided in Appendix K.

4. Ratings of food-related self-control and guilt were obtained after the *ad libitum* buffet. Perceived control over food intake was measured by answering the following questions: "How much control did you feel you had over how much food you ate?", and "How in control did you feel about the food choices you made?" using a 100mm VAS. Rating across the two scales had relatively high internal consistency (α=.75), and thus scores were averaged to form one composite variable.
5. Eating-related guilt concerns were assessed by asking "do you feel guilty with the amount of food you have consumed?" and "Do you feel guilty with the types of food you have consumed?". Responses were indicated using 100mm VAS scale, ranging from "not guilty" to "extremely guilty". Ratings for guilt were combined into a composite variable, due to their high internal consistency (α=.83). All of these additional measures were presented, and responses recorded, on a laptop computer using Inquisit 3.0. (Millisecond Software, 2012).
6. Finally, after the *ad-libitum* food intake, ratings for meal enjoyment were obtained. Participants were asked to indicate how enjoyable they found the food. Responses were provided on a 100mm VAS scale, ranging from "not enjoyable at all" to "extremely enjoyable".

The experiment took approximately 60 minutes to complete.

4.6.3. Data analysis

Four separate 2(condition; craving vs. control) x 2 (group; LCS available vs. LCS unavailable) ANOVAs were conducted, on the following dependent variables: energy intake (Hypothesis 1), guilt, perceived behavioural control, and meal enjoyment (Hypothesis 2), with condition and group as between-subjects variables. We also conducted exploratory analyses to examine the effects of group (i.e. LCS available vs. LCS unavailable) on intake of specific food-types (i.e. sweet foods, savoury foods, beverages).

4.7. Study 4 Results

4.7.1. Participant characteristics

One-way ANOVAs revealed no differences between the experimental conditions with regard to age, BMI, restraint, emotional and external eating traits, indicating that all groups were evenly matched (*ps*>.105). Participant characteristics are provided in Table 4.2. A chi-square analysis confirmed that there was no difference in the number of males and females between conditions, $\chi^2(3)=3.81$, $p=.283$.

Table 4.2. *Descriptive statistics for LCS beverage (available vs. unavailable) and craving (vs. control) groups. Values are means with standard deviations in parentheses.*

Characteristic	Craving LCS available	Control LCS available	Craving LCS unavailable	Control LCS unavailable
N	43	43	43	43
Age (y)	29.05 (12.94)	27.00(9.48)	26.86(11.95)	28.16(12.66)
BMI (kg/m2)	26.94(4.67)	25.90(4.19)	27.36(3.97)	27.54(3.71)
DEBQ				
Restraint	3.25(.78)	3.15(.87)	3.16(.84)	3.25(.75)
Emotional	2.91(.91)	2.79(.84)	3.05(.81)	2.75(.76)
External	2.92(.85)	2.93(.73)	2.86(.91)	2.83(.75)

4.7.2. Craving manipulation

A mixed-ANOVA revealed a main effect of condition on craving for chocolate, $F(1,168)=51.08$, $p<.001$, $\eta_p^2=.23$, and a condition x time interaction, $F(2.25,378.92)=35.20$, $p<.001$, $\eta_p^2=.17$. Planned comparisons using t-tests revealed a significant difference in craving for chocolate between time-points T2 ($p<.001$; first craving exposure), T3 ($p<.001$; booster craving exposure), T4 ($p<.001$; end of VPT task) and T5 ($p<.001$; after food intake) but not at

T1 (p=.078), indicating that the manipulation was successful. There was no main effect of group (p=.562) or interaction between condition x time x group, F(2.25,378.92)=1.70, p=.179, η_p^2 =.01. This indicates that the effect of the craving manipulation over time was consistent in the LCS available and LCS unavailable groups (Figure 4.5). Please see Appendix J for results for appetite ratings of hunger, fullness and thirst.

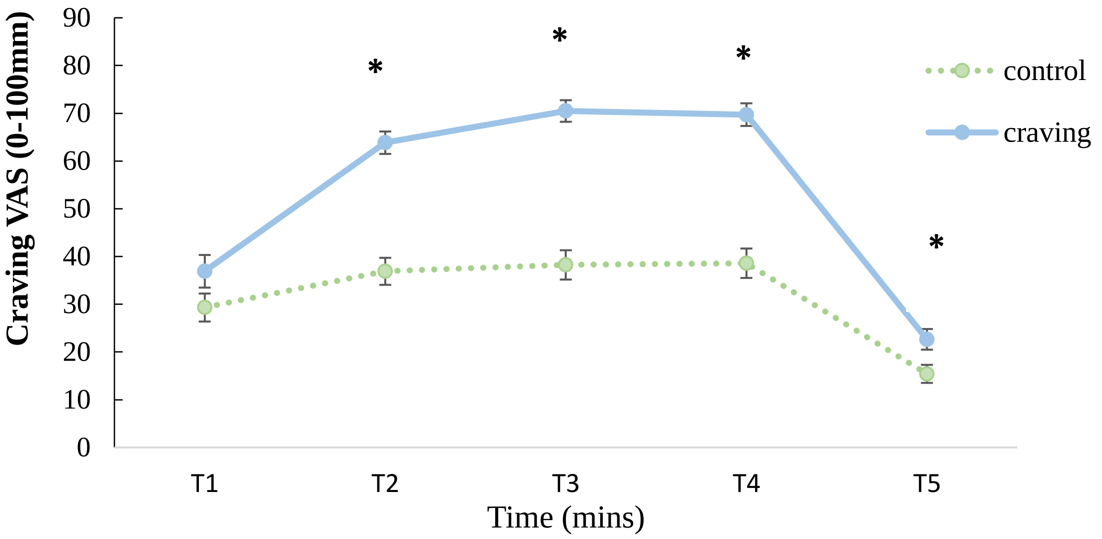


Figure 4.5. Ratings of craving for chocolate at each time-point in the craving and control condition conditions collapsed across the LCS available and LCS unavailable groups. Values are means and standard errors of the mean. *p<.001.

4.7.3. Energy intake

Inconsistent with Hypothesis 1, there was no significant interaction between condition and group on energy intake, F(1,168)=0.59, p=.808, η_p^2<.01. There was a main effect of condition, F(1,168)=6.64, p=.011, η_p^2=.04 (see Figure 4.6.); participants consumed significantly more overall in the craving condition relative to the non-craving control condition. There was also a main effect of group, F(1,168) =5.87, p=.016, η_p^2 =.03; participants consumed more calories overall when LCS beverage were unavailable (M=647.85 kcal ±332.19) relative to when they were available (M=516.80 kcal ±385.20).

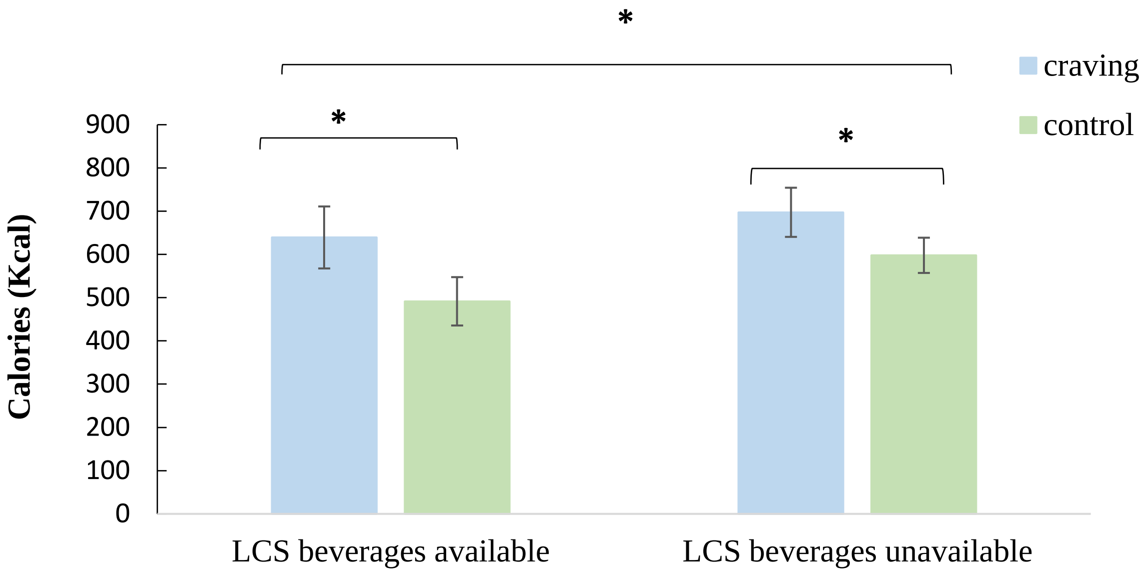


Figure 4.6. Mean energy intake in the craving and control conditions and in the LCS available and unavailable groups. *p<.05. Error bars represent standard error of the mean.

Correlational analyses revealed that there was no positive association between craving and energy intake in the LCS available group (r=.134, p=.219) or the LCS unavailable group (r= -.011, p=.923).

As expected, results revealed no effects of condition or group on response latency bias for LCS beverages-related images relative to water-related or sugar related images (see Appendix K for analyses conducted on the reaction time data for the VPT task).

4.7.3.1. Exploratory analysis on energy intake

To further explore the significant main effect of group (i.e. LCS available vs. LCS unavailable) on energy intake, we conducted a mixed ANOVA with group (LCS available vs. LCS unavailable) as the between-subjects factor and food type (sweet, savoury and beverages) as the within-subjects factor, and intake reported in kcal as the dependent variable (see also Appendix L for a breakdown of means for each food type in the different groups). There was no group x food type interaction, $F(1.72, 292.11)$ =.73, p=.485 η_p^2<.01. This indicates that the main effect of group on total energy intake was not driven solely by calories from sweet, or savoury foods, or beverages.

To further explore potential differences in the volumes of beverages consumed, we conducted a mixed-ANOVA, with condition (craving vs. control) and group (LCS available vs. LCS unavailable) as between-subjects factor and beverage type (SSB, water) as the within-subjects factor, and intake reported in ml as the dependent factor (it was not possible to include LCS beverages in this analysis due to them only being present in the available condition). There were main effects of beverage type, $F(1,167)=87.03$, $p<.001$, $\eta_p^2=.34$ and group, $F(1,167)=211.13$, $p<.001$, $\eta_p^2=.56$, and an interaction between group and beverage type, $F(1,167)=36.14$, $p<.001$, $\eta_p^2=.18$. Post-hoc t-tests revealed that participants drank SSB beverages (M=41.29ml; ±83.42) when LCS beverages were unavailable, but they did not consume any SSB (M=0.00ml ±0.00) in the available condition, $t(85)=-4.59$, $p<.001$. Furthermore, participants drank significantly more water (M=187.94ml; ±117.87) when LCS beverages were unavailable relative to the LCS available group, (M=31.71ml; ±57.74), $t(123.57)=-11.04$, $p<.001$. There was no main effect of condition or condition x group interaction (both *ps*>.230).

4.7.4. Perceived behavioural control

Inconsistent with our second hypothesis, there was no interaction between condition and group on perceived control over food consumed, and there was also no significant main effect of condition (both *ps*>.290). However, there was a main effect of group, $F(1,168)=15.36$, $p<.001$, $\eta_p^2=.08$; perceived behavioural control was significantly lower in the unavailable condition relative to the available condition (Figure 4.7.).

4.7.5. Guilt over food intake

Similar to behavioural control, and against our second hypothesis, there was no condition x group interaction on guilt over food consumed, (p=.332). There was a main effect of group, $F(1,168)=9.97$, p=.002, η_p^2=.06; guilt ratings were significantly higher in the unavailable condition relation to the available condition (Figure 4.7.). There was also a main effect of condition $F(1,168)=5.31$, p=.022, η_p^2 =.03; guilt ratings were significantly higher in the craving condition compared to the control condition.

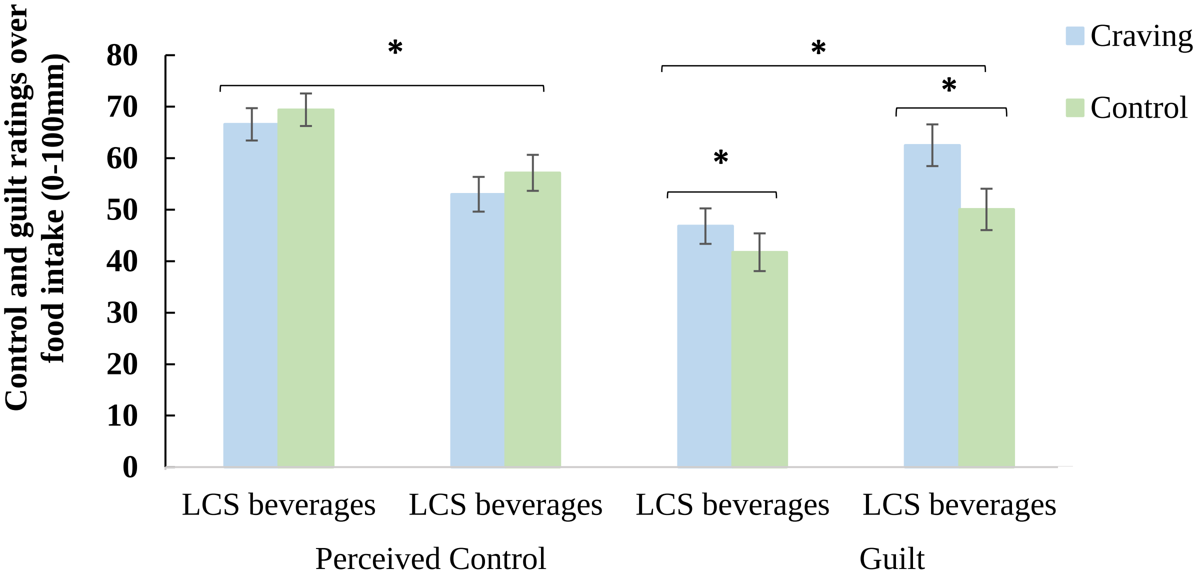


Figure 4.7. Mean perceived control and guilt over food intake ratings following *ad libitum* food intake in the available and unavailable conditions, *p<.05. Error bars represent standard error of the mean.

4.7.6. Meal enjoyment

There was no condition x group interaction or main effect of condition (both ps>.445). There was a main effect of group, $F(1,168)=5.57$, p=.019, η_p^2=.03, participants reported lower meal enjoyment in the unavailable condition (M=64.44 ±22.94) relative to the available condition (M=71.94 ±18.30).

4.8. Discussion

The present studies examined the impact of priming hedonic eating goals (i.e. craving for chocolate) on energy intake in frequent and non-consumers of LCS beverages. Study 3 aimed to determine whether frequent consumers would be protected from craving-induced increases in energy intake, whereas non-consumers were predicted to show greater energy intake in the craving condition relative to control condition. Results supported this prediction. A potential explanation is that, because LCS beverages were available for consumption in the *ad libitum* eating context, they may have satisfied the frequent consumers' craving for chocolate (however, there was no corresponding increase in LCS beverage intake in the craving condition, relative to the control condition, in frequent consumers). LCS beverages contain almost zero calories which would mean that participants could maintain their dieting goals and the presence of LCS beverages in the eating context may have further served as an additional diet prime. This is consistent with Papies and Hamstra's (2010) and Anschutz et al.'s (2008) work, illustrating that the subtle activation of a diet goal can motivate individuals to pursue it, even when surrounded by hedonic food cues. That non-consumers ate more following the craving exposure relative to the control exposure is not surprising given the substantial evidence indicating that exposure to palatable food cues increases food consumption (Boswell & Kober, 2016; van den Akker, Jansen, Frentz, & Havermans, 2013; Coelho, Polivy Herman & Pliner, 2009; Jansen et al., 2008). Study 3 thus supports the idea that LCS beverages may benefit some individuals, perhaps by subtly reminding them of their weight maintenance goals whilst helping to satisfy their desire for sweetness.

In Study 4, we directly manipulated the availability of LCS beverages in the context of the craving (relative to control) manipulation; however, we failed to replicate the protective effect of LCS beverages on craving-induced energy intake in frequent consumers. Participants ate more in the craving condition relative to control condition regardless of whether LCS beverages were available or unavailable indicating that the presence and consumption of LCS beverages was not sufficient to satisfy hedonic eating motivations. On this basis, it is not possible to conclude that LCS beverages reliably protect individuals from craving-induced increases in food consumption. The reason for the conflicting findings in the two studies is not clear. It is possible that there were differences between the samples of frequent consumers in Studies 3 and 4; however, inspection of the data indicates that these participant groups were similar on variables such as age, BMI, and eating behaviour traits. It is possible that the result in Study 3 is spurious, and further studies are needed in different populations to determine the reproducibility of this finding.

However, in Study 4 we did find that overall food intake was significantly higher when LCS beverages were unavailable relative to when they were available. Participants in the unavailable condition also reported lower perceived behavioural control (i.e., self-efficacy), lower meal enjoyment and higher eating-related guilt relative to the condition when LCS beverages were available. This indicates that when frequent consumers are able to consume these beverages, they feel more in control over their food intake and less guilty. This is important because previous research indicates that when food items become associated with negative emotions such as guilt, this can lead to feelings of helplessness and lack of control over eating (Kuijer & Boyce, 2014; Kuijer et al., 2015; Rozin, Bauer, & Catanese, 2003; Tangney et al., 2007). Food-related guilt may, in turn, lead to unhealthier food choices, impulsive eating and long-term weight gain (e.g., Macht, 2008; de Witt Huberts, Evers & de Ridder, 2013). Furthermore, literature has shown that an increase in guilt is likely to be accompanied by a decline in pleasure derived from eating (Lindeman & Stark, 2000; Macht & Dettmer, 2006; Macht, Gerer & Ellgring, 2003), which is consistent with our findings (i.e., higher guilt and lower meal enjoyment in the LCS-unavailable condition relative to the available condition).

An interesting finding was that participants had lower meal enjoyment in the LCS unavailable condition, relative to the available condition, despite consuming more food. This suggests that when frequent consumers do not have access to LCS beverages, they may feel their desire for sweetness is less satisfied and may subsequently consume more hedonically pleasing food as a way to satisfy this. Given the growing interest surrounding LCS beverages, our findings suggest that frequent consumers are perhaps more vulnerable to temptation and over-consumption when LCS beverages are unavailable. Therefore, LCS could play a meaningful role in reducing energy intake.

To our knowledge, Study 3 is the is the first to show that frequent LCS beverage consumers have an attentional bias towards LCS beverage-related cues relative to both sugar and water beverage cues as measured by eye-tracking, whereas no such bias was seen in the non-consumers. This finding supports previous research, suggesting that individuals selectively attend to environmental stimuli that are congruent with self-relevant concerns (Field et al., 2016; Kemps & Tiggemann, 2009). It also suggests that frequent consumers view LCS beverages as hedonically-desirable and that cues associated with LCS beverages are motivationally relevant to these individuals. The specific bias towards LCS beverages, rather than a bias towards other sweet beverages, is an important finding and suggests that frequent consumers' attentional bias is specific to LCS beverages rather than reflecting a general preference for sweet products. This lends support to initial evidence that exposure to sweet taste does not promote a subsequent preference for sweet products (Appleton et al., 2018).

In Study 3, we also predicted that attentional bias to LCS beverages would be amplified in the craving condition (i.e. when hedonic eating motivations were activated) relative to the control condition, consistent with Kemps and Tiggeman (2009). However, this was not supported. This lack of effect of craving exposure on attentional bias in the frequent consumers could be because these individuals are naturally drawn towards LCS-beverage stimuli which could create a ceiling effect. Notably, we used personalised stimuli so that the attentional bias towards each consumer's favourite LCS beverages was assessed. This is consistent with work by Christiansen et al. (2015) on the use of personalised stimuli to improve the internal reliability of attentional bias.

The present studies have several strengths and limitations. Notable strengths include the use of personalised LCS beverage-stimuli such that the task was tailored to the preferred LCS beverage of that individual. The research also employed direct measurement of food intake in a controlled laboratory setting. In Study 3, frequent consumers differed from non-consumers on BMI, disinhibition, restraint, and trait guilt, and in future research it would be advisable to include a control group of non-LCS beverage consumers who score highly on these characteristics. However, Study 4 addressed this by only recruiting frequent consumers and the experimental groups were matched on all measured variables. In terms of other limitations, participants were mostly British, with an overweight BMI. Therefore, the findings of this study cannot be generalized to other ethnicities, ages or more extreme BMI groups. The sample recruited was a university staff and student population who would have a higher than average level of education. Future research should recruit other sociodemographic groups to consider the generalisability of the current findings. This was a short term-study conducted in a laboratory context, therefore further research should establish the longer-term effects of whether LCS beverages are sufficient in satisfying hedonic eating motivations in real-world settings.

4.9. Conclusion

LCS beverages did not consistently protect consumers from craving-induced increases in food intake. However, frequent consumers consumed fewer calories overall when LCS beverages were available (relative to unavailable), as well as experiencing more control over their food intake, greater meal enjoyment and less guilt. These findings provide novel insight into the psychological mechanisms underpinning frequent consumption of LCS beverages in the context of their positive effect on weight, as has been shown elsewhere in the literature (Rogers et al., 2016).

Chapter 5: The effects of 7-day deprivation of low-calorie sweetened beverages on craving, energy intake and mood in frequent consumers

5.1. Abstract

Findings from Chapter 4 showed that 24-hour deprivation of LCS beverages resulted in greater food intake and eating-related guilt in individuals who frequently consume them. To extend these findings, the present study examined the psychological effects of longer-term LCS beverage deprivation on craving, energy intake and mood in frequent consumers in both a free-living and laboratory setting. Participants were randomised to either the LCS-deprived condition (*n*=48; instructed not to consume any LCS beverages for 7 days) or the non-deprived condition (*n*=48; instructed to consume food and beverages as normal for 7 days). During the period of deprivation, food cravings, appetite, mood, guilt and energy intake were measured on days 5, 6 and 7. Following the 7-day deprivation, food cravings, mood, and energy intake were also measured in the laboratory and compared across conditions. Main effects of time, deprivation, and the deprivation-by-time interaction were investigated for the variables of interest. **Results**: Food cravings increased over time for the deprived condition relative to the non-deprived condition. The deprived condition had higher overall energy intake (free-living), $F(1,94)=10.17$, $p=.002$, $\eta_p^2=.10$ and consumption of chocolate (laboratory), $F(1,94)=4.29$, $p=.041$, $\eta_p^2=.04$ relative to the non-deprived condition. Greater eating-related guilt in the deprived condition was found in both the free-living, $F(1,94)=16.59$, $p<.001$, $\eta_p^2=.15$ and laboratory setting, $F(1,94)=4.27$, $p=.042$, $\eta_p^2=.04$ compared to the non-deprived condition. Further, the deprived condition reported lower meal enjoyment $F(1,94)=5.73$, $p=.019$, $\eta_p^2=.06$ relative to the non-deprived condition in the free-living setting. The deprived condition also reported greater negative mood $F(2,188)=8.25$, $p<.001$, $\eta_p^2=.08$ on day 7 of the free-living setting and following the one-week deprivation at laboratory session 2 $F(1,94)=12.21$, $p<001$, $\eta_p^2=.12$, relative to the non-deprived condition. **Conclusion:** Deprivation of LCS beverages

resulted in increases in energy intake, craving, eating-related guilt, and greater negative mood compared to the non-deprived condition. These findings suggest that frequent consumers may be more vulnerable to overconsumption when these beverages are unavailable.

5.2. Introduction

Deprivation of a specific food (without an energy deficit) has been shown to induce craving for that food (Moreno-Domínguez, Rodríguez-Ruiz, Fernández-Santaella, Ortega-Roldán & Cepeda-Benito, 2012; Blechert, Naumann, Schmitz, Herbert & Tuschen-Caffier, 2014; Coelho Polivy & Herman, 2006; Komatsu, Kyutoku, Dan & Aoyama, 2015; Polivy, Coleman & Herman, 2005) and is consequently associated with low dieting success (Meule, Westenhöfer & Kübler, 2011). In this way, the hedonic effects of restricted intake of craved foods may undermine dietary adherence.

Consistent with this idea, our previous study (Chapter 4) explored the short-term effects of LCS beverage deprivation and found that overall food intake was lower in individuals who frequently consume these beverages. This suggests that, when LCS beverages are available, they may act as a "diet prime", subtly reminding consumers of their weight control thoughts and motivations thereby facilitating control over their eating behaviour. However, when LCS beverages are unavailable, people's hedonic motives may override their weight management goal, leading to a preferential processing of palatable food stimuli and subsequent loss of control over food intake. Indeed, exposure to highly palatable energy dense foods has been shown to activate the hedonic goal, while simultaneously inhibiting the cognitive representation of the dieting goal, leading to periods of disinhibition in restrained eaters (Papies et al., 2009; Fisher & Birch, 1999). Nevertheless, LCS beverages may allow some individuals to be "successful" restrained eaters by satisfying their hedonic goals and also increasing the accessibility of their weight control goal thereby preventing them from over-eating even when exposed to food cues. It could therefore be argued that the relationship between frequent consumers' food cravings and control over eating is moderated by the availability of LCS beverages.

Interestingly, in our previous study (Chapter 4), short-term deprivation of LCS beverages also resulted in lower perceived self-control and increased eating-related guilt. In support of this, diet-breaking has been shown to induce negative affect and self-criticism (Heatherton, 1993; Heatherton & Polivy, 1990) and may lead to further episodes of over-eating (Ruderman, 1986). Accordingly, examining the impact of LCS beverage deprivation on the psychological processes that guide consumption over time represents the next important step in understanding consumers' eating behaviour. Further, examining the triggers of cravings among consumers of LCS beverages and the typical strategies these individuals use to resist their cravings will help determine if LCS beverage consumption leads to more control over food intake and healthier food choices. As such, it will provide new insights into the ongoing debate about whether LCS beverages help or hinder consumers' weight management goals.

To date, the majority of research investigating deprivation of specific types of food has been performed under laboratory conditions (Komatsu et al., 2015; Moreno-Dominguez et al., 2012; Polivy et al., 2005). While this allows for increased levels of experimental control, using laboratory techniques alone, it is uncertain whether the eating behaviour observed will generalise to free-living eating behaviour. Thus, by measuring eating behaviour of frequent consumers of LCS beverages in their natural setting, it enables us to study changes in their craving, mood, food selection and motives.

Drawing on the above, the overarching goal of the present study was to extend our previous findings by examining the long-term effects of deprivation versus non-deprivation of LCS beverages in frequent consumers. Specifically, it aimed to determine whether deprivation of LCS beverages would be associated with a greater frequency of cravings and food intake, combined with a lower mood. Habitual self-reported measures of mood and intake were used in order to capture changes in these parameters in the natural environment. Similarly, measures of mood and food intake were taken in a laboratory setting to further examine these measures in a controlled setting, free from external influences typically present in the free-living environment. The following hypotheses were tested; (1) Self-reported food cravings (in both the free-living and controlled laboratory settings) would be higher in the LCS-deprived condition than in the non-deprived control condition. (2) Energy intake (in both the free-living and controlled laboratory settings) would be higher in the LCS-deprived condition than in the non-deprived control condition. As a result of this increase in energy intake (3) negative mood and guilt (in both the free-living and controlled laboratory settings) would be greater in the LCS-deprived condition than in the non-deprived control condition.

5.3. Method

5.3.1. Participants

Ninety-six university staff and students (mean age 27.5 ±11.54 y) were recruited from the University of Liverpool via poster and online advertisements. Prior to attending the laboratory session, participants were identified and classified as frequent consumers of LCS beverages if they reported consuming ≥825 ml LCS beverages/day according to the Food Frequency Questionnaire (FFQ) developed by Appleton and Conner (2001) (see Chapter 2, section 2.3.2.2. for a full description of this measure). In addition to being a frequent consumer of LCS beverages, inclusion criteria required that participants were non-smokers, had no food allergies or intolerances, were not currently taking medication that affects appetite and mood, or had never been diagnosed with an eating disorder. All participants completed an online screening questionnaire administered via Qualtrics prior to taking part to ensure they met the inclusion criteria. Those respondents who met the study's criteria were invited by e-mail to participate in the study.

On the basis of their responses to the screening questionnaire, frequent consumers of LCS beverages were randomly allocated to either the LCS deprived condition (*N*=48) or the non-deprived condition (*N*=48) in a between-subjects design. Ethical approval was granted by the University Research Ethics Committee and all participants gave written informed consent before participation. Participants received course credits or were reimbursed with a £25 shopping voucher as compensation for their time and travel expenses.

5.3.2. Measures

5.3.2.1. Overview of the study method

Figure 5.1. presents an overview of the study procedure. In a between-subjects design, participants were randomly allocated to either the LCS deprived condition (*N*=48) or the non-deprived condition (*N*=48). Participants in the LCS-deprived condition were asked not to consume any beverages containing LCS for 7 days.

Participants attended two laboratory sessions, 7 days apart. During the first session, measures of craving for sweet foods, mood, several trait measures of eating behaviour, and height and weight were assessed. Participants only in the deprivation condition were further told to refrain from consuming any diet beverages for the 7 days. A saliva sample was then obtained as part of the cover story (i.e., measuring hormones that are affected by sweeteners). Participants in the non-deprived condition were told to continue their habitual diet as normal.

During these 7 days, all participants recorded their food intake (see Appendix M for details of the food diary) and completed measures of mood, guilt, control and craving for sweet foods on days 5, 6 and 7. To ensure a high burden was not placed on participants, free-living measures were only completed on days 5 to 7 of the free-living period.

All participants then attended the second laboratory session, and participants in the deprived condition were asked to confirm that they complied with their instructions (i.e., did not consume any LCS beverages). All participants completed measures of craving for sweet foods, mood, craving for chocolate and whether they substituted any foods over the seven days. Their second saliva sample was obtained in line with the cover story. Participants then completed an anagram task, followed by a bogus taste test consisting of chocolate. Finally, another measure of craving was taken, and guilt, control over food intake and body weight were assessed.

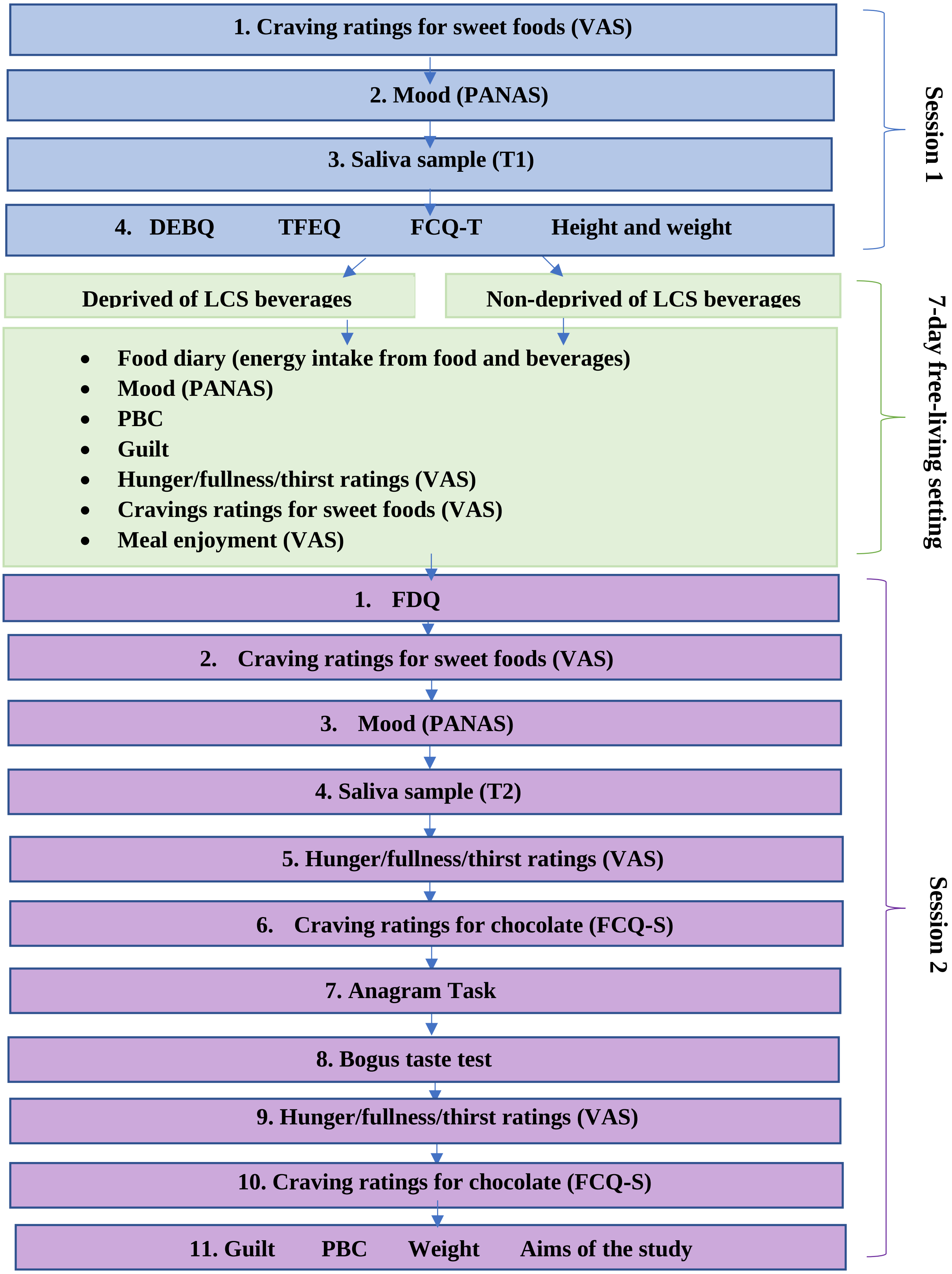


Figure 5.1. Flow chart in order of the procedure in session 1, free-living setting* and session 2. DEBQ= Dutch Eating Behaviour Questionnaire. TFEQ= Three Factor Eating Behaviour. FCQ-T-r=Food Craving Questionnaire-Trait-reduced. PANAS= The Positive and Negative Affect Scales. PBC=Perceived behavioural control. FDQ=Food Desirability Questionnaire. FCQ-S= The Food Cravings Questionnaire-State. *Free-living measures were only completed on days 5-7 of the free-living period.

5.3.2.2. Appetite ratings

Levels of hunger, fullness, and thirst were assessed using 100mm Visual Analogue Scales (VAS). Each scale was anchored by 'Not at all' on the left and 'Extremely' on the right.

5.3.2.3. Craving for sweet foods

Subjective measures of state craving for sweet foods were assed using Visual Analogue Scales (VAS). In the laboratory, participants were asked to rate "how strong is your craving for sweet foods?", ranging from "Not at all" to "Extremely strong". Participants also rated "How strongly did you crave sweet food today?" using visual analogue scales (100 mm), from "Not at all" to "Extremely" in their free-living setting. Participants were required to indicate their craving for sweet foods during both laboratory sessions and on days 5 to 7 of the free-living period at the end of the evening while logging their food diary.

5.3.2.4. Energy intake (free-living setting only)

Energy intake was recorded during the free-living period (i.e. between the laboratory sessions one and two), where participants were asked to record the type, quantity of every food and beverage they ate and drank over three days (days 5-7) in an electronic food diary. Participants were fully briefed on how to complete the diaries, and a written example of a diary was given to participants to take away. They received a daily email with a link on Qualtrics (specific to them) to complete their food diary. Using the food diary (see Appendix M, for more details), they were asked to record the time of consumption, foods consumed, brand (where appropriate), and the approximate quantity of food and drink consumed over the entire day. The intention of the diary was to locate food craving experiences relative to eating episodes rather than as a measure of food intake. Energy intake and in particular consumption of energy dense foods were entered into the nutritional analysis software NetWISP version 4.0 (Weighed Intake Software Program; Tinuviel Software, Warrington, UK). This software utilises the food composition database from the 6th edition of the McCance and Widdowson's food composition tables (Food Standards Agency, 2002). The Composition of Foods is widely acknowledged as the primary reference tool for examining the nutritional value of foods consumed in the UK (Robertson, 2003).

5.3.2.4.1. Snack foods (free-living setting only)

Snack foods were distinct from foods which were eaten as part of a meal. Participants were asked to record the snacks they ate that day in a separate section to their breakfast, lunch and dinner. These foods were subsequently classified as “snacks”.

5.3.2.4.2. Beverage intake (free-living setting only)

From the food diaries, beverage intake was quantified. Four mutually exclusive beverage categories were identified: (1) LCS beverages (including diet beverages, diet sport drinks, low-calorie fruit drinks and punches, tea sweetened with sweeteners, and other artificially sweetened beverages; following the Appleton and Connor questionnaire, (2001)). (2) SSBs (including carbonated sugar drinks (i.e., coke), sport drinks, fruit drinks and punches, sweetened tea, and other sweetened beverages). (3) Other drinks, this included 100% fruit juice, unsweetened tea, coffee, alcoholic and other beverages. (4) Water (including plain tap water, water from a drinking fountain, water from a water cooler, bottled water, and spring water). We also quantified the total weight of beverages and water in kcal and mls.

5.3.2.5. Bogus taste test (laboratory only)

The "bogus taste test" technique (Robinson et al., 2017) was used to measure food intake in the laboratory following the 7-day period of deprivation (or non-deprivation). For the taste test, participants were provided with a selection of popular chocolate foods, consisting of a 120g bowl of Maltesers (503kcal/100g, 24.6g fat/100g), a 130g bowl of Minstrels (498kcal/100g, 21.9g fat/100g), a 90g bowl of Maryland cookies (491kcal/100g, 22.1g fat/100g) and a 120g bowl of Tesco Chocolate brownie bites (394.1kcal/100g, 15g fat/100g).

Taste ratings were provided on 100-mm visual analogue scales in order to rate the chocolate for pleasantness, strength of flavour and crunchiness (e.g. how sweet, crunchy?). All scales were anchored with ‘Not at all’ on the left and ‘Extremely’ on the right. Participants were left alone for 10 minutes to taste and complete these ratings for each type of chocolate. To assess food intake, bowls were covertly weighed before and after participants completed the taste task. Grams consumed were converted into energy intake (calories) for each food.

5.3.2.6. Questionnaires

The Positive and Negative Affect Scales: (PANAS; Watson, Clark, & Tellegen, 1988) was administered to measure positive and negative affect (mood) during both laboratory sessions and in the free-living environment. Participants rated the extent to which a number of questions matched their present state (happy, hungry, tired, anxious and alert). This 20-item checklist uses a five-point Likert scale rated from “Not at all” to “Extremely”. The scales are highly internally consistent, largely uncorrelated, and stable over a two-month period (Watson et al., 1988). The PANAS is widely used and has identified reliable decreases in positive affect and/or increases in negative affect following experimental mood manipulations (e.g. Oliver, Wardle & Gibson, 2000; Wallis & Hetherington, 2009). Internal consistency was α=.76 for PANAS-positive and α=.73 for PANAS-negative in the current study.

Food Desirability Questionnaire: Participants were asked to complete a questionnaire during lab session two (modified from Weingarten and Elston 1990) about their food cravings over the past 7 days (i.e., ‘‘To what extent do you experience intense desires to eat and drink specific foods and beverages?’’). Participants answered with respect to a short list of food and beverages including chocolate, LCS and sugar-sweetened beverages. Participants rated from 1 “Not at all” to 5 “Extremely” the extent to which they experienced cravings for that specific food or beverage over the past 7 days. The questionnaire also asked about substitutions for craved foods (i.e. "When you are experiencing a craving for the food you crave the most, is there any other food which would satisfy that craving?").

The Food Cravings Questionnaire-State: (FCQ-S; Meule & Hormes, 2015) was used to measure the intensity of current chocolate craving in laboratory session 2, at pre and post bogus taste test. Its 15 items (e.g., "I have an intense desire to eat chocolate.") are scored on a 5-point scale "Strongly disagree" to "Strongly agree". Internal consistency was α =.91 in the current study.

5.3.2.7. Food enjoyment

Participants rated their meal enjoyment by answering "How enjoyable did you find the food?" when recording their food intake into their food diary on days 5 to 7 of the free-living period. Participants recorded their responses on a 100mm VAS scale from "Not enjoyable at all" to "Extremely enjoyable".

5.3.2.8. Perceived behavioural control

Ratings of food-related self-control was obtained at the end of each of the free-living measurement days (i.e. days 5-7) and after the taste test in laboratory session 2. For full details of this measure, please see Chapter 4, (section 4.6.2.). Rating across the two scales had relatively high internal consistency (α =.77), scores were then averaged to form one composite variable. Perceived behavioural control ratings were presented, and responses recorded, on a laptop computer using Inquisit 3.0 software (Millisecond Software, 2012).

5.3.2.9. Eating-related guilt

Participants rated how guilty they felt at the end of each day (i.e. days 5, 6 and 7) in their free-living setting and at end of the taste session in laboratory session 2 (please refer to Chapter 4, section 4.6.2. for further details). Responses were indicated using 100mm VAS scale, ranging from "Not guilty" to "Extremely guilty". Ratings for guilt were combined into a composite variable, due to their high internal consistency (α=.81). All of these additional measures were presented, and responses recorded, on a laptop computer using Inquisit 3.0. (Millisecond Software, 2012).

5.3.2.10. Additional measures and eating trait questionnaires

The following questionnaires were used to provide descriptive information about the sample and ensure there were no trait differences between the conditions. The Dutch Eating Behaviour questionnaire (DEBQ; van Strien et al., 1986) and the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985) were used to measure restrained and disinhibited eating respectively. These scales assess eating patterns directly related to body weight (see Chapter 2, section 2.3.2.3. for a full description of these measures).

The Food Cravings Questionnaire-Trait-reduced: (Meule & Hormes, 2015) was used to measure the frequency and intensity of food craving experiences in general. It consists of 15 items (e.g., "I find myself preoccupied with food.", "If I eat what I am craving, I often lose control and eat too much."). The instructions of the FCQ-T asked how frequently each statement 'would be true for you in general' using a 6-point scale that ranges from "Never/not applicable" to "Always". Higher scores indicate more frequent and intense food craving experiences and has been shown to have high retest-reliability over a six months period (Meule, et al., 2014). Internal consistency was α =.85 in the current study.

5.3.3. Procedure

See Figure 5.1. and section 5.3.2.1 for an overview of the study procedure. Participants were required to attend two study sessions, 1 week apart. Testing took place in the Department of Psychological Sciences on the University of Liverpool campus. All sessions were conducted between 12-6pm. Informed consent was obtained upon arrival and participants were randomly assigned to one of two experimental conditions (deprived of LCS beverages or non-deprived of LCS beverages) for a 7-day period. Participants indicated their current level of food craving for sweet foods (VAS) and the PANAS to measure their mood. Participants were then given an information pack. All participants were told the cover story that we are interested in the relationship between number of hormones including *insulin, glucagon-like peptide-1* (GLP-1), *peptide YY* (*PYY*) and mood. Participants only in the deprivation condition were further told that these hormones are affected by sweeteners and were therefore asked to refrain from consuming any diet beverages for the 7 days. Participants in the deprived condition were also told that the study would measure their hormone levels using saliva samples (to ensure compliance) and this would be measured again in 7 days. Participants subsequently gave their first saliva sample. All participants then completed the DEBQ and TFEQ to measure dietary restraint and disinhibition. They also completed the Food Cravings questionnaire Trait (FCQ-T). Height and weight were measured at the end of the first session.

Participants assigned to the LCS-deprived condition were asked to refrain from consuming any diet beverages for seven days, while the non-deprived condition were asked to continue with their habitual diet as normal. All participants were requested to record their food intake using a food diary administered on Qualtrics at the end of each day on days 5, 6 and 7. They were asked to rate the strength of their cravings for sweet foods on that day using the 100-mm VAS measure. Visual analogue scales (100 mm) were also used for participants to rate their overall hunger, fullness and thirst levels on each day. Additionally, eating-related guilt, perceived behavioural control and meal enjoyment were assessed at the end of each day using a VAS-100 mm. Participants also completed the PANAS at the end of each day to measure their overall mood throughout the day. Each participant received daily reminders by email to complete their food and behavioural logs.

Participants attended the laboratory for their second session 7 days after the first session. Participants were asked to not eat for at least 3 hours prior to the session and they had to confirm their compliance with this instruction at the start of the session. The LCS-deprived condition were also asked to confirm that they did not consume any LCS beverages for the 7 days. Participants then completed the Food Desirability Questionnaire regarding their food cravings over the past 7 days. VAS ratings were also obtained for cravings for sweet foods, and the PANAS was administered to measure mood. A second saliva sample was then obtained in line with the cover story. Participants also completed current hunger, fullness and thirst VAS and FCQ-S to measure craving specifically for chocolate. Next, participants were told that they were going to taste some food items and rate them on various dimensions. Participants were informed that the purpose of the task was to assess their taste perception of the chocolate foods. Before participants were presented with the food, they were asked to work on a short task (75 anagrams). Following the protocol of Polivy et al. (2005), the participants were told: “We need to see how long this task remains absorbing, fun, or difficult. Please work on as many as you like. The foods that you are going to taste are ready so please ring this bell whenever you are ready for me to bring them in”. The experimenter measured how quickly the participant rang the bell. It was expected that the deprived condition would crave the food more and grow tired of the task earlier than the non-deprived condition.

Participants were then asked to complete the taste test. They completed taste ratings for each food item in a set time period. They were informed that once they had completed the ratings, they would be free to help themselves to more after completing the ratings, as long as they did not change them. Participants were left alone for 10 min to complete these ratings (and eat), after which time the experimenter returned and removed the food items (which were weighed), while leaving a questionnaire assessing current VAS ratings for hunger, fullness and thirst. Craving for chocolate (FCQ-S) was measured again (i.e. post-taste test). Eating-related guilt and perceived behavioural control were also measured following the taste session. The amount consumed of each food (in g) was measured by weighing the bowls before and after the taste test. To ensure the absence of demand characteristics, participants were asked to indicate what they thought the aims of the study were. Participants' weight was taken and then participants were debriefed.

5.3.4. Data analysis

5.3.4.1. Craving (hypothesis 1)

In the free-living setting, a 2 x 3 mixed design ANOVA was conducted with craving for sweet foods (VAS) as the dependent variable, condition (LCS deprived vs. LCS non-deprived) as the between-subjects factor, and time (day 5 vs. day 6 vs. day 7) as the within-subjects factor. In the laboratory setting, a 2 x 2 mixed design ANOVA was conducted with craving for sweet foods (VAS) as the dependent variable, condition (LCS deprived vs. LCS non-deprived) as the between-subjects factor, and time (session 1 vs. session 2) as a within-subjects factor.

5.3.4.2. Energy intake (hypothesis 2)

The amount (in g) of food consumed was converted into calories. For the free-living setting, a 2 x 3 mixed design ANOVA was conducted, with condition (LCS deprived vs. LCS non-deprived) as the between-subjects factor and time (day 5 vs. day 6 vs. day 7) as the within-subjects factor and total energy intake as the dependent variable. We also conducted exploratory analyses to examine the effects of condition on intake of specific food-types (i.e. snack foods, beverages).

For the laboratory assessment of food intake (i.e. taste test), a one-way ANOVA on total energy intake was conducted, with condition (LCS deprived vs. LCS non-deprived) as the between-subjects factor and total energy intake as the dependent variable.

5.3.4.3. Mood and guilt (hypothesis 3)

For the free-living setting, negative mood (PANAS) and guilt (VAS) were analysed in a repeated measures MANOVA, with condition (LCS deprived vs. LCS non-deprived) as the between-subjects factor and time (day 5 vs. day 6 vs. day 7) as the within-subjects factor and negative mood and guilt as the dependent variables.

In the laboratory setting, a 2 x 2 mixed design ANOVA was conducted with condition (LCS deprived vs. LCS non-deprived) as the between-subjects factor and time (session 1 vs. session 2) as a within-subjects factor, and mood as the dependent variable. Guilt was only measured in the second laboratory session, following the taste test. Therefore, a one-way ANOVA was conducted with condition (LCS deprived vs. LCS non-deprived) entered as the between-subjects factor and guilt as the dependent variable.

5.3.4.4. Supplementary analysis

Differences between conditions in perceived behavioural control were explored in the free-living setting, using a 2 x 3 mixed design ANOVA, with condition (LCS deprived vs. LCS non-deprived) as the between-subjects factor, time (day 5 vs. day 6 vs. day 7) as the within-subjects factor and perceived behavioural control (VAS) as the dependent variable. Additionally, meal enjoyment differences were also explored in the free-living setting, with condition (LCS deprived vs. LCS non-deprived) entered as the between-subjects factor, time (day 5 vs. day 6 vs. day 7) and meal type (breakfast vs. lunch vs. dinner vs. snack) as the within-subjects factor and meal enjoyment ratings (VAS) as the dependent variable

In the laboratory session 2, condition differences in craving specifically for chocolate (FCQ-S) were explored using a 2 x 2 mixed design ANOVAs. For each analysis, time (pre taste test vs. post taste test) was entered as the within-subjects factor, and condition (LCS deprived vs. LCS non-deprived) was entered as the between-subjects factor and craving for chocolate (FCQ-S) was the dependent variable.

In addition, for laboratory session 2, one-way ANOVA's were also conducted to compare the conditions on latency to eat (i.e. time taken for the anagram task) and perceived behavioural control, with condition (LCS deprived vs. LCS non-deprived) as the independent variable, latency to eat and perceived behavioural control ratings were entered as dependent variables.

5.3.4.4.1. General food cravings

In laboratory session two, participants answered with respect to a short list of food and beverages including chocolate, LCS beverages, sugar-sweetened beverages and substitutions for craved foods. A MANOVA was used to look at differences between conditions on cravings for specific foods, with condition (LCS deprived vs. LCS non-deprived) entered as the between-subjects factor and craving for chocolate, LCS, sugar-sweetened beverages and substitutions for craved foods as the dependent variables.

5.3.4.4.2. Hunger, thirst and fullness

Differences in appetite ratings were explored in the free-living environment using a 2 x 3 mixed design ANOVA, with condition (LCS deprived vs. LCS non-deprived) as the between-subjects factor and time (day 5 vs. day 6 vs. day 7) as the within-subjects factor and hunger, fullness and thirst (VAS) as the dependent variables. In laboratory session 2, hunger, thirst and fullness ratings were analysed using 2 x 2 mixed design factorial ANOVAs. Time (before and after the taste test) was the within-subjects factor, and condition (LCS deprived vs. LCS non-deprived) was the between-subjects factor and hunger, thirst and fullness ratings were the dependent variables.

5.4. Results

5.4.1. Participant characteristics

Due to difficulties in complying with the protocol, 7 participants from the deprived condition and 1 from the non-deprived condition withdrew from the study. 1 participant informed us that they did consume LCS beverages and was subsequently removed from the study. An additional 9 participants were recruited to replace them. All participants in the deprived condition confirmed during session 2 that they complied with their instructions (i.e., did not consume any LCS beverages). No participants correctly guessed the aims of the study. Participant characteristics of both conditions are presented in Table 5.1. Independent samples t-tests confirmed that there were no differences between conditions with regards to age, BMI, restraint, emotional eating, external eating, disinhibition or trait craving (*ps*>.283). A chi-squared test showed that there were no significant differences in the number of males and females between conditions, $\chi(1) = .057$, $p=.811$.

Table 5.1. *Descriptive statistics of each condition. Values are means with standard deviations in parentheses*

Variable	**LCS deprived (n=48)**	**Non-LCS deprived (n=48)**	***p***
Age (y)	26.04 (10.70)	28.25(12.33)	.351
DEBQ			
Restraint	3.31(.78)	3.21(.84)	.573
Emotional	2.69(.93)	2.82(.87)	.483
External	3.56(.58)	3.54(.52)	.883
TFEQ			
Disinhibition	8.35(2.31)	8.02(2.29)	.480
FCQ-Trait-r	48.08(12.70)	45.48(10.88)	.283
Chi-square			
Gender %	23M 77F	25M 75F	.811

DEBQ= Dutch Eating Behaviour Questionnaire. TFEQ= Three Factor Eating Behaviour. FCQ-T-r=Food Craving Questionnaire-Trait-reduced. Deprived LCS beverage consumers vs. non-deprived LCS beverage consumers.

5.4.2. Craving (hypothesis 1)

In the free-living setting, a 2 x 3 mixed ANOVA revealed a main effect of condition on cravings for sweet foods, $F(1,94)=39.19$, $p<.001$, $\eta_p^2=.29$; the LCS-deprived condition's cravings for sweet foods were significantly higher compared to the non-deprived condition. There was no main effect of time ($p=.205$), however there was a condition x time

$F(2,188)=3.08$, $p=.048$, $\eta_p^2=.03$. Post-hoc tests revealed that the deprived condition reported higher cravings (M=62.44 mm; ±18.96) for sweet foods on day 5 $t(94)=3.29$, $p=.001$, $d= 0.67$, day 6 (M=68.79 mm; ±20.79), $t(94)=4.83$, $p<.001$, $d= 0.97$ and day 7 (M=73.60 mm; ±22.96), $t(94)=5.30$, $p<.001$, $d=1.08$ compared to the non-deprived condition (day 5: M=49.42 mm; ±19.84; day 6: M=46.44 mm; ±24.40; day 7: M=47.53 mm; ±25.08) see Figure 5.2.

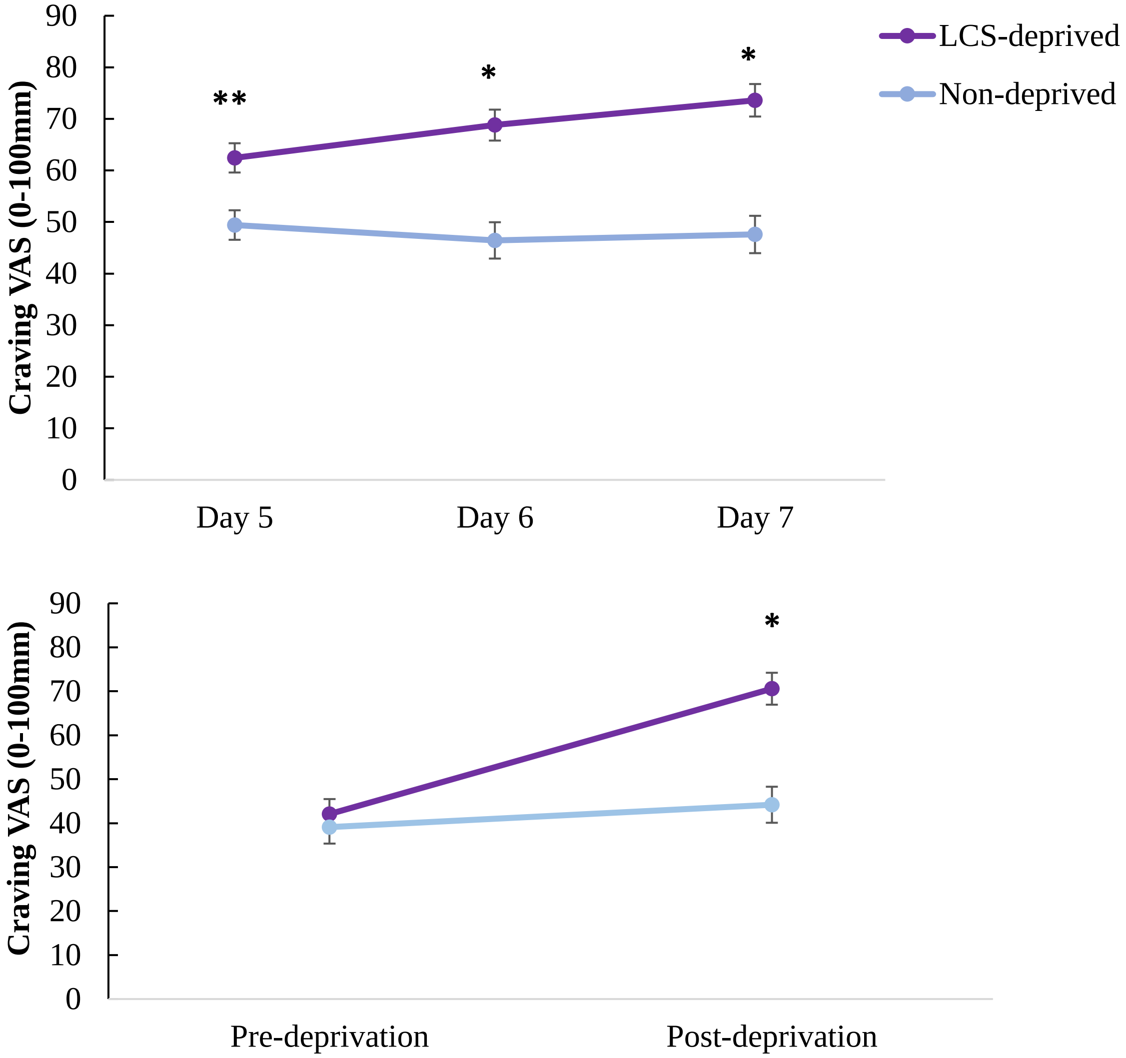


Figure 5.2. Mean craving ratings by condition in free-living (Panel A) and laboratory (Panel B), *significant at *p*<.001,**significant at *p*<.05. Error bars are standard error of the mean.

Similarly, in the laboratory setting, an ANOVA revealed a main effect of condition, $F(1,94)=13.06$, $p<.001$, $\eta_p^2=.12$ and a main effect of time on craving for sweet foods $F(1, 94)=24.41$, $p<.001$, $\eta_p^2=.21$. In addition, there was also a condition x time interaction,

$F(1,94)=12.13$, $p=.001$, $\eta_p^2=.11$. Post-hoc independent t-tests revealed that there was no difference in craving for sweet foods between conditions before deprivation (i.e. laboratory session 1) ($p=.678$). However, the deprived condition (M=70.57 mm; ±25.14) reported higher craving for sweet foods at post-deprivation (laboratory session 2) compared to participants in the non-deprived condition (M=44.19 mm; ±28.37), $t(94)=4.83$, $p<.001$, $d=0.99$.

5.4.3. Energy intake (hypothesis 2)

In the free-living environment, the 2 x 3 mixed ANOVA revealed a main effect of condition on daily energy intake, $F(1,94)=10.17$, $p=.002$, $\eta_p^2=.10$; the LCS-deprived condition (M= 2276.82 kcal; ±550.30) reported consuming a higher mean daily energy intake relative to the non-LCS deprived condition (M=1982.53 kcal; ±333.43) (Figure 5.3.). There was no main effect of time on energy intake or condition x time interaction, both *Fs* < 1.17, both *ps* > .313.

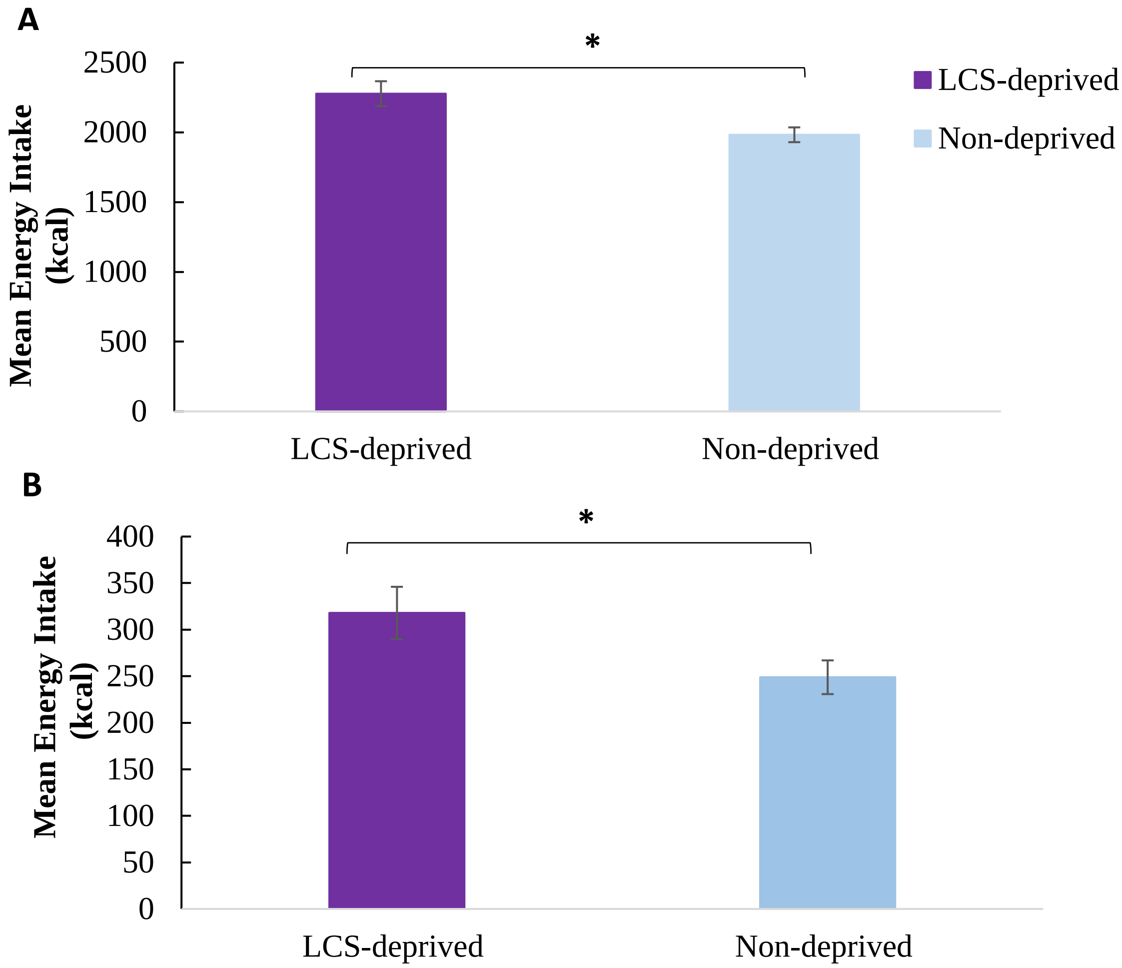


Figure 5.3. Mean energy intake in the free-living environment (panel A) and laboratory (taste test) (panel B) for the LCS-deprived condition and non-deprived conditions, *p<.05. Error bars are standard error of the mean.

Similarly, in the laboratory context, participants in the LCS-deprived condition (M =317.96 kcal; ± 194.40) consumed significantly more calories during the taste task compared to the non-deprived condition (M = 248.89kcal; ± 125.42), $F(1,94)=4.29$, $p=.041$, $\eta_p^2=.04$.

5.4.3.2. Exploratory analyses on energy intake (free-living context)

To further explore the effects of deprivation of LCS beverages on free-living energy intake, a 2 x 2 x 3 mixed design ANOVA was conducted with condition (LCS deprived vs. LCS non-deprived) as the between subjects factor and snack type (sweet, savoury) and time (day 5 vs. day 6 vs. day 7) as the within-subjects factors, and intake reported in kcal as the dependent variable. There was a main effect of condition, $F(1,94)=6.67$, $p=.013$, $\eta_p^2=.07$. However, there was no main effect of snack type, main effect of time or condition x time interaction, all $Fs < 2.87$, all $ps > .093$. Additionally, there was no snack type x time interaction or condition x snack type x time interaction, both $Fs < 1.34$, both $ps > .264$. There was however, a condition x snack type intake interaction, $F(1,94)=3.93$, $p=.050$, $\eta_p^2=.04$. Follow-up t-tests revealed that the deprived condition consumed significantly more calories overall from sweet snack foods (M=191.26 kcal; ±145.80) relative to the non-deprived (M=106.67 kcal; ±106.76) condition, $t(86.15)=3.24$, $p=.002$, $d=0.66$. There was no difference in consumption of savoury snack foods between conditions ($p=.480$).

5.3.3.3. Exploratory energy intake; beverage intake

To explore potential differences in the calories of beverages consumed, we conducted a mixed-ANOVA, with condition (deprived vs. non-deprived) as the between-subjects factor and beverage type (SSB and other drinks) and time (day 5 vs. day 6 vs. day 7) as the within-subject factors, and beverage intake reported in kcal as the dependent variable (it was not possible to include LCS beverages in this analysis due to the deprived condition not having access to them). Analysis revealed a main effect of time, $F(1.83,171.86)=3.46$, $p=.034$, $\eta_p^2=.04$ and a main effect of condition, $F(1,94)=8.34$, $p=.005$, $\eta_p^2=.08$. However, there was no condition x time interaction ($p=.290$). There were main effects of beverage type, $F(1,94)=17.44$, $p<.001$, $\eta_p^2=.15$ and a condition x beverage type interaction, $F(1,94)=4.02$, $p=.048$, $\eta_p^2=.40$. Post-hoc t-tests revealed that participants in the deprived condition drank significantly more calories from SSB beverages (M=97.17 kcal; ±109.56) in comparison to the non-deprived condition (M=13.63 kcal; ±32.73), $t(55.32)=5.06$, $p<.001$, $d=1.02$. There was no difference in consumption of other beverages between the conditions, ($p=.743$). Finally, there was no condition x beverage type x time interaction, ($p=.149$).

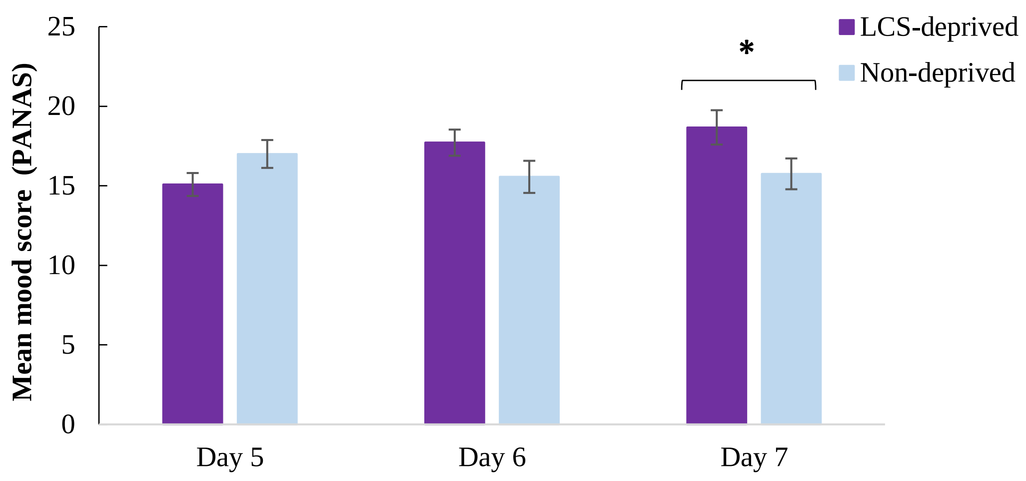
5.4.4. Self-perceived mood and guilt (hypothesis 3)

Free-living setting. A repeated measures MANOVA was used to determine if negative mood (PANAS) and guilt (VAS) were higher in the LCS-deprived condition compared to the non-deprived control condition (between-subjects factor) with time (day 5 vs. day 6 vs. day 7) as the within-subject factor. The MANOVA revealed an overall effect of condition for mood and guilt, $F(4,372)=4.13$, $p=.003$, $\eta_p^2=.42$.

Both negative mood and eating-related guilt were decomposed separately. There was no main effect of condition for negative mood, $F(1,94)=.95$, $p=.331$, $\eta_p^2=.01$ and no main effect of time ($p=.192$). However, there was a condition x time interaction, $F(2,188)=8.25$, $p<.001$, $\eta_p^2=.08$. Post-hoc tests revealed that participants in the deprived condition (M=18.67 mm; ±7.50) reported greater negative mood on day 7 compared to the non-deprived (M=15.75 mm; ±6.72) condition, $t(92.88)=2.01$, $p=.048$, d=0.41 (Figure. 5.4., panel A). There was no difference in negative mood between conditions on days 5 or 6 (*ps*>.094). See Appendix N for positive mood analysis.

There was a main effect of condition on eating-related guilt, $F(1,94)=16.59$, $p<.001$, $\eta_p^2=.15$, participants in the deprived condition (M=52.74 mm; ±16.39) reported higher overall guilt relative to the non-deprived condition (M=37.74 mm; ±19.53), see Figure 5.5., panel A. However, there was no main effect of time or condition x time interaction on guilt ratings, both *Fs* < 1.07, both *ps* >.345.

A



B

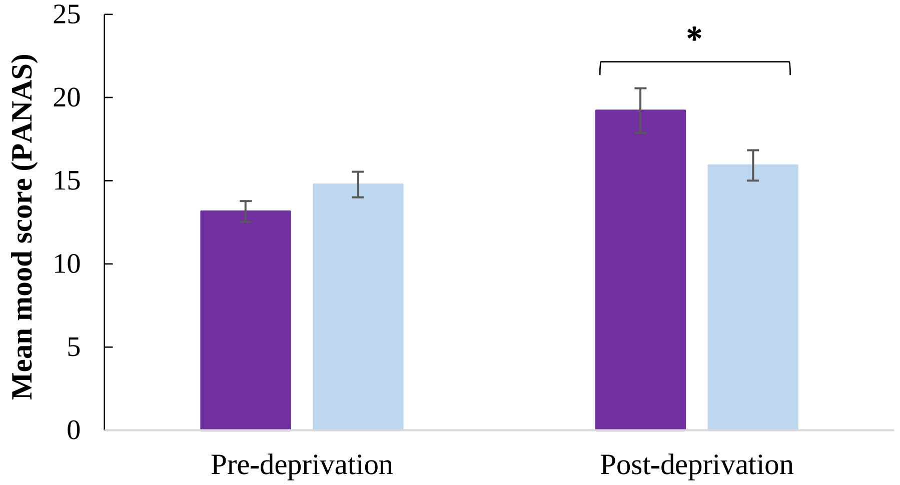


Figure 5.4. Mean negative mood ratings by condition in free-living (Panel A) and laboratory (Panel B), *significant at $p<.05$. Error bars are standard error of the mean.

Laboratory setting. A repeated measures ANOVA was conducted with state measures of negative mood as the dependent variables and time (session 1 vs. session 2) as the within-subjects factor and condition (LCS-deprived vs. LCS non-deprived) as the between-subjects factor. There was no main effect of condition on negative mood, $F(1,94)=1.22$, $p=.272$, $\eta_p^2=.01$. However, there was a main effect of time, $F(1, 94)=24.18$, $p<.001$, $\eta_p^2=.21$, and a time x condition interaction $F(1,94)=12.21$, $p<.001$, $\eta_p^2=.12$. Follow-up t-tests revealed that negative mood was significantly higher at session 2 (i.e. post-deprivation) in the deprived condition (M=19.92 mm; ±9.26) compared to participants in the non-deprived (M=15.92 mm; ±6.33) condition, $t(83.04)=2.47$, $p=.016$, $d= 0.50$ (Figure 5.4., panel B), while there was no difference in negative mood at session 1 (i.e. *pre*-deprivation) between conditions ($p=.104$).

A one-way ANOVA revealed that the LCS-deprived condition (M=51.00; ±17.90) reported significantly higher guilt over food consumed relative to the non-deprived condition (M=42.85; ±20.85) following the taste test, $F(1,94)=4.27$, $p=.042$, $\eta_p^2=.04$, see Figure 5.5., panel B.

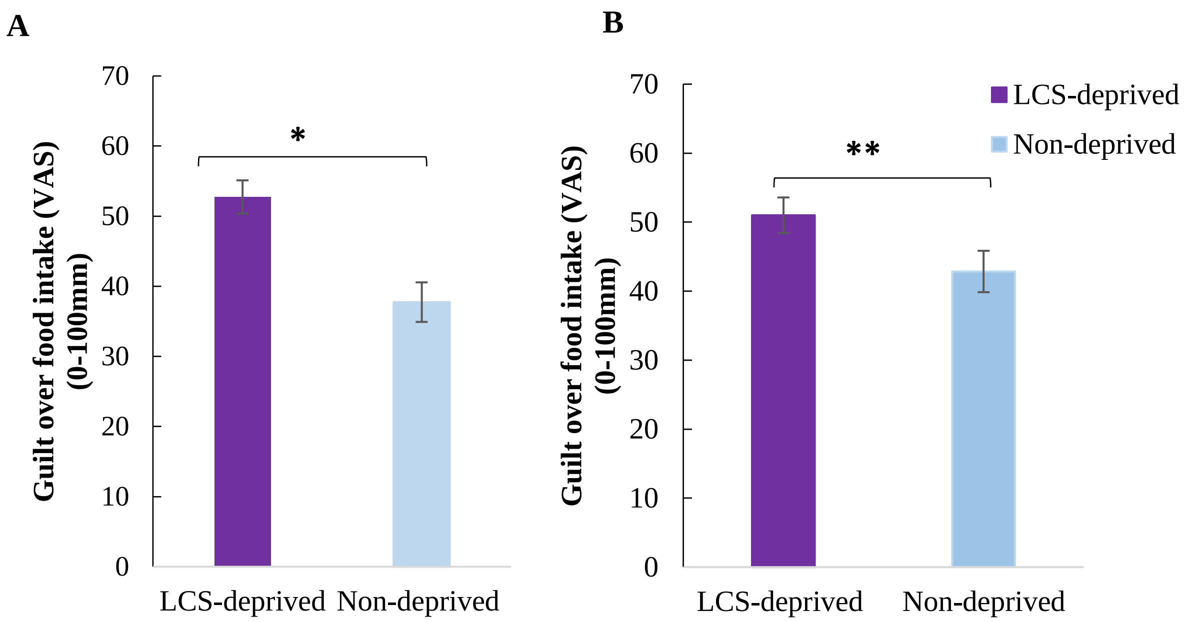


Figure 5.5. Mean Guilt over food intake ratings by condition in free-living (Panel A) and laboratory (Panel B), *significant at $p<.001$,**significant at $p<.05$. Error bars are standard error of the mean.

5.4.5. Supplementary analyses

5.4.5.1. Craving for chocolate (laboratory session 2 only)

A 2 x 2 mixed design ANOVA examining craving differences for chocolate (FCQ-S) was conducted, with time (pre and post taste test in session 2) as the within-subjects variable and condition (LCS deprived vs. LCS non-deprived) as the between-subjects factor. Analysis revealed a main effect of condition, $F(1,94)=6.13$, $p=.022$, $\eta_p^2=.07$ and a main effect of time on craving for chocolate $F(1,94)=28.22$, $p<.001$, $\eta_p{}^2=.29$. In addition, there was a condition x time interaction $F(1,94)=5.71$, $p=.012$, $\eta_p{}^2=.06$. Specifically, in the deprived condition (M=48.59 mm; ± 12.38), participants reported greater craving for chocolate before the taste session compared to the non-deprived condition, (M=35.85mm; ± 10.12), $t(94)=2.01$, $p=.048$, $d=1.12$. In contrast, cravings for chocolate did not differ between conditions following the taste session ($p=.355$).

5.4.5.2. General craving questions (laboratory session 2 only)

Using the FDQ at session 2 in the laboratory, participants rated the extent to which they experienced cravings for a list of food and beverages including chocolate, LCS and sugar-sweetened beverages over the previous 7 days from 1 “Not at all” to 5 “Extremely”. The deprived condition reported experiencing more cravings for food in general (M=3.42; ±1.33) than the non-deprived condition (M=2.42; ±1.09), $F(1,94)=16.43$, $p<.001$, $\eta_p{}^2=.15$. Both conditions reported chocolate as the most frequently craved food, however the deprived condition reported a higher number of chocolate cravings (M=3.98; ±1.02) compared to the non-deprived (M=3.19; ±1.45) condition $F(1,94)=9.54$, $p=.003$, $\eta_p{}^2=.09$. The deprived condition reported higher cravings for LCS beverages (M=3.46; ±1.30), $F(1, 94)=5.02$, $p=.027$, $\eta_p{}^2=.05$, SSB (M=2.21; ±1.60), $F(1,94)=26.31$, $p<.001$, $\eta_p{}^2=.22$ and sweets and desserts (M=3.52; ±1.58), $F(1,94)=5.81$, $p=.018$, $\eta_p{}^2=.06$ compared to the non-deprived condition (LCS beverages: M=2.85; ±1.34; SSB: M=1.02; ±0.14; Sweets & Desserts: M=2.77; ±1.46). The non-deprived condition reported higher craving for meat (M=2.98; ±1.58), $F(1,94)=13.76$, $p<.001$, $\eta_p{}^2=.13$ compared to the deprived condition (M=1.96; ±1.07) see Figure 5.6. There were no differences in reported cravings for the remaining foods, all $Fs < 1.703$, all $ps>.195$.

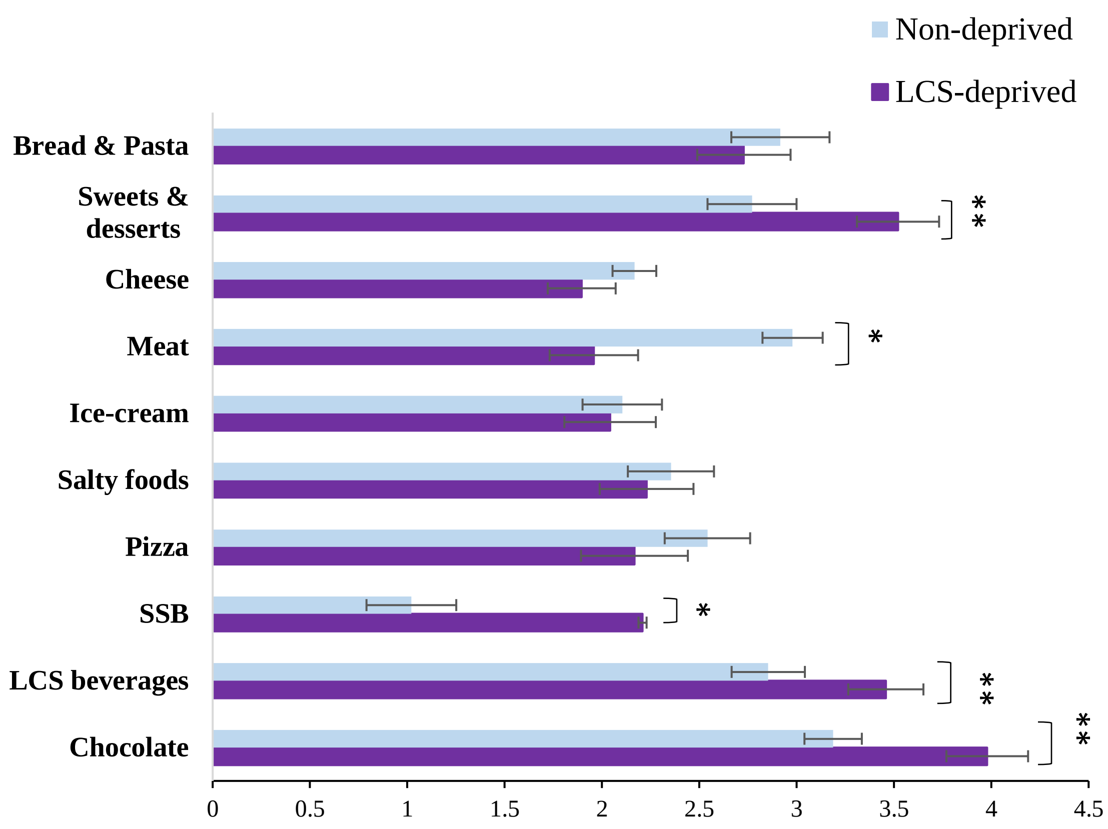


Figure 5.6. Mean craving ratings for food and beverages by condition using the FDQ taken at session 2 laborator, *significant at p<.001,**significant at p<.05. Error bars are standard error of the mean.

Participants were asked how often they ate the food they craved. The deprived condition reported (M=3.08; ±1.23) following through and eating the craved food more than the non-deprived condition (M=2.29; ±1.28), $F(1,94)=10.13$, $p=.002$, $\eta_p^2=.10$. There were no differences between conditions with respect to the degree to which participants reported substituting another food for a craved one, $F(1,94)=.424$, $p=.516$, $\eta_p^2<.01$.

5.4.5.3. Latency to eat (laboratory session 2 only)

A one-way ANOVA revealed that there was no difference in the amount of time spent on the anagram task, $F(1,94)=.98$, $p=.326$, $\eta_p^2=.01$ between the deprived condition (M=723.73s; ±283.83) and the non-deprived condition (M=843.74s; ±792.08).

5.4.5.4. Meal enjoyment (free-living setting only)

A mixed design ANOVA revealed a main effect of condition, $F(1,94)=5.73$, $p=.019$, $\eta_p^2=.06$, participants in the deprived condition (M=54.51; ±12.80) reported lower overall meal enjoyment relative to the non-deprived condition (M=60.16; ±10.16) in their free living environment. There was also a main effect of time, $F(1.62,151.84)=3.95$, $p=.021$, $\eta_p^2=.04$, and a main effect of meal type (breakfast vs. lunch vs. dinner vs. snack) on meal enjoyment, $F(2.63,246.80)=9.73$, $p<.001$, $\eta_p^2=.09$. However, there was no significant interactions between any of the variables, all $Fs < 2.02$, all $ps > .061$.

5.4.5.5. Perceived behavioural control

In the free-living environment, a mixed design ANOVA revealed a main effect of condition, $F(1,94)=11.79$, $p=.001$, $\eta_p^2=.04$, participants in the deprived condition (M=53.24; ±13.17) reported lower perceived behavioural control relative to the non-deprived condition (M=65.56; ±16.12). There was also a main effect of time, $F(1,94)=4.26$, $p=.016$, $\eta_p^2=.04$ but no condition x time interaction on perceived behavioural control ($p=.162$).

Following the taste test (laboratory session 2), participants in the deprived condition reported significantly lower perceived control (M=43.42; ±22.00) over food consumed, $F(1,94)=5.68$, $p=.019$, $\eta_p^2=.06$ compared to the non-deprived condition (M=54.25; ±22.54).

5.4.5.6. Hunger, fullness and thirst

Separate mixed design ANOVAs revealed no main effect of condition, main effect of time or condition x time interaction for overall hunger and fullness ratings, all $Fs < 2.75$, all $ps > .067$ in the free-living environment. However, there was a main effect of condition for overall thirst ratings $F(1,94)=4.97$, $p=.028$, $\eta_p^2=.05$; participants deprived of LCS beverages (M=68.05 mm; ± 21.89), had higher overall thirst ratings relative to the non-deprived condition(M=58.29 mm; ± 20.98). There was no main effect of time or condition x time interaction on thirst ratings ($ps>.184$).

For the laboratory setting, 2 (condition: LCS-deprived vs. LCS non-deprived) x 2 (pre taste test vs. post taste test) ANOVAs were conducted for hunger, fullness and thirst ratings. Analysis revealed no main effect of condition (*ps*>.588), and no condition x time interaction (*ps* >.500), on hunger and fullness ratings. There was a main effect of time on hunger, $F(1, 94)=68.60$, $p<.001$, $\eta_p^2= .42$, and fullness ratings, $F(1,94)=65.40$, $p<.001$, $\eta_p^2=.41$. Specifically, prior to the taste test, hunger ratings were significantly greater (M=62.83 mm; ± 28.01 mm), and fullness ratings significantly lower (M=34.00 mm; ±21.73), than after the taste test. (Hunger: M=33.92 mm; ± 17.24; Fullness: M=63.25 mm; ± 28.31).

However, there was a main effect of condition $F(1, 94)=5.34$ $p=.023$, $\eta_p^2 =.05$ on thirst; participants in the deprived condition (M=46.45 mm; ±16.34) reported greater thirst relative to the non-deprived condition (M=38.23 mm; ±18.44). There was also a main effect of time on thirst, $F(1,94)=73.68$ $p<.001$, $\eta_p^2=.44$ but no condition x time interaction, ($p=.416$).

5.4.5.7. Condition difference in body weight

A repeated measures ANOVA revealed there was no main effect of condition, no main effect of time or no condition x time interaction on body weight or BMI (all *ps*>.122), see table 5.2. below.

Table 5.2. *Mean change in body weight and BMI between LCS deprived and non-LCS deprived condition. Values are means with standard deviations in parentheses.*

	LCS deprived (n=48)		**Non-LCS deprived (n=48)**	
	Session 1	**Session 2**	**Session 1**	**Session 2**
Weight (kg)	77.96(15.94)	78.65(16.04)	77.94(14.81)	77.40(14.8)
BMI (kg/m²)	27.80(5.16)	27.93(5.11)	27.03(5.11)	26.84(5.08)

Condition differences between session 1 and session 2.

5.5. Discussion

The overarching goal of the present study was to examine how 7-day deprivation of LCS beverages affects cravings, mood and energy intake in frequent consumers. Specifically, we predicted that food cravings (in both the free-living and controlled laboratory settings) would be higher in the LCS-deprived condition than in the non-deprived control condition (hypothesis 1). In addition, we expected energy intake (in both the free-living and controlled laboratory settings) to be higher in the LCS-deprived condition than in the non-deprived control condition (hypothesis 2). Finally, as a result of this deprivation, negative mood and guilt (in both the free-living and controlled laboratory settings) would be higher in the LCS-deprived condition than in the non-deprived control condition (hypothesis 3).

Consistent with our first hypothesis; we found that frequent consumers deprived of LCS beverages for one week, reported higher craving for sweet foods relative to the non-deprived condition. This was also mirrored in both the pre- and post- laboratory sessions, where craving in the deprived condition increased significantly from baseline in the deprived group. This is in line with previous studies suggesting that individuals deprived of a desirable food usually experience increases in craving (Polivy et al., 2005; Coelho et al., 2006; Moreno-Dominguez, Rodríguez-Ruiz, Martín & Warren, 2012; Rogers & Smit, 2000). With regard to energy intake, as hypothesised (2), overall daily energy intake was significantly higher in the deprived condition relative to the non-deprived condition. Similarly, the deprived condition consumed more chocolate during the taste test than the non-deprived group in the laboratory. The negative effect of LCS beverage deprivation on craving and energy intake in the free-living setting was therefore directly in line with our laboratory results. These findings suggest that when consumers are deprived of LCS beverages, they find it difficult to resist tempting foods, making them more susceptible to periods of disinhibited eating.

Importantly, these results go against the idea that consumption of LCS beverages is associated with increased food intake and weight gain, (Fowler et al., 2008; Nettleton et al., 2009; Piernas et al., 2013). The findings suggest that consumption of LCS beverages does not impede consumers' weight loss goals but instead, may help to control craving and overall intake. This finding is consistent with our previous study (Chapter 4 of the present thesis) and previous research showing that LCS beverages can assist in reducing food intake and preventing weight gain or promoting weight loss (Blackburn, Kanders, Lavin, Keller & Whatley, 1997; de Ruyter, et al., 2012; Raben, Vasilaras, Møller & Astrup, 2002). It also extends this prior research by providing the first analyses of the psychological impact of consuming LCS beverages in frequent consumers. It is, however, important to mention that the current findings are specific to frequent consumers. It is uncertain whether similar effects would be found in non or infrequent consumers.

With regard to the effect of deprivation on mood (hypothesis 3), consistent with our third hypothesis, results revealed an effect of deprivation on negative mood over time. Individuals reported greater negative mood on their final day of deprivation relative to the non-deprived condition. The laboratory study further confirmed this effect, where negative mood was higher for the deprived condition at the post- laboratory session, compared to the non-deprived condition. As such, negative mood following the deprivation of LCS beverages, appears to be another influential factor, which may encourage consumers to lose motivation in regulating their food intake and avoiding certain "forbidden" or "diet breaking" foods. This may in turn, increase the salience of their short-term hedonic goal, resulting in a greater preference for tempting foods over healthy foods (Gardner, Wansink, Kim & Park, 2014). The present results also correspond to the findings where negative mood has been shown to trigger overeating in clinical and non-clinical samples (Alpers & Tuschen-Caffier, 2001; Carter, Bulik, McIntosh, & Joyce, 2001; Cools, Schotte & McNally, 1997; Yeomans & Coughlan, 2009).

Furthermore, there was an effect of deprivation on guilt in both the free-living and laboratory setting, whereby the deprived condition reported greater eating-related guilt relative to the non-deprived condition. The present findings build on our previous work (see Chapter 4), where participants reported lower perceived behavioural control, lower meal enjoyment and higher eating-related guilt in the deprived condition relative to the condition when LCS beverages were available. The current study thus provides further evidence that when frequent consumers are able to consume these beverages, they feel more in control over their food intake and less guilty. These findings are compatible with previous research which found that chocolate consumption elicited guilt responses (Macht & Dettmer, 2006; Macdiarmid & Hetherington 1995) and lowered levels of self-efficacy (Kuijer & Boyce, 2014), particularly in females who are overweight.

Post-hoc analysis revealed that deprivation of LCS beverages resulted in an increase in calories consumed from snack foods, which was largely driven by sweet snack foods in the deprived compared to the non-deprived condition. This is a particularly novel finding and suggests that when these beverages are unavailable, frequent consumers may subsequently compensate by consuming more hedonically pleasing sweet foods in order to satisfy that desire. Interestingly, there was also an effect of deprivation on beverage choice during the one-week deprivation period, specifically; the deprived condition drank considerably more SSB compared to the non-deprived condition. This finding was in keeping with the general cravings questionnaire where the deprived condition reported a higher number of cravings for SSB, (in addition to LCS, chocolate and sweets and desserts) compared to the non-deprived condition. This is an important finding in view of the growing concerns among some researchers that LCS beverages use is associated with higher sugar consumption and lower-quality diets (Swithers, 2013; Swithers, 2010; Fowler et al., 2008). Our findings suggest that this is not the case, and instead, provide support for LCS beverages as a potential aid to lower sugar consumption while satisfying the desire for sweetness. Indeed, previous evidence suggests that consumers of LCS beverages have diets that are lower in energy and sugar compared to SSB consumers, and do not compensate for the sugar or energy deficit by consuming more sugary foods (Gibson et al., 2016).

To our knowledge, the current study is the first to provide insight into the psychological impact of LCS beverages on factors that play a role in energy regulation in frequent consumers. The present work suggests that LCS beverages have a beneficial effect on diet quality, perhaps by satisfying hedonic eating motives and reducing occurrences of disinhibited eating. In view of this, consumption of LCS beverages may minimise feelings of guilt and negative mood, while enabling individuals to exert control over their food choices and intake. Certainly, when deprived of LCS beverages, consumers appear to suspend their self-imposed restraint, thereby activating their underlying desire to eat and acting on their temptations. Thus, without the assistance of LCS beverages, consumers may trigger food-seeking behaviour and desire for sweet foods. Accordingly, our findings contribute to a body of evidence suggesting that LCS beverages are a viable tool in reducing energy intake while supporting weight management (Bellisle, 2015; Rogers et al., 2016).

The present study has a number of strengths and limitations which should be addressed in future. Firstly, the use of both free-living and laboratory measures is a strength of our study. It gave us an indication of consumer patterns of behaviour over a longer period, with a greater diversity and comprehensiveness of foods. Secondly, we used a 3-day diary, which provides a better representation of typical consumption than the more common 24-h dietary recall (Crawford, Obarzanek, Morrison, & Sabry, 1994). As such, it allowed us to estimate the impact of dietary change on energy intake whilst controlling for inter-personal difference. Regarding the limitations of the present study, food intake in the free-living setting was self-reported retrospectively which may be affected by recall and response biases.

However, it enabled us to capture the change in energy intake outside of the laboratory. In addition, our findings from the free-living are in line with the measures taken in the laboratory study, which included objective measurement of food intake. While every effort was made to ensure participants were well trained and followed instructions for dietary assessment, underreporting may have influenced these findings. Dietary assessment in individuals with BMIs of 30 kg/m^2 or more can be confounded by underreporting and miss-reporting (Hirvonen, Männistö, Roos & Pietinen, 1997; Stubbs et al., 2014; Wehling & Lusher, 2017), particularly in women (Rennie, Coward & Jebb, 2007). Unfortunately, there is no reliable way of adjusting for this (Black, 2000).

Furthermore, this was a short-term study; as such it is difficult to know the long-term impact of LCS beverage consumption on energy intake and weight management. Therefore, future research would benefit from a prolonged longitudinal study to look at the impact of LCS beverage deprivation. Due to the study being short-term, we cannot estimate the impact of diet-beverage intake on obesity incidence. In addition, we cannot ensure that the deprived condition did not consume LCS beverages during the 7-day experimental manipulation. However, the increase in body weight (although non-significant) and energy intake reported in their food diaries suggest that they followed the protocol. Finally, this experiment was conducted on mainly University staff and students, which may not generalize to other populations.

5.6. Conclusion

The current study provides evidence that 7-day deprivation of LCS beverages produces increased energy intake, craving sensations, eating-related guilt and lower mood in frequent consumers. In addition, consumers appear to find their food less rewarding when LCS beverages are not available and may be subsequently motivated to satisfy their hedonic desire by consuming sweet foods. In view of this, the results suggest that consuming LCS beverages has a beneficial impact on frequent consumers' control over energy intake, by reducing craving, eating-related guilt and increasing mood. Our findings contribute to the growing evidence that LCS beverages facilitate energy regulation in frequent consumers. Further research is nevertheless required to establish the longer-term effects of deprivation of LCS beverages, to determine the sustained impact of LCS beverage use on energy intake and weight management in frequent consumers. In spite of this, these findings may assist in framing future weight management approaches for health professionals tackling the obesity epidemic.

Chapter 6: General Discussion

6.1. Overview of Aims

By providing little or no energy whilst preserving the hedonic value of sweetness, consumption of LCS beverages has emerged as an attractive approach to achieve reductions in energy intake and better weight control (Drewnowski et al., 2012; Rogers et al., 2016). These benefits appear to be at the core of LCS beverage use. Indeed, Appleton and Conner (2001) reported a dietary restraint and weight concern in frequent consumers of LCS beverages compared with non-habitual users. Similarly, Elfhag et al. (2007) found that consumption of LCS beverages were associated with more restrained eating in adults. Collectively, these findings suggest that frequent consumers perhaps use these beverages as a strategy to restrict energy intake in order to control their body weight. Despite these insights, detailed understanding of the characteristics associated with LCS beverage consumption is limited. Specifically, previous research has failed to identify the specific psychological factors that drive consumer demands for LCS beverages or to quantify the relative importance of these drivers with regard to eating motivations. In view of this, the first aim of the thesis was to establish the psychological predictors underpinning LCS beverage consumption in frequent consumers by determining attitudes and beliefs associated with LCS beverages. Desire-related cognitions motivating consumption of LCS beverages in individuals who frequent consume them were also examined. This aim was addressed in Chapters 2-3.

A second aim of the current thesis was to examine the psychological mechanisms and consequences associated with LCS beverage consumption with regard to eating behaviour; more specifically, to assess their subsequent impact on eating motivations and behaviours. In two experimental studies, Chapter 4 examined whether LCS beverages have a helpful or counterproductive effect on satisfying hedonic eating motives. Drawing upon these findings, Chapter 5 examined the psychological effects of LCS beverage deprivation and whether this may lead to changes in craving, mood, food intake and eating motivations.

6.2. Establishing the psychological predictors (antecedents) underpinning low-calorie sweetened beverage consumption

6.2.1. A novel approach to the assessment of attitudes and beliefs associated with low-calorie sweetened beverages

To understand the psychological factors motivating consumption of LCS beverages, it is necessary to understand the beliefs and attitudes associated with this particular food or beverage (Zandstra et al., 2001; Forestell et al., 2012). In support of this, previous research has shown that attitudes and beliefs influence food choice and behaviour (Aikman, Min & Graham, 2006; Teff & Engelman, 1996; Shepherd & Stockley, 1987; Shepherd, 1989) therefore by determining these attitudes and beliefs, insight into more proximal determinants of food choice can be determined. However, as previously discussed (Chapter 1), the assessment of attitudes and beliefs associated with LCS beverages is limited by the lack of a suitable tool to capture such psychological motivators. In order to identify the salient attitudes and beliefs motivating consumption of LCS beverages, it was therefore necessary to develop a validated psychometric instrument for assessing LCS beverage consumption motives, specifically designed to measure beliefs and attitudes towards LCS beverages.

This was addressed in Chapter 2 which presents the development of the Attitude and Beliefs associated with LCS Beverages Questionnaire. This questionnaire assesses the beliefs that are commonly associated with consumption of LCS beverages and is comprised of two underlying factors which reflect craving/weight control concerns, and beverage palatability/hedonic enjoyment. In doing so, this questionnaire offers a means to identify the driving factors for consumers who seek LCS beverages and provides an understanding of the factors that contribute to the characterisation and desire for LCS beverages. Nevertheless, further research is required to provide behavioural validation of the scale. For example, it will be important to establish the extent to which this questionnaire is able to account for LCS beverage consumption and prospective weight gain and weight-loss success.

6.2.2. Motivation behind low-calorie sweetened beverages and the consumer

Using the novel attitudes and beliefs questionnaire, Chapter 2 also aimed to understand consumer profiles and to identify the psychological factors that underpin attitudes and beliefs towards LCS beverage consumption in frequent relative to non-consumers of LCS beverages. In addition, a further aim was to determine whether frequent consumption of LCS beverages was associated with a greater BMI, body weight concerns and dietary restraint. Interestingly, findings suggested that frequent and non-consumers had contrasting differences in their beliefs surrounding LCS beverages. Specifically, frequent consumers had higher positive beliefs that LCS beverages are more palatable and effective in controlling appetite and weight concerns in comparison to non-consumers of LCS beverages.

Furthermore, frequent consumers reported having significantly higher BMI, dietary restraint and significantly higher tendencies towards body dissatisfaction and drive for thinness compared to non-frequent consumers. In contrast, non-consumers reported significantly higher levels of external eating. These findings were not surprising, as discussed in Chapter 1, they are consistent with Appleton and Conner (2001) who reported that frequent consumers had significantly higher dietary restraint, strong concerns about weight and weight-related issues (see also Schoeller et al., 1997; Alexander & Tepper, 1995). Similarly, this relationship between body concerns and greater consumption of LCS beverages was found among adolescents and female adults (Drewnowski & Rehm, 2016; Grech, Kam, Gemming, & Rangan, 2018; Hedrick, Passaro, Davy, You, & Zoellner, 2017; Wardle et al., 2004). Furthermore, previous studies have also reported that high levels of BMI are associated with frequent consumption of LCS beverages and products (Appleton & Conner, 2001; Drewnowski & Rehm, 2016; Stellman & Garfinkel, 1986). The higher BMI and levels of restrained eating is consistent with the argument that some individuals with high BMIs may use LCS beverages as a way to lower their weight by avoiding additional calories (Gibson et al., 2016; Grech et al., 2018). Collectively, findings from Chapter 2 suggest that concerns surrounding their body image and weight, coupled with positive health and hedonic enjoyment beliefs associated with LCS beverages appear to be significant factors in motivating appetitive behaviour for these beverages.

According to Papies and Barsalou (2015), applying the grounded cognition theory to food enables the underlying desire and motivation for a particular food or beverage to be conceptualised and assessed. In view of this, Chapter 3 aimed to extend the findings from Chapter 2 and further explored desire and motivations towards LCS beverages by examining whether frequent consumers experienced eating simulations (i.e., partial re-enactment of an earlier LCS beverage experience that was rewarding) in response to LCS beverages stimuli. This would indicate that they associate these beverages as both psychologically hedonic and rewarding food experiences. The first aim of this study was therefore, to explore whether eating simulations play a role in the representation of LCS beverages. It was predicted that frequent LCS consumers would generate higher number of eating simulations when describing LCS beverages compared to neutral foods. Furthermore, it was also expected that frequent consumers would generate a similar number of eating simulations for both LCS beverages and tempting foods, whereas for non-consumers, a greater number of eating simulations would be generated for tempting foods relative to neutral foods and LCS beverages.

Consistent with our hypotheses, frequent LCS consumers generated a higher proportion of eating simulations when describing LCS beverages relative to neutral foods; but a similar proportion were generated for both LCS beverages and tempting foods. As expected, non-consumers generated more eating simulations for tempting foods compared to neutral foods and LCS beverages. These findings are consistent with previous research (Keesman et al., 2018; Papies 2013), where attractive food and beverage words trigger more eating simulations compared to neutral food and beverages. It suggests that for frequent consumers, LCS beverages are cognitively represented as a hedonically rewarding experience. In support of this, tempting foods have been shown to be experienced as rewarding, triggering simulations of previous rewarding hedonic experiences (Papies 2013; Stroebe et al., 2008). Interestingly, for non-consumers, LCS beverages were heavily represented in terms of their negative hedonic experience compared to tempting and neutral foods. Certainly, these contrasting findings suggest that aspects of the positive hedonic experience play an important role in the motivation to consume LCS beverages, and that simulating them in response to appetitive cues could affect their motivational processes.

Furthermore, based on findings from Chapter 2, a further aim of Chapter 3 was to determine whether frequent consumers would generate a higher number of positive health features for LCS beverages relative to non-consumers. In support of this hypothesis, the representation of positive health features was more pronounced for LCS beverages and neutral foods compared to tempting foods in frequent consumers. Notably, frequent consumers produced words such as "healthier alternative" and "low in sugar" for the underlying conceptual properties of LCS beverages. Contrastingly, for non-consumers, LCS beverages were primarily represented by negative health features, namely characterizing LCS beverages as "unhealthy" and "carcinogenic". While health features are not directly involved in simulations of a food, this is nevertheless an important finding. It further supports findings from Chapter 2 and suggests that beliefs regarding LCS beverages' impact on health, whether they are positive or negative, are influential in motivating appetitive behaviour towards these beverages. Findings from Chapter 2 and 3 are consistent with the idea that frequent consumers are using these beverages as part of an effort to make healthier food choices and reductions in energy intake (Drewnowski & Rehm, 2016). Unsurprisingly, for non-consumers, LCS beverages were represented in terms of their negative qualities such as being artificial and encouraging a sweet tooth. Indeed, findings from Chapter 2 and 3 have shown that these consumers believe LCS beverages are unhelpful in managing weight concerns, instead believing they encourage a preference for sweetness. These attitudes appear to be significant in deterring non-consumers from using LCS beverages.

Importantly, the disparity found in Chapters 2 and 3 between consumer groups reveals the importance of the individual's goals and desire attached to the food and further suggests that health-related attributes are salient psychological drivers behind consumption of LCS beverages. It is these factors that appear to influence consumer decisions about consumption or avoidance of LCS beverages. Fundamentally, both hedonic enjoyment experiences and positive health beliefs appear to be key determinants of LCS beverage consumption.

6.2.3. Low-calorie sweetened beverages and the goal conflict theory

Findings from the current thesis support the notion that LCS beverages help consumers by satisfying their hedonic food cravings without violating dieting goals, thus removing the goal conflict. Specifically, LCS beverages may help remind consumers of their dieting motivations and feel more in control in regulating their food decisions. Consistent with this, findings from Chapter 2 indicate that the two-factor structure of the attitudes and beliefs associated with LCS beverages questionnaire captures both goals within the goal-conflict theory of eating model (Stroebe et al., 2008). The goal of enjoying hedonic foods is reflected by the 'palatability and enjoyment' subscale. In turn, the weight management goal is reflected by the 'appetite and weight concerns' subscale, relating to control over eating and weight. Building on goal conflict theory, Chapter 2 indicates that frequent consumers believe that LCS beverages are an effective strategy in controlling their diet whilst also being palatable and enjoyable to consume. Consistent with Chapter 2, both Chapters 3 and 4 showed that frequent consumers believed LCS beverages were beneficial in promoting weight control and providing hedonic pleasure relative to non-consumers. Essentially, LCS beverages appear to realign conflicting goals for frequent consumers by providing an alternative sweetness source to satisfy that hedonic desire without the additional calories, thus preserving their weight control goal.

Notably, the results for eating simulations in Chapter 3 further suggest that frequent consumers activate cognitive representations of these beverages that relate to their hedonic goal qualities but also their health goal attributes. Indeed, findings suggest that when consumers use these beverages, they do so with their long-term weight control goal in mind, as such, research suggests that this becomes part of the situated representation of the behaviour (Barsalou, 2009; Papies & Barsalou, 2015). Accordingly, consumers of LCS beverages may activate this goal-directed behaviour when in a tempting environment, triggering goal-directed cognition and successful control over their eating behaviour. To activate such strategies, it is important that the individual has successfully attained this long-term goal in similar situations (Fishbach et al., 2003; Papies et al., 2008b). This ensures that memories of situated conceptualizations of previously successful pursuits of the dieting goal in tempting situations are stored, and could be retrieved in response to tempting food cues. Indeed, our findings suggest that situated conceptualizations of LCS beverages consumption may become activated and could be implemented to prevent pursuit of tempting foods. Further, frequent consumers of LCS beverages may attempt to use these beverages as a strategy to handle their desires responsibly, by retrieving cues related to their previously rewarding experiences of LCS beverage consumption that support both their weight management and hedonic goals. Essentially, exposure to a LCS beverage stimulus is likely to trigger simulations of the individual interacting with it, how enjoyable and rewarding the beverage is, whilst making thoughts of a long-term diet goal more accessible. Collectively, these findings provide support for the suggestion that LCS beverages help frequent consumers to satisfy their conflicting hedonic and weight management goals, even in such tempting environments, by consuming LCS beverages.

6.3. What are the psychological mechanisms and consequences associated with low-calorie sweetened beverage consumption?

6.3.1. Priming hedonic eating motives, attentional bias and energy intake

The second aim of the current thesis was addressed in Chapters 4 and 5. Specifically, Chapter 4 presents two experimental studies which examined the effect of priming hedonic eating motives using a chocolate craving manipulation on energy intake. In study 3, frequent and non-consumers were randomised to either a craving manipulation (chocolate cues) or control condition (neutral cues) and then completed a beverage-related visual probe task with concurrent eye-tracking. During the task, they were presented with 3 different beverage types (LCS, SSB and water) as stimuli. Measures of appetite (craving, thirst, hunger and fullness) were completed throughout the experiment. Finally, *ad libitum* intake of sweet and savoury foods along with a selection of beverages was measured. Based on findings from Chapter 2 and 3, it was hypothesised that energy intake would be greater following the hedonic eating prime relative to a control prime in non-consumers, but that frequent LCS beverage consumers would be protected from this effect. More specifically, frequent consumers would not increase their energy intake in the craving relative to the control condition.

In support of this hypothesis, frequent consumers did not increase their energy intake following the craving exposure relative to the control exposure, despite reporting increased craving for chocolate (indicating hedonic eating motivations were activated). Contrastingly, non-consumers consumed more energy in the craving condition relative to the control condition. Notably, craving was positively associated with energy intake in non-consumers while there was no evidence for this association in frequent consumers. These findings suggest that, by consuming LCS beverages, consumers' hedonic desire for sweetness may have been satisfied whilst protecting their weight management goal. Further, despite reporting greater trait disinhibited eating, frequent consumers vulnerability to craving-induced eating (Bryant, King & Blundell, 2007; Westenhoefer, Broeckmann, Munch & Pudel, 1994; Woods, Racine & Klump, 2010) was protected. Frequent consumers may therefore be less susceptible to uncontrolled eating, and capable of exerting more control over their energy intake when they consume LCS beverages. Interestingly, the presence of these beverages potentially served as a diet prime, subtly reminding consumers of their dieting goal. In support of this, previous work has shown that priming the goal of an individual (who values this goal) can effectively adapt the individual's behaviour, even in tempting situations where short-term hedonic temptations typically succeed (Papies, 2016a). This however, was not directly tested.

In view of this, study 4 of Chapter 4 aimed to reproduce and extend this finding in frequent consumers and incorporated a new condition where the availability of LCS beverage was manipulated to examine its impact on appetitive behaviour. Specifically, LCS beverages were either available in addition to the snack food (available condition) or unavailable (non-available condition) to participants during the *ad libitum* buffet. However, the original result was not replicated – that is, frequent consumers were not protected from craving-induced increases in energy intake. They ate more in the craving condition relative to control condition regardless of whether LCS beverages were available or unavailable. This finding suggests that, in this case, consumption of LCS beverages was not sufficient to satisfy hedonic eating motivations and preventing craving-induced increases in food consumption. While it is difficult to ascertain this discrepancy between the studies, one possibility is that the result in Study 3 was not a robust finding. In consideration of this, further studies are necessary to determine the robustness of this finding in different populations.

6.3.1.1. Attentional bias towards low-calorie sweetened beverages

According to Field et al. (2016), the incentive reward value of a food or beverage can be assessed by examining the bias in attention towards a relevant food-cue (i.e. a stimulus that has previously been associated with a food or beverage). As such, Study 3 (Chapter 4) aimed to examine whether frequent consumers would demonstrate increased attention towards LCS beverage stimuli, relative to neutral (i.e. water and SSB) stimuli (i.e. attentional bias). Furthermore, we hypothesised that this bias would be more pronounced when frequent consumers were in a state of craving (i.e. when hedonic eating motivations were activated) compared to the control condition.

In partial support of these hypotheses, frequent consumers demonstrated an attentional bias towards LCS beverage images, relative to both sugar and water beverage images. For non-consumers, no such bias was found in any measure of attention. However, there was no augmented craving effect of attention towards LCS beverages in frequent consumers. This contrasts with Werthmann, Roefs, Nederkoorn and Jansen (2013) findings where high chocolate cravers demonstrated a longer initial duration of gaze on chocolate compared to low cravers. One possibility for this lack of craving effect on attentional bias is that these individuals are naturally drawn towards these beverages, and changes in appetitive motivation do not impact the salience of these beverages. Despite the lack of an amplified effect of craving, these findings suggest that individuals who frequently consume LCS beverages have an increased attention towards LCS beverages, in favour of water and sugar beverages.

Importantly, this biased attention was only present in the eye-tracking data, no difference was found in any of the other measures of attentional bias (i.e. response latencies in the VPT) for both frequent and non-consumers. Similarly, study 4 (Chapter 4), also failed to find a relationship between frequent consumers and reaction time data towards LCS beverages-related images relative to water or SSB-related images. Previous research has also failed to find any differences in manual response latencies (Werthmann et al., 2011). A possible explanation for the null findings in both studies could be attributed to our stimuli presentation time of 2000 ms, some researchers argue that it can be difficult to interpret results obtained from visual probe tasks, particularly those with a longer stimulus presentation time (e.g. >500 ms) as it is not possible to measure shifts in attention between stimuli presented side by side or gauge participant disengagement from stimuli presented during the task (Field, Mogg & Bradley, 2004; Bradley, Field, Mogg & De Houwer, 2004). Furthermore, it has been shown that associations between craving and attentional bias to substance-related cues are stronger for direct measures of attention (i.e. eye movement measures) than indirect measures (Field, Munafò & Franken, 2009).

Nevertheless, the overall present findings provide support for the suggestion that individuals who frequently consume LCS beverages have an attentional bias towards LCS beverage-related cues relative to both sugar and water beverage cues. Interestingly, this bias was not evident for non-consumers, which is comparable with previous research showing that the biased attention towards environmental stimuli is consistent with the self-relevant concerns of the individual (Field et al., 2016; Kemps & Tiggemann, 2009). Notably, this bias is specific to LCS beverages rather than a general bias towards sweet beverages. It goes against the notion that LCS beverages prevent consumers from managing their response to sweetness by encouraging a 'sweet tooth' and intake of sweet energy-containing foods and beverages (Sclafani & Ackroff, 2012; Swithers et al., 2010). Alternatively, the present findings suggest that consumers repeated exposure to LCS beverages consequently directs their attention towards LCS beverages, away from competing sources of sugar. Finally, consistent with Chapter 2 and 3, these findings suggest that frequent consumers view LCS beverages as hedonically desirable and thus are motivationally relevant to these individuals.

6.3.3. Deprivation of low-calorie sweetened beverages, craving and energy intake

A further aim of Chapter 4 (study 4) was to examine the impact of LCS beverage availability on consumers' appetitive motivations and behaviour. Food-related self-control and eating-related guilt were measured before and after the *ad libitum* buffet. It was predicted that, when frequent LCS consumers did not have access to LCS beverages, they would consume more sweet and savoury foods during the *ad libitum* buffet, when they were in a state of craving, compared to their control condition. Interestingly, results revealed that participants had a greater overall food intake when LCS beverages were unavailable relative to when they were available. It suggests that while LCS beverages are not sufficient to completely satisfy hedonic eating motivations, they are still a beneficial tool in reducing overall energy intake.

To test this further, Chapter 5 explored the psychological effects of longer-term LCS beverage deprivation on craving and subsequent energy intake. Participants were randomly allocated to either the LCS deprived or the non-deprived condition. They attended two laboratory sessions, 7 days apart, where measures of mood, craving for sweet foods and several trait measures of eating behaviour were assessed. During these 7 days, food intake and measures of mood, guilt and craving for sweet foods were assessed in the free-living environment on day 5, 6 and 7. In Session 2, participants also completed an anagram task, followed by bogus taste test. Finally, guilt, mood, control over food intake and body weight were assessed. Frequent consumers deprived of LCS beverages reported higher craving for sweet foods relative to the non-deprived condition. Further, overall daily energy intake and consumption of chocolate (during the taste test) was greater when individuals were deprived of LCS beverages, compared to when they were not. These findings further support earlier studies in the thesis that LCS beverages have a positive influence on consumers' eating behaviour by satisfying hedonic eating motives and subsequently enabling them to regulate their energy intake.

Notably, post-hoc analysis revealed that deprivation of LCS beverages resulted in consumers ingesting additional calories consumed from snack foods, consisting mainly of sweet snack foods compared to the non-deprived condition. This important finding suggests that when these beverages are unavailable, frequent consumers are subsequently motivated to consume more hedonically pleasing sweet foods in order to satisfy that desire. This result builds on findings found in Chapter 4, opposing the idea that LCS beverages have an enhancing effect on appetite for sweet-tasting products, lower satiating power resulting in energy compensation or that LCS beverage consumption is associated with higher sugar consumption and with lower-quality diets (Fowler et al., 2008; Holt, Sandona & Brand-Miller, 2000; Swithers, 2013; Swithers, 2010). Alternatively, it suggests that LCS beverages may satisfy rather than enhance desire for sweetness. This is consistent with the sensory-specific satiety concept; where LCS beverage consumers' motivation to seek out alternative sources of sweetness is reduced following consumption of these beverages (Rogers et al., 2016; Rogers, 2018).

Collectively, findings from Chapter 4 and 5 dispute this idea that consumption of LCS beverages promotes appetite by encouraging a preference for sweetness, thus encouraging higher dietary energy intake. Alternatively, the present findings suggest that consumption of LCS beverages plays a beneficial role in helping to reduce cravings and overall energy intake. Further, the present findings support the idea that, by consuming LCS beverages, consumers inherent desire for sweetness is satisfied, as such it reduces their motivation to consume other sweet foods. This is in line with the systematic review by Appleton et al. (2018) which found that exposing individuals to sweet taste reduces their preference for sweet products. Additionally, Gibson et al. (2014) have argued that based on the current evidence, consumption of LCS beverages does not enhance an appetite for sweet foods, but instead, can assist weight loss by reducing intake for sugar and sweet tasting products. The present findings extend this research by determining the psychological impact of LCS beverages on overall energy intake and weight management in frequent consumers. Nevertheless, it is necessary to explore this association in other population samples before firm conclusions can be drawn.

6.3.4. Perceived behavioural control, guilt and mood

The impact of LCS beverages on eating-related guilt, enjoyment of the meal, and perceived behavioural control was explored in study 4 of Chapter 4. It was predicted that, when LCS were unavailable, participants would report higher guilt, lower meal enjoyment and lower perceived control in the craving condition relative to the control condition (due to greater energy intake in the former versus the latter). However, no such difference between the craving and control conditions was expected in the LCS available condition. In contrast to our hypothesis, frequent consumers reported higher eating-related guilt and lower perceived behavioural control in the craving condition relative to the control condition regardless of whether they had access to LCS beverages. Nevertheless, overall, participants in the unavailable condition reported lower perceived behavioural, lower meal enjoyment and higher eating-related guilt relative to the condition when LCS beverages were available. Thus, while our hypothesis regarding the impact of craving was not fully supported, the findings do suggest that consumers feel more in control and les guilty regarding their food intake, when they are able to consume LCS beverages.

This was further explored in Chapter 5, where participants were randomly deprived of LCS beverages over a 7-day period. It was hypothesised that negative mood and eating-related guilt (in both the free-living and controlled laboratory settings) would be greater in the LCS-deprived condition than in the non-deprived control condition. Consistent with Chapter 4, results revealed that individuals deprived of LCS beverages reported greater eating-related guilt and lower perceived behavioural control in contrast to individuals who were not deprived of LCS beverages. By acting on these cravings or urges, consumers appear to disrupt and thwart their dieting attempts, leading to feelings of guilt. These findings are consistent with those of Macdiarmid and Hetherington (1995) who also found greater experiences of eating-related guilt and shame following the consumption of chocolate. In addition, lower control over intake has been shown to result in individuals selecting more unhealthy foods, increased food intake and weight gain over time (Kuijer & Boyce, 2014; Kuijer et al., 2015). In view of this, consumption of LCS beverages may therefore help protect individuals from such maladaptive outcomes, ultimately enabling them to stay motivated in pursuing their weight control goal.

Indeed, findings from Chapters 4 and 5 provide support for this idea that consumption of LCS beverages increases the accessibility of their diet cognitions by facilitating greater control over food intake and reducing eating-related guilt in individuals who frequently consume these beverages.

Furthermore, deprivation of LCS beverages had a negative impact on mood over time in the free-living setting. This was also evident in the laboratory, where negative mood was higher for the deprived condition compared to the non-deprived condition following the 7-day deprivation. The present findings suggest that deprivation of LCS beverages could encourage unhealthy eating patterns in consumers by increasing negative mood. This is important given that previous research has demonstrated that negative mood in addition to disinhibited eating was positively associated with individuals desire to eat (Loxton, Dawne & Cahill, 2011) and occurrences of binge eating (Alpers & Tuschen-Caffier, 2001; Waters et al., 2001). As such, consumption of LCS beverages appears to have a beneficial impact on consumer's mood and subsequent appetitive behaviour. This follows previous suggestions that positive mood enhances self-control and resistance to unhealthy food choices (Fedorikhin & Patrick, 2010; Winterich & Haws, 2011).

Finally, findings in Chapter 4, study 4 and Chapter 5 demonstrated that despite having a greater energy intake, consumers reported lower meal enjoyment when deprived of LCS beverages in comparison to when they were available. This suggests that when consumers of LCS beverages do not have access to these beverages, they may compensate for this void by consuming more hedonically pleasing food to satisfy this hedonic need for sweetness. As such, the present findings suggest that by using LCS beverage, consumers desire for sweetness is satisfied, thereby reducing their motivation to consume other tempting foods. Accordingly, consumption of LCS beverages may help to reduce consumers vulnerability to temptation and over-consumption.

Collectively, these beverages appear to be fulfilling a psychological role regarding desire for consumers. LCS beverages may help individuals to deal with desire and cravings by providing a sweetness reward, whilst also helping regulation of food intake and preservation of their weight control goal, even in tempting environments.

6.4. Theoretical implications and directions for future research

This thesis explored the salient motivations underpinning consumption of LCS beverages and examined the psychological mechanisms associated with frequent use. Thus, in doing so, this work generates a number of implications, both from a theoretical and a practical standpoint. Firstly, findings suggest that frequent consumers believe these beverages are a beneficial tool in managing their weight whilst providing hedonic pleasure. It is these factors that appear to be the most powerful in predicting preferences, intentions and behaviours towards LCS beverages. Secondly, while we did not consistently show that LCS beverages are capable of protecting consumers from craving-induced increases in energy intake, consumption of LCS beverages did reduce energy intake *overall* and this finding was supported in both a laboratory and natural setting.

Furthermore, the current thesis focused on the effects of priming a hedonic goal (chocolate craving) in frequent consumers. However, to further explore the cognitive strategies these consumers employ in managing their diet, one approach may be to prime their dieting goal and assess the impact of activating this goal on their eating motivations and appetitive behaviour. For instance, a systematic review by Buckland, Er, Redpath and Beaulieu (2018) examined the effects of exposing individuals to diet-congruent cues. They found that following the exposure to such cues, individuals who have strong weight control goals are prompted to pursue their weight control goal by reducing their food intake, even in tempting situations. In consideration of this, by exposing consumers of LCS beverages to cues relevant to their dieting goal (i.e., diet-relevant words or images) whilst making a food choice, consumers are subtly reminded to pursue their invested dieting goal. This may therefore help to increase consumers control over food intake and selecting of healthier choices. Essentially, it will determine whether LCS beverages also act as a diet prime for frequent consumers.

As previously mentioned in Chapter 1 (section 1.2.2.3.), the activation of an individual's goal-relevant cognitions has been shown to assist their goal pursuit by supressing competing thoughts about tempting foods (Papies, 2016b; Papies & Aarts, 2016). In line with previous studies, (Anschutz et al., 2008; Ferguson & Bargh, 2004; Fishbach, Zhang & Trope, 2010; Papies & Hamstra, 2010) the activation of a diet goal motivates consumers to pursue this goal by directing their attention towards healthy stimuli despite being in a food-rich environment. This may help to ensure frequent consumers' success in exerting self-control over their goal pursuit by regulating their eating behaviour, even in situations in which LCS beverages are not sufficient in protecting them from short-term hedonic temptations. Specifically, by satisfying hedonic desire for sweetness, LCS beverages may help to both inhibit competing thoughts that would interfere with the pursuit of their long-term goals but also limit visual attention to cues for such goals. Finally, if consumers are repeatedly primed and continuously performing this primed behaviour, this may enable them to form healthy eating habits (Lally & Gardner, 2013) and have a beneficial effect on their health over time. Future work, however, is needed to provide further insight into this area.

Findings from the current thesis yield important implications particularly with regards to the beneficial impact of LCS beverages as an aid in weight management strategies, specifically for individuals who are vulnerable to craving temptations when presented with palatable foods. Findings from Chapters 2, 4 and 5 suggest that frequent consumers of LCS beverages are typically characterised as highly restrained and disinhibited in addition to having a high BMI. As such, these individuals appear to be sensitive to hedonic eating cues and eating in excess of energy intake. By avoiding forbidden foods, these foods become more desirable and results in greater cravings and less control (Rodgers et al., 2011; Rogers & Smit, 2000). Accordingly, consumers may benefit from a more versatile approach to weight management; using LCS beverages may enable consumers to feel hedonically and psychologically satisfied while providing them with a means to reduce energy density and maintain their body weight in the long-term. In support of this, systematic reviews, including meta-analyses indicate that LCS beverages compared to SSB reliably reduce energy intake and body weight and may indeed present as a useful tool in weight management (Miller & Perez, 2014; Rogers et al., 2016). Additionally, by providing a low-calorie sweet reward to quench their hedonic food cravings, consumers may be more likely to resist high-calorie sweet foods. This strategy may also be of benefit to individuals who have a higher preference for sweet tasting foods (Garneau, Nuessle, Mendelsberg, Robin & Tucker, 2018). Certainly, strategies to reduce energy intake are generally less successful without the additional assistance of sweetness within the diet due to our inherent desire for sweetness (Drewnowski et al., 2012). Findings from the current thesis suggest that consuming less energy does not need to be less rewarding if LCS beverages are used to provide the reward of sweetness. Thus, whilst following a weight programme, LCS beverages may be of particular beneficial for individuals who struggle with their weight and hedonic temptations, and future research should investigate this possibility.

Importantly, Chapter 4 and 5 showed that when frequent consumers did not have access to LCS beverages this led to lower meal enjoyment despite consuming more foods. Further, exploratory analysis in Chapter 5 revealed that deprivation of LCS beverages subsequently resulted in consumers eating more sweet foods. These findings suggest that consumers may find their food less rewarding when LCS beverages are not available and consequently seek out alternative sources of sweet foods to satisfy this desire. Thus, without the assistance of LCS beverages, consumers may feel unsatisfied and this may subsequently trigger food-seeking behaviour and provoke desire for sweet foods in particular. LCS beverages appear to be an important strategy for some individuals, as such, investigating the psychological mechanisms and subsequent effects on behaviour in these consumers presented in this thesis is necessary. Furthermore, it will considerably enhance the research efforts in this area and in turn, our understanding of potential effects on health weight management.

Finally, on a more theoretical level, this research highlights the role that LCS beverages could play in supporting eating-related goals (in relation to the goal conflict model of eating). The current findings suggest that consumption of LCS beverages are the result of consumers struggling with managing their weight and subsequently using them as a viable strategy to satisfy their hedonic desires but not at the expense of their weight control goal. Importantly, Chapter 4 and 5 showed that frequent consumers ate more food when deprived of LCS beverages. In addition, there was some evidence that consumers were protected from disinhibited eating in Chapter 4 (study 3) following the priming of their hedonic eating motives. Collectively, these findings show support for the idea that LCS beverages are a beneficial psychological strategy potentially because they align frequent consumers' hedonic eating goals whilst simultaneously preserving their weight control goal (i.e. removing the goal conflict).

In order to explain how LCS beverages may reconcile the conflict between these two goals, Figure 6.1. proposes a schematic relationship between frequent consumption of LCS beverages, the long-term goal of weight control, the short-term goal of food enjoyment and prevention of increased calorie consumption. Specifically, it is proposed that in pursuit of their highly valued weight control goal, consumption of LCS beverages may subtly remind consumers of goal-relevant information. We also suggest that when the goal of eating enjoyment is activated, consumers of LCS beverages are able to satisfy their hedonic eating motives using LCS beverages. For instance, by providing them with a low-calorie source of sweetness, LCS beverages enable them to suppress their hedonic thoughts for tempting foods, without violating their diet (see Figure 6.1.). In support, Chapter 2 and 3 found that frequent consumers view these beverages as hedonically pleasing while not compromising their long-term goal of weight control.

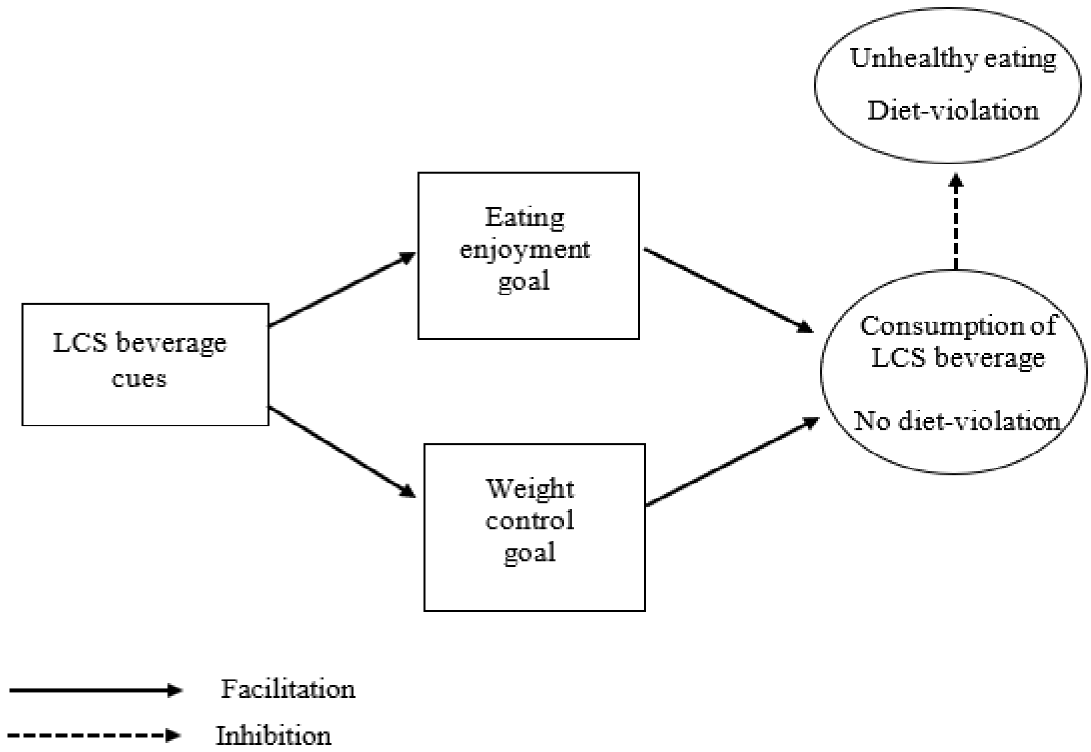


Figure 6.1. A proposed adapted model of the goal conflict theory of eating between frequent consumers of LCS beverages and food intake. In this model, LCS beverages help to align both goals instead of the current model where one goal inhibits the other. LCS beverages help to satisfy hedonic motivations for sweetness and consequently inhibit consumption of high-calorie or unhealthy foods. This reduces cravings and overconsumption of unhealthy foods, thus protecting the weight control goal. This may reinforce consumption of LCS beverages.

Importantly, this does not mean that these individuals are completely resistant to temptation, as demonstrated by findings in Chapter 4 (study 4), where consumers ate more food following the priming of their hedonic goal despite consuming LCS beverages. Nevertheless, by consuming less food overall, reporting greater behavioural control and lower eating-related guilt when LCS beverages are available, it suggests that these beverages have a positive cognitive and behavioural influence on food intake. Based on this, our model predicts that consumption of LCS beverages facilitates self-regulation over energy intake and reduces disinhibition occurrences. In support of previous work (Papies, 2016b), this coping mechanism may reinforce dietary goals and thus promote further attempts at regulating energy intake through LCS beverage consumption. Consistent with previous research (Kavanagh, et al., 2005), very subtle reminders of LCS beverages perhaps trigger associative processes that activate the goal of eating enjoyment outside of their conscious awareness. Environmental cues of temptation, where highly palatable and energy dense foods are easily accessible, play a critical role in disrupting weight-regulation for restrained individuals. In view of this, we also suggest that LCS beverages have a dual function (as seen in Figure 6.1.), they activate an individual's health motivations by reminding consumers of their healthy goal and possibly directing their attention towards LCS beverage stimuli in their environment. In addition, LCS beverages offer consumers a powerful source of sweetness and it is this hedonic characteristic that pleases their hedonic goal. As such, we suggest that this cognitive strategy may enable consumers to control their diet by activating their health goals, even outside conscious awareness. Future research is required however, to explore this potential relationship between consumption of LCS beverages, hedonic and weight control thoughts and regulation of food consumption. In particular, it would be informative to extend findings from Chapter 5 by examining the longer-term effects of manipulating the availability of LCS beverages on managing food cravings and subsequent consumption.

6.5. Limitations

The present studies have a number of limitations. Firstly, the studies contained mostly a female sample, thus findings provide limited applicability to male populations and possibly result in some biases in relation to the findings obtained. This is most likely a reflection of the fact that females are more inclined to continuously regulate their weight and use LCS beverages to do so. In support of this, Sylvetsky et al. (2017) found that LCS consumption was higher in females compared with males (see Pollard et al., 2016 and Sylvetsky & Rother, 2016 for similar findings). In view of this, further research is required within a male population to determine whether males and females differ with regards to their motivations behind LCS beverage consumption.

Secondly, the studies described in the current thesis included participants that were predominantly university staff and student population who would have a higher than average level of education. While this is consistent with previous research (Drewnowski & Rehm, 2016) suggesting that frequent consumers of LCS beverages are more likely have a higher education and income, it is necessary to recruit other sociodemographic groups in future research before the generalisability of the current findings are considered. Furthermore, there were group differences between participants from Chapter 2, 3 and study 3 of Chapter 4 on BMI and dietary restraint. These findings can be explained as a reflection of the group characteristics. For instance, frequent consumers generally had a higher BMI, dietary restraint and disinhibition relative to non-consumers, who were generally of normal weight. As such, these differences may be explained as reflections of the type of people who use these beverages to manage their weight. However, this issue was addressed in study 4 of Chapter 4 and Chapter 5 by only recruiting frequent consumers and the experimental groups were matched on all measured variables. Nevertheless, future research should include a non-LCS beverage consumers group, who score highly on these characteristics to further determine LCS beverage effects on food motivations and appetitive behaviour. Additionally, given that throughout this thesis frequent consumers were generally of an overweight BMI and British, future work should consider other ethnicities, ages or more extreme BMI groups.

Thirdly, it is important to mention that food intake (when in their natural setting) was self-reported retrospectively from Chapter 5; as such it may be subject to recall and response biases because respondents may have had memory lapses or intentionally avoided reporting "unhealthy" foods. Additionally, this was a short-term study, as such, the long-term impact of LCS beverage consumption on appetitive behaviour and energy intake are still unclear. Therefore, a prolonged longitudinal study, determining the impact of LCS beverages on psychological control of eating behaviour over time is needed before conclusions are drawn.

Finally, none of the effects found are necessarily causal. Whilst the findings above demonstrate some clear associations between frequent consumption of LCS beverages and lower energy intake, the observed differences in appetite control or the impact of LCS beverage intake on obesity incidence cannot be distinguished between them. Future research is required to explore the causality of these possibilities.

6.6. Overall conclusion

By identifying the key motivations behind consumption in frequent consumers, the current thesis has provided insight into the underlying psychological drivers behind consumption of LCS beverages and how these psychological factors impact on eating motivations and behaviour. Findings suggest that consumption of LCS beverages is driven by the belief that they are a *helpful* tool in managing weight concerns and cravings whilst also offering a hedonic reward and palatability (Chapter 2 and 3). The attitudes and beliefs associated with LCS beverages questionnaire provides a novel tool for the assessment of such motivators that are driving consumption of the beverages, and thus should be incorporated within future research to understand how LCS beverages impact on food consumption.

From a cognitive perspective, findings from the current thesis support the goal conflict of eating model suggesting that LCS beverages enable consumers to satisfy their hedonic eating motivations whilst also managing their weight/weight loss goals. This strategy appears to promote lower eating-related guilt, increased mood, meal enjoyment and control over food intake. The present thesis thus provides novel insight into some of the psychological processes involved, namely, using these beverages to control eating by satisfying hedonic desires. However, future research should examine the *longer-term* patterns of LCS beverages and self-regulation in tempting eating situations for frequent consumers. In addition, it is necessary to further explore findings of increased calorie intake and dietary disinhibition in frequent consumers when access to LCS beverages is restricted (Chapter 4, study 4 and Chapter 5). Nevertheless, the culmination of these studies highlights the positive role LCS beverages have on eating behaviour and relevant psychological factors in frequent consumers.

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Appendix A: Original Questionnaire (Chapter 2)

In this section you will be asked about **low-calorie sweetened beverages** (LCS beverages). **LCS beverages** are low calorie soft drinks, such as diet coke, diet pepsi, coke zero or diet.

I believe drinking LCS beverages may make me feel drowsy

1———2———3———4———5———6———7

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe drinking LCS beverages may make me feel bloated

1———2———3———4———5———6———7

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are as pleasant as their sugar alternatives

1———2———3———4———5———6———7

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe that LCS beverages are good for keeping hydrated

1———2———3———4———5———6———7

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages have no impact on my hunger levels

1———2———3———4———5———6———7

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages may control my desire for sweet foods

1———2———3———4———5———6———7

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I like the taste of LCS beverages

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages can help to focus my attention

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages offer a healthier alternative to sugar sweetened drinks

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages have no impact on appetite

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are a proper drink

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are acceptable beverages compared with their caloric alternatives

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe drinking LCS beverages can help me control my weight

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverage help me to manage my cravings for sweet foods

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages have no impact on weight loss

1——————2—————— 3——————4——————5——————6 ——————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages help me to lose weight

1——————2—————— 3——————4——————5——————6 ——————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are beneficial for health

1——————2—————— 3——————4——————5——————6 ——————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages help me to become less pre-occupied with sweet foods

1——————2—————— 3——————4——————5——————6 ——————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages will help me control my appetite

1——————2—————— 3——————4——————5——————6 ——————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are harmful to my health

1——————2—————— 3——————4——————5——————6 ——————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I do not like the taste of LCS beverages

1——————2—————— 3——————4——————5——————6 ——————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are not acceptable beverages compared with their caloric alternatives

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages have a positive influence on my weight

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are not very filling

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are not beneficial for health

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages help me to feel full

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages have no impact on my sweetness cravings

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are a normal drink product

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are not a real drink

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages have no impact on weight management

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe drinking LCS beverages may make me crave 'sweet' food

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages have no impact on my desire for sweet foods

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages can help me stay alert

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are not harmful to my health

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages taste as good as their sugar alternatives

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages have no effect on my attention

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages make me more pre-occupied with sweet foods

1——————2——————3——————4——————5——————6——————7

Strongly disagree | Somewhat disagree | Disagree | Neutral | Somewhat agree | Agree | Strongly disagree

I believe LCS beverages help me feel less hungry

1——————2——————3——————4——————5——————6——————7

Strongly disagree | Somewhat disagree | Disagree | Neutral | Somewhat agree | Agree | Strongly disagree

I believe that LCS beverages are as satisfying as their sugar alternatives

1——————2——————3——————4——————5——————6——————7

Strongly disagree | Somewhat disagree | Disagree | Neutral | Somewhat agree | Agree | Strongly disagree

I believe LCS beverages are not an appropriate drink

1——————2——————3——————4——————5——————6——————7

Strongly disagree | Somewhat disagree | Disagree | Neutral | Somewhat agree | Agree | Strongly disagree

I believe LCS beverages are not as enjoyable as caloric beverages

1——————2——————3——————4——————5——————6——————7

Strongly disagree | Somewhat disagree | Disagree | Neutral | Somewhat agree | Agree | Strongly disagree

I believe LCS beverages are not refreshing

1——————2——————3——————4——————5——————6——————7

Strongly disagree | Somewhat disagree | Disagree | Neutral | Somewhat agree | Agree | Strongly disagree

I believe LCS beverages are artificial and not a normal drink

1——————2——————3——————4——————5——————6——————7

Strongly disagree | Somewhat disagree | Disagree | Neutral | Somewhat agree | Agree | Strongly disagree

I believe drinking LCS beverages has no impact on weight control

1——2——3——4——5——6——7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverage help to manage my weight

1——2——3——4——5——6——7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe that LCS beverages are as refreshing as their sugar alternatives

1——2——3——4——5——6——7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe that LCS beverages can satisfy a craving for something 'sweet'

1——2——3——4——5——6——7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are an appropriate drink

1——2——3——4——5——6——7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

I believe LCS beverages are unhealthy

1——2——3——4——5——6——7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

In this section please write any further **POSITIVE** feelings you have about LCS as a beverage. Please remember LCS beverages are low calorie soft drinks/beverages with artificial sweeteners, such as diet coke, coke zero or diet pepsi.

In this section please write any further **NEGATIVE** feelings you have about LCS as a beverage. Please remember LCS beverages are low calorie soft drinks/beverages with artificial sweeteners, such as diet coke, coke zero or diet pepsi.

Appendix B: Food Frequency Questionnaire for LCS beverages (Appleton & Conner, 2001; Chapter 2)

<u>Diet Questionnaire</u>

INSTRUCTIONS - Please consider each of the following foods, and mark down the quantity of each you consume, at present. Delete whether each is consumed on a daily or weekly rate.

Water	- .... glasses per day / week
Regular squash	- .... glasses per day / week
'Diet' squash	- .... glasses per day / week
Regular carbonated drinks	- .... cans per day / week
'Diet' carbonated drinks	- .... cans 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	- .... glasses per day / week
Fruit Juice	- .... glasses per day / week

Appendix C: Factors and factor loadings following the exploratory factor analysis (Chapter 2)

Factor	Factor Items	Factor Loadings
Positive beliefs towards LCS beverages	I believe LCS beverages help me to lose weight	.971
	I believe LCS beverages have a positive influence on my weight	.884
	I believe LCS beverage help me to manage my cravings for sweet foods	.831
	I believe LCS beverage help me control my appetite	.869
	I believe drinking LCS beverages can help me control my weight	.868
	I believe LCS beverages help me to become less pre-occupied with sweet foods	.831
	I believe LCS beverages help me to manage my weight	.803
	I believe LCS beverages help me to control my desire for sweet foods	.700
	I believe LCS beverages help me to feel less hungry	.585
Neutral Beliefs towards LCS beverages	*I believe LCS beverages have no impact on my hunger levels	.810
	*I believe LCS beverages have no impact on appetite	.801
	*I believe LCS beverages have no impact on my desire for sweet foods	.710
	*I believe LCS beverages have no impact on weight management	.690
	*I believe LCS beverages have no impact on sweetness cravings	.679
	*I believe LCS beverages have no impact on weight control	.593
	*I do not like the taste of LCS beverages	.848
Enjoyment and Palatability	I believe LCS beverages are as pleasant as their sugar alternatives	.807
	I like the taste of LCS beverages	.811
	I believe LCS beverages taste as good as sugar alternatives	.838
	*I believe LCS beverages are not as refreshing	.779
	*I believe LCS beverages are not as enjoyable as caloric beverages	.907
	I believe LCS beverages are as refreshing as this sugar alternatives	.826
	I believe LCS beverages are as satisfying as this sugar alternatives	.780

Appendix D: Final Questionnaire (Chapter 2)

In this section you will be asked about **low-calorie sweetened beverages** (LCS beverages). **LCS beverages** are low calorie soft drinks, such as diet coke, diet pepsi, coke zero or diet.

1. I believe LCS beverages taste as good as their sugar alternatives

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

2. I believe LCS beverages can help me control my weight

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

3. I believe LCS beverages are as satisfying as their sugar alternatives

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

4. I believe LCS beverages help me to manage my cravings for sweet foods

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

5. I believe LCS beverages help me to lose weight

1	2	3	4	5	6	7
Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

6. I believe LCS beverages help me to become less pre-occupied with sweet foods

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

7. I do not like the taste of LCS beverages

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

8. I believe LCS beverages will help me control my appetite

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

9. I believe LCS beverages are not as enjoyable as caloric beverages

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

10. I believe LCS beverages have a positive influence on my weight

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

11. I believe LCS beverages are as refreshing as their sugar alternatives

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

12. I believe LCS beverages help me to manage my weight

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

13. I believe LCS beverages are as pleasant as their sugar alternatives

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

14. I like the taste of LCS beverages

1————2————3————4————5————6————7

Strongly disagree	Somewhat disagree	Disagree	Neutral	Somewhat agree	Agree	Strongly disagree

In this section please write any further **POSITIVE** feelings you have about LCS as a beverage. Please remember LCS beverages are low calorie soft drinks/beverages with artificial sweeteners, such as diet coke, coke zero or diet pepsi.

In this section please write any further **NEGATIVE** feelings you have about LCS as a beverage. Please remember LCS beverages are low calorie soft drinks/beverages with artificial sweeteners, such as diet coke, coke zero or diet pepsi.

Attitudes and beliefs scoring Instructions:

Each item is given a score ranging from 1 (‘Strongly disagree’) to 7 (‘Strongly agree’). Items 7 and 9 are REVERSE scored (i.e. ‘Strongly agree’ = 1; and ‘Strongly disagree’ =7).

To obtain a score for the weight management and appetite subscale and enjoyment and palatability subscales: scores are added up and divided by the number of items in each subscale.

Mean scores range from 1 (minimum) to 7 (maximum) for both the weight management and appetite subscale and enjoyment and palatability subscale.

Weight management and appetite subscale: Items 2,4,5,6,7,8,10,12.

Enjoyment and palatability subscale: Items 1,2,3,7,9,11,13,14.

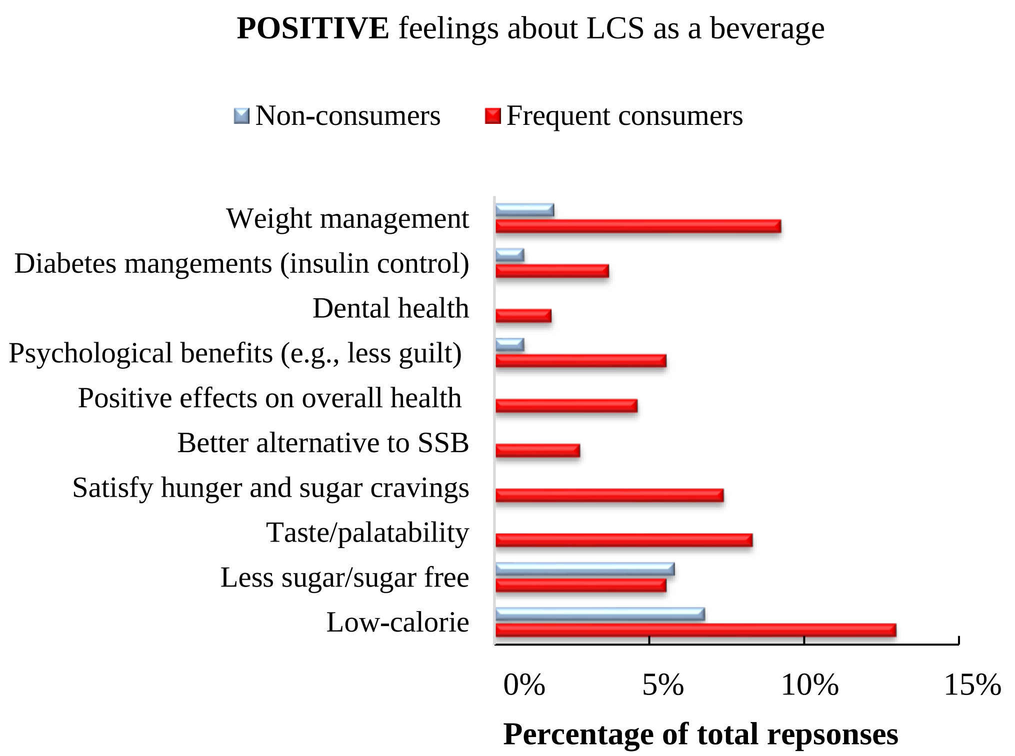
Appendix E: Supplementary results (Chapter 2)

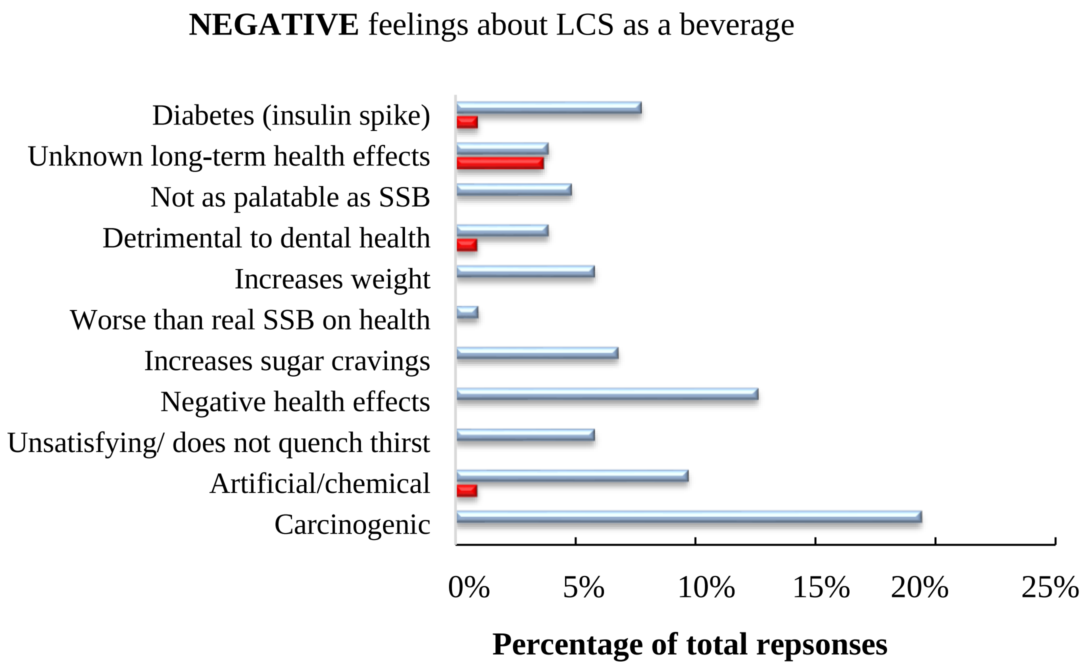
Table A1. *Consumption levels of LCS beverages and all other beverages by frequent and non-consumers (mean millilitres/day).*

	LCS Beverages Mean (*SD*)	**SSB Beverages Mean (*SD*)**	**Water Beverages Mean (*SD*)**
Frequent Consumers	1668.17 (775.34)*	139.91 (290.02)	862.43 (509.58)
Non-consumers	0.0 (0.0)	1175.94 (807.52)*	935.37 (558.75)

*Significant differences between frequent consumers and non-consumers of LCS beverages, *p* <.05.

Appendix F: Frequent and non-consumers qualitative results (Chapter 2)





Appendix G: Feature-listing task (Chapter 3)

In this task you are asked to describe properties that are GENERALLY TRUE of the object.

Please write at least 5 properties for the object (there is room to add up to 15 properties).

Please type the properties in the text box BELOW the Object.

Please remember there is no time limit.

You can single words or phrases when listing properties of the object. Before you begin there will be two examples shown.

PRESS the "spacebar" to view the examples.

Press [space] for next page

Diet Coke

Please describe at least 5 properties that are GENERALLY TRUE for Diet Coke.You can use single words OR phrases when listing properties of the object.Please remember there is no time limit.

Can you please type your responses into the text boxes below?

Next

Appendix H: Specific non-simulation features (Chapter 3)

To look at non-simulations in more detail (i.e., visual vs. non-eating situations vs. other), a three-way mixed ANOVA was conducted to look at the proportion of specific non-simulations features generated for each food type between frequent and non-consumers. Analysis revealed a main effect of feature type, $F(1.79,208.95)=52.62$, $p<.001$, $\eta_p^2=.48$ but there was no interaction between consumer group x feature type $F(1.79,208.95)=.021$, $p=.979$, $\eta_p^2<.01$. However, there was a food group x feature type interaction, $F(4,232)=11.60$, $p<.001$, $\eta_p^2=.17$ and a consumer group x food group x feature type interaction $F(4,232)=3.72$, $p=.006$, $\eta_p^2=.06$.

To further explore this interaction, a two-way mixed ANOVA was conducted for each consumer group separately, with food type (LCS beverages vs. tempting vs. neutral) and specific feature type (visual features, non-eating situations and other) as the within-subjects factors. For frequent consumers, there was a main effect of food type, $F(2,58)=50.90$, $p<.001$, $\eta_p^2=.64$ and non-simulation feature type, $F(2,58)=31.01$, $p<.001$, $\eta_p^2=.52$ and a food type x non-simulation feature type interaction, $F(6,174)=10.58$, $p<.001$, $\eta_p^2=.27$. Similarly, for non-consumers, there were main effects for food type $F(2,58)=23.06$, $p<.001$, $\eta_p^2=.44$ and non-simulations feature type $F(2,58)=22.64$, $p<.001$, $\eta_p^2=.44$ and an interaction between the two, $F(4,116)=6.19$, $p<.001$, $\eta_p^2=.18$.

Exploring this further, for each consumer group, the effect of food type was analysed for specific non-simulation feature (visual features, non-eating situations and other) separately.

Visual features

A repeated measures ANOVA revealed a main effect of food type for the proportion of visual features for frequent consumers, $F(2,58)=32.05$, $p<.001$, $\eta_p^2=.53$. Paired t-tests revealed that frequent consumer generated more visual features for neutral foods compared to LCS beverages $t(29)=5.85$, $p<.001$, $d=1.07$ and tempting foods, $t(29)=7.39$, $p<.001$, $d=1.34$. There was no difference between tempting and LCS beverages with frequent consumers generating a similar proportion of visual features for both, $t(29)=1.20$, $p=.239$, $d=0.22$.

Similarly, in non-consumers there was a main effect of food type for the proportion of visual features, $F(2,58)=20.64$, $p<.001$, $\eta_p^2=.42$. Post-hoc t-tests revealed that non-consumers generated a higher proportion of visual features for neutral foods compared to LCS beverages, $t(29)=5.19$, $p<.001$, $d=0.95$, and tempting foods $t(29)=5.33$, $p<.001$, $d=0.97$. There was no difference between tempting and LCS beverages, $t(29)=1.21$, $p=.23$, $d=0.22$ (see Figure A1.).

Non-eating situations

Analysis revealed a main effect of food type for the proportion of non-eating situations features for frequent consumers $F(2,58)=25.46$, $p<.001$, $\eta_p^2=.47$. Post-hoc analysis revealed that frequent consumers generated more non-eating situations for neutral foods, compared to tempting $t(29)=3.17$, $p=.004$, $d=0.58$ and LCS beverages $t(29)=-6.58$, $p<.001$, $d=1.20$. Frequent consumers also generated a higher proportion of non-eating situations for tempting foods compared to LCS beverages, $t(29)=4.40$, $p<.001$, $d=0.80$.

In contrast, there was no main effect of food type for the proportion non-eating situations features for non-consumers, $F(1.67,48.59)=3.28$, $p=.054$, $\eta_p^2=.10$.

Other features

There was no main effect of food type for the proportion of other features for frequent consumers $F(2,58)=1.91$, $p=.157$, $\eta_p^2=.06$.

However analysis revealed a main effect of food type for the proportion of other features for non-consumers, $F(2,58)=5.69$, $p=.006$, $\eta_p^2=.16$. Paired t-tests revealed that non-consumers generated a higher proportion of other features for LCS beverages, $t(29)=2.68$, $p=.012$, $d=0.51$ and neutral foods $t(29)=2.99$, $p=.006$, $d=0.55$ compared to tempting foods. There was no difference between LCS beverages and neutral foods for proportions of other features, $t(29)=2.68$, $p=.314$, $d=0.06$.

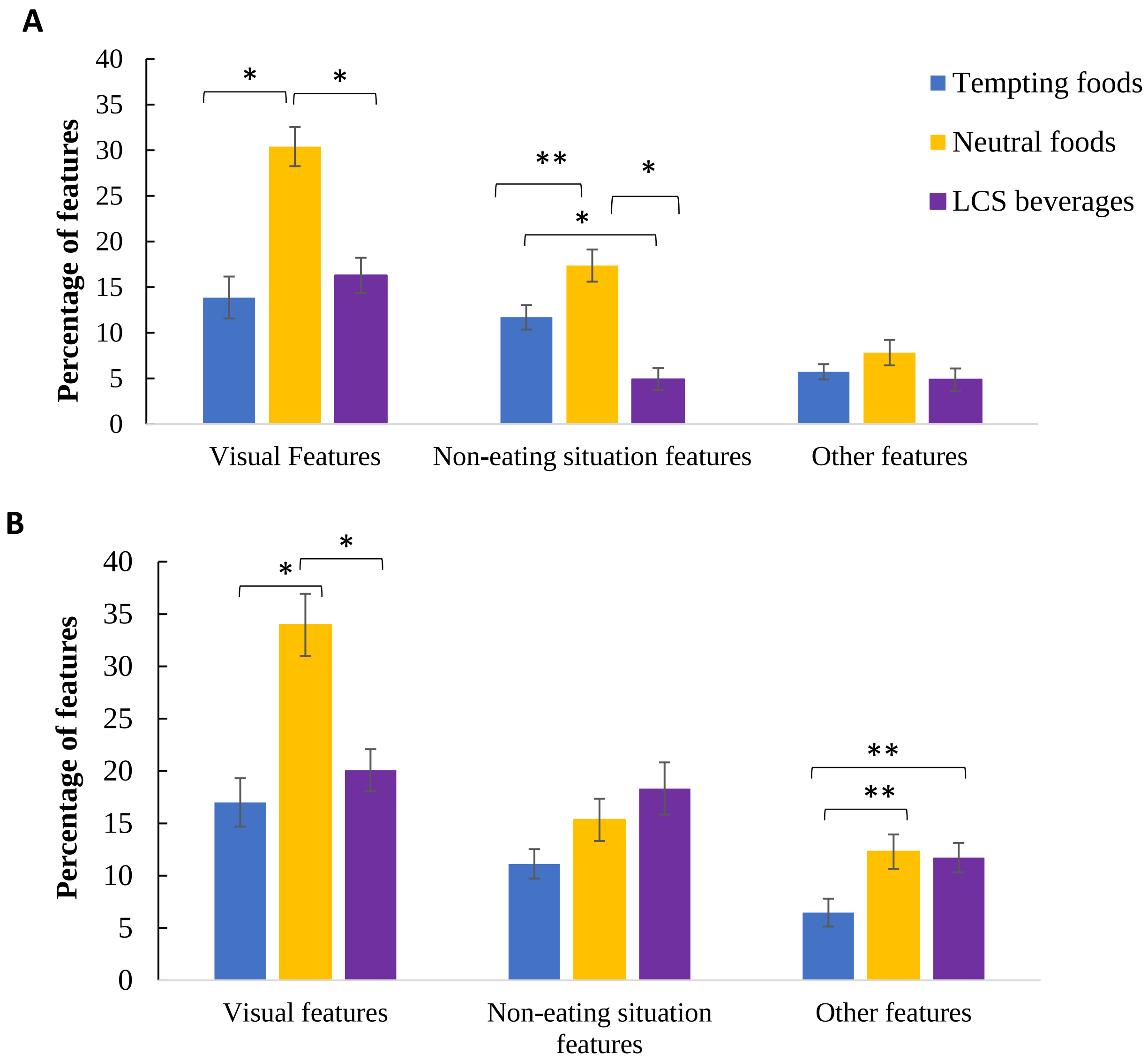


Figure A1. Percentages of each of four types of other features generated for tempting, neutral foods and LCS beverages for frequent (Panel A) and non-consumers (Panel B). Values are means and standard errors of the mean. *Significant at p<.001, **significant at p<.05.

Appendix I: Appetite ratings (Chapter 4; study 3)

A mixed ANOVA revealed a main effect of condition on hunger ratings, $F(1,116)=9.62$, $p=.002$, $\eta_p^2=.08$. There was also a condition x time interaction, $F(2.18, 253.28)=7.54$, $p<.001$, $\eta_p^2=.06$. Follow-up t-tests revealed that there was a significant difference in hunger levels between the craving and control conditions at T2 ($p<.001$; following first craving exposure), T3 ($p<.001$; mini-craving exposure) and T4 ($p<.001$; end of VPT). There was no significant difference between conditions at T1 and T5 (*ps*>.105). Furthermore, there was no main effect of group or interaction between condition x group x time indicating that the effect was consistent in frequent and non-consumers, (*ps*>.746).

There was a main effect of condition on fullness, $F(1,116)=5.69$, $p=.019$, $\eta_p^2=.05$, and a condition x time interaction, $F(1.58, 183.03)=5.01$, $p=.013$, $\eta_p^2=.04$. Follow-up t-tests showed that participants in the craving condition reported significantly lower fullness levels at time-point T2 ($p=.021$), T3 ($p=.003$) and T4 ($p<.001$) relative to the control condition. There was also no difference between conditions at T1 or T5 (*ps*>.120). Furthermore, there was no main effect of group or condition x group x time interaction for fullness ratings, (*ps*>.830).

There was no main effect of condition or condition x time on thirst ratings, (*ps*>.125). There was no main effect of consumer group, $F(1,116)=.505$, $p=.479$, $\eta_p^2=.01$ but there was an interaction between consumer group x time on thirst ratings, $F(2.32, 268.73)=3.39$, $p=.029$, $\eta_p^2=.03$. Frequent consumers had (marginally) higher thirst at T4 ($p=.069$) relative to non-consumers. Furthermore, there was no interaction between condition x group x time on thirst ratings, ($p=.118$).

Appendix J: Appetite ratings (Chapter 4; study 4)

There was a main effect of condition on hunger, $F(1,168)=9.23$, $p=.003$, $\eta_p^2=.05$ and a condition x time interaction, $F(3.14, 527.28)=6.24$, $p<.001$, $\eta_p^2=.04$. Follow-up t-tests revealed that participants in the craving condition reported significantly higher hunger levels at time-point T2 ($p<.001$), T3 ($p<.001$) and T4 ($p=.003$) relative to the control condition. Importantly, there was no difference between conditions at T1 or T5 ($ps>.439$). There was no main effect of group and no group x condition interaction (both $ps>.776$). There was also no group x condition x time interaction ($p=.476$), indicating that the effect of condition over time was consistent in LCS available and the LCS unavailable groups.

Similarly, there was a main effect of condition on fullness, $F(1,168)=8.09$, $p=.010$, $\eta_p^2=.05$; fullness was lower in the craving condition relative to the control. However there was no significant condition x time interaction, $F(1.86, 312.22)=2.01$, $p=.140$, $\eta_p^2=.01$. There was no main effect of group or group x condition interaction (both $ps>.862$). Additionally, there was no group x condition x time interaction ($p=.381$).

There was a main effect of condition on thirst ratings, $F(1,168)=5.02$, $p=.026$, $\eta_p^2=.03$ and condition x time interaction, $F(2.64, 444.10)=13.62$, $p<.001$, $\eta_p^2=.08$. Follow-up t-tests revealed participants in the craving condition reported significantly higher thirst levels at time-point T3 ($p=.022$) and T4 ($p<.001$), relative to the control condition. There was no difference between conditions at T1, T2 or T5 ($ps>.271$). There was no main effect of group or group x condition interaction, ($ps>.654$) or group x condition x time interaction ($p=.477$).

Appendix K: Attentional bias (Chapter 4; study 4)

Two separate ANOVAs were conducted to look at attentional bias towards LCS beverage-related images in relation to water and SSB related images, respectively. Results showed no main effects of condition or group on response latency bias for LCS beverages-related images relative to water-related images, *Fs* $<.248$, all *ps*$>.619$. There was also no condition x group interaction on response latency bias for LCS beverage-related images relative to water-related image, $F(1,168)=.248$, $p=.619$, $\eta_p^2<.01$. Similarly, there were no main effects of condition or group on response latency bias for LCS beverage-related images relative to SSB-related images, all *Fs* $< .029$, all *ps*$>.865$. There was also no condition x group interaction on response latency bias for LCS beverage-related images relative to SSB-related images, $F(1,168)=0.03$, $p=.865$, $\eta_p^2<.01$.

Appendix L: Energy intake supplementary results (Chapter 4; study 4)

Energy intake was further broken down to show the calories consumed from the food and beverage types in each condition separately (see table A2 below). The results of the exploratory analyses to examine the effects of group (i.e. LCS available vs. LCS unavailable) on intake of specific food-types (i.e. sweet foods, savoury foods, beverages) are reported in the main manuscript file.

Table A2. *Energy intake from food type by consumer group. Values are means with standard deviations in parentheses.*

Condition	**Sweet foods (kcal)**	**Savoury (kcal)**	**Beverages (kcal)**	**Total (kcal)**
LCS beverage available; Craving	301.97 (234.15)	289.98 (296.35)	1.13 (.44)	593.08 (404.14)
LCS beverage available; Control	240.28 (302.91)	199.12 (196.10)	1.11 (.40)	440.51 (353.63)
LCS beverage unavailable; Craving	359.92 (183.66)	327.70 (284.42)	23.35 (40.89)	710.97 (368.48)
LCS beverage unavailable; Control	289.47 (178.62)	284.42 (209.29)	10.78 (27.16)	584.72 281.77)

Appendix M: Food diary (Chapter 5)

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Sample Food JOURNAL. Below is an **EXAMPLE** of how to keep accurate records. Include a detailed description and amounts for each item. Remember to record water and notes on product details.

	Food and Beverage Items (include details such as brand, restaurant name, etc.)	**Quantity/ Amount eaten Grams, Ounces, Cups, Number/ count,**	**Did this food have any type of Nutrition Claim? 1% fat, fat-free, light, low carb If so, please list below:**	**Brand Name? Yoplait, Lean Cuisine, Pepsi...**	**Preparation method Baked, Boiled, Grilled, Fried, Steamed, Sautéed... Did you add any butter/oil? Did you add any salt?**
Breakfast	Cereal	Medium bowl	Regular Brand	Honey Nut Cheerios	
	Milk	1 large glass	Semi-skim	Tesco	
	Banana	1 medium			
AM Snack	Apple	1medium		Gala	
	Apple juice	1 large glass		Tesco pure apple juice	
Lunch	Grilled cheese sandwich				
	Whole wheat bread	1 slice		Tesco wholemeal	toasted
	Cheese slice	1 slice		Cathedral city	melted
	Butter on bread	1 Tbsp		Kerrygold	
	Yogurt – strawberry	125g (1 pot)		Activia	
	Milk	1 glass	Semi-skim	Tesco	
PM Snack	Granola bar	1 bar – 42g	Oats & Honey	Nature Valley	
Evening Meal	Chicken Breast	1 ½		Asda	Grilled
	Baked potato (with skin)	1 large			
	cheese	2 Tbsp		Cheddar- Tesco	Grated
	Ketchup	2 Tbsp			Heinz
	Carrots	1 handful			boiled
Evening Snack	Ice cream	3 large spoonful's		Ben & Jerrys cookie dough	
Beverages (including alcohol, water, soft drinks)	-Orange Juice -cup of tea -Milk -Pepsi -Red wine -Water	-1 large glass -4 Medium cups -1 glass -4 cans -3 large glasses -8 medium glasses	Tesco - - Semi-skim -Diet Pepsi - -	- - -Tesco - Jacob's Creek -	- -With 2 spoonful's of semi-skimmed milk & 1 sweetener) - - - -

Please record all food, drink and snack items you consumed TODAY

	Food and Beverage Items (include details such as brand, restaurant name, etc)	Quantity/Amount eaten Grams, Ounces, Cups, Number/count,	Did this food have any type of Nutrition Claim? 1% fat, fat-free, light, low carb If so, please list below:	Brand Name? Yoplait, Lean Cuisine, Pepsi...	Preparation method Baked, Boiled, Grilled, Fried, Steamed, Sautéed... Did you add any butter/oil? Did you add any salt?
Breakfast					
AM Snacks					
Lunch					
PM snacks					
Evening Meal (Dinner/Tea)					
Beverages (including alcohol, soft drinks and water intake)					

Appendix N: Supplementary results: Self-perceived positive mood (Chapter 5)

Free-living setting. A 2 x 3 mixed ANOVA was used to determine if positive mood (PANAS) was lower in the LCS-deprived condition compared to the non-deprived control condition (between-subjects factor) with time (day 5 vs. day 6 vs. day 7) as the within-subject factor.

There was no main effect of condition or condition x time interaction for positive mood, both $F < 2.613$, both $ps > .076$. There was however a main effect of time, $F(2,188)=3.95$, $p=.021$, $\eta_p^2=.04$. Paired t-tests revealed that participants reported a higher positive mood on day 5 (M=28.33mm; ±7.61) compared to day 7 (M=26.10mm; ±7.85), $t(95)=2.75$, $p=.007$, $d=0.32$. There was no difference in positive mood between other days ($ps > .158$).

Laboratory setting. A repeated measures ANOVA was conducted with state measures of positive mood as the dependent variables and time (session 1 vs. session 2) as the within-subjects factor and condition (LCS-deprived vs. LCS non-deprived) as the between-subjects factor. There was no main effect of condition or time x condition interaction on positive mood, both $Fs < 2.91$, both $ps > .151$. However, there was a main effect of time, $F(1, 94)= 8.67$, $p=.004$, $\eta_p^2=.08$. Follow-up paired t-tests revealed that participants had a greater positive mood at session 1 (M=31.34mm; ±8.69) (i.e. pre-deprivation) compared to positive mood measured at session 2 (M=29.49mm; ±8.56), $t(95)=2.85$, $p=.005$, $d=0.24$.