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0402699270





The role of nutritional information in human energy intake regulation

by

Robert Owen

A Doctoral Thesis


Submitted in partial fulfillment of the requirements

for the award of

Doctor of Philosophy of Loughborough University

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# **The role of nutritional information in human energy intake regulation**

Robert Owen

Previous research has shown that over time, humans can develop learnt associations between the sensory profile of a food and the energy it contains. These associations are then used to guide appetite for the same food in future situations. However, whether more acute, explicit information relating to the nutritional content of food can also shape eating behaviours in non-dieting individuals remains undecided. Following a review of previous literature, several methodological questions were raised relating to the effectiveness and validity of experimental manipulations used in some previous studies. The main aim of this thesis is to re-assess whether nutritional information could influence eating behaviours when these factors have been taken into consideration. In two initial experiments designed to address these issues, an interesting association was observed between participants' initial expectations of a preload and their ability to compensate for covert manipulations of its energy content.

In order to further investigate this association, measures were developed based upon psychophysical analysis to provide an alternative method of measuring expectancies of the satiating efficacy of a food. The use of this measure allowed a quantifiable measurement of a participant's expectancies towards a food, while lessening the risk that demand effects were contaminating results. The final experiments of this thesis then re-examined the earlier observation that expectations of foods could mediate the regulatory responses that ingesting the food creates. The observed results did not support the proposal that expectancies of a preload were mediating compensatory ability by prompting attention towards visceral cues. Instead, results suggested that enhanced compensation was observed when participants were provided with an unexpected deficit in energy intake, rather than an unexpected surplus. This introduces the concept that an individual's short-term compensatory ability may be partly determined by pre-existing expectations about the food they are eating. The implications of this finding with regard to dietary preloading paradigms are discussed, and the possibility that this mechanism could explain the poor compensatory ability often associated with liquid loads is explored.

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# **Chapter 1   Introduction: the role of information in energy regulation**

## 1.1 Introduction

Traditional models of food intake regulation rely on the theory of homeostasis. The Glucostatic theory and lipostatic hypothesis of intake regulation (Mayer, 1955) propose that glucose or fat levels in the body are monitored by the peripheral nervous system, and stimulate food intake when stores become depleted. Similarly, when stores exceed desired levels, satiety mechanisms are thought to be activated. The term homeostasis, originally introduced by Cannon (1932), literally means the maintaining of a stable internal state, and homeostatic mechanisms have in-built set points against which the actual internal state is compared against. In the context of the Glucostatic theory, these set points would be a desired cellular or blood glucose level. When the system detects that the actual state has deviated from the preferred set point, error signals are generated which in turn elicit appropriate responses to correct the discrepancy. Thus by constant monitoring of the internal state, homeostasis can continually act to maintain a specific set point. Homeostasis is often compared to the thermostatic control of central heating, which upon detecting a change in temperature will turn the heating system on or off in order to bring room temperature back to the predetermined set point.

The basic premise of homeostatic mechanisms still appears to provide a reasonable account of human eating, as we eat when we are hungry, and stop when we are full. More recently it has been suggested that human eating may not technically be a homeostatic mechanism, but merely provide outcomes that are “homeostasis-like” (Berridge, 2004). It is suggested that a regulatory mechanism that relies on anticipatory mechanisms to correct deficits before they even occur may produce outcomes that could be mistaken for homeostasis. While a response appears to be ‘homeostatic’, it may actually be demonstrating a learnt response to a given situation. For a learnt dietary response to act, an individual needs to receive some form of information from their environment that can be associated to the food they are about to consume. This may take the form of sensory information gained from the food itself, but it also may potentially arise from more explicit forms of information, such as nutritional information provided on the food wrapper. While there is a large base of

evidence from which to base a claim that information provision can influence eating behaviours, experimental designs that have specifically examined manipulating the provision of nutritional information available to participants have found mixed results. The research question that this thesis seeks to answer is as follows:

Are the eating behaviours of non-dieting participants in experimental situations influenced by nutritional information they gain about the foods they are consuming?

The disparity observed in experiments that try to manipulate information cues will be reviewed in this thesis, along with evidence to support the claim that humans use a wide variety of information during eating situations. Potential reasons for some of this disparity will also be presented, which will illustrate why the above question requires further attention.

### **1.1.1 The role of information in energy regulation**

By considering the Satiety Cascade, first proposed by Blundell (1991), the relative meanings of satiation and satiety can be elucidated. Satiation can be defined as a process that takes place during the course of a meal, and it describes the inhibitory feedback processes that act to bring on the cessation of eating. Satiety begins after the cessation of eating, and describes the period in which the individual refrains from eating. Due to its short-term nature, satiation is mediated primarily via sensory feedback mechanisms evoked by the ingestion of the food. As such, it can be considered a within-meal process. As satiety operates over longer time scales, it is mediated by cognitive mechanisms such as the memory of recent eating, as well as post-ingestive and post-absorptive mechanisms stimulated by the passing of the food through the digestive tract. As such, this can be considered a between-meal process.

The notion that these processes are completely controlled by homeostatic mechanisms cannot account for many modern experimental findings in studies of human eating behaviours. Increasingly, the role of cognition is being considered alongside physiological factors as potential determinates of the generation of satiation. While there are many different ways in which cognitions have been proposed to influence eating behaviours, often such proposed mechanisms rely on the evaluation of information obtained by the individual with regard to the food they are eating, or the situation in which they are eating the food. Possibly the most obvious sources of information available in modern eating situations are that of the nutritional information available on many pre-packed food wrappers. However, the extent to which satiety and satiation are influenced by this information is unclear. Unsurprisingly, dieters would be expected to show large changes in behaviour in response to nutritional labels, but it is the responses of non-dieting, non-weight conscious individuals that this thesis wishes to examine. While this group should not worry about the calorie content of the food they are consuming, they will have gradually learnt associations between foods and their satiating properties. These associations have been observed to influence intake in humans, with studies illustrating that participants can be insensitive changes in the actual energy content of a food, as long as its flavour stays the same. This process is termed learnt satiety.

### **1.1.2 Learnt satiety**

It has been proposed that much of humans' daily intake regulation arises from conditioned responses to external stimuli, rather than merely biological responses to actual post-ingestive effects of consumed food (Mela 1999). Several forms of learning are thought to influence eating behaviours (Brunstrom 2004), but one with particular relevance to the current research is termed flavour-nutrient learning. This kind of conditioning occurs when a flavour becomes liked due to a learned association between the sensory characteristics of a food and the reward gained from eating it; i.e. the nutrients it contains. Flavour-nutrient learning has been demonstrated in both rats (Elizalde & Sclafani, 1988) and humans (Booth, Mather & Fuller, 1982; Gibson, Wainwright & Booth, 1995). There is sound biological reasoning for such a learning process, as it would reinforce the consumption of more concentrated energy sources, which of course are essential for survival when food is scarce. A related concept is that of learned satiety, where the post-ingestive effects of a food become associated with its sensory profile. Future experiences with this food will then rely on this learned response as well as visceral feedback when terminating a meal. This effect can be highlighted in experimental situations by giving participants repeated exposure to a preload, and measuring subsequent intake and appetite. After several exposures to the preload, a further repetition is conducted using a preload that tastes identical, but with an altered energy content. Typically, participants still show a conditioned response to the first energy load, even though they have consumed a considerably different amount of energy. With further trials this effect gradually diminishes, as the participant becomes conditioned to the new energy content of the preload.

Birch & Deysher (1985) conducted 2 experiments using three to five year old children, in which chocolate and vanilla desserts were used as preloads, each matched with a different energy density. The children took part in a minimum of two pairs of conditioning trials in which, on different days, each flavour was paired with a different energy content, and a minimum of one pair of extinction trials in which the two flavours were paired with the same, intermediate energy content. One each test day, participants consumed a preload, and then 40 minutes later were allowed ad-lib access to other snack foods. Participants accurately compensated for the energy

content of the preload during the conditioning phase, and continued to exhibit these eating patterns even when the energy contents of the preloads were matched. This therefore suggests that in the extinction trials, the children were observed to respond to the learned association between flavour and energy content, rather than the intermediate energy level of the preload used in the extinction trials. Similar findings were also seen by Birch et al., 1990 and Johnson et al., 1991, Earlier studies by Booth et al., (1976) and Booth et al., (1982) demonstrated learned satiety to a lesser degree in adults, with participants exhibiting some, albeit incomplete compensation.

The short duration of the studies using adult participants is a possible explanation for the poor conditioning seen within this group, as in the studies by Booth et al., (1976; 1982) participants only received a maximum of five exposures to the flavour-nutrient pairing. However, a recent study (Zandstra et al., 2002) suggests that this is not the case. This study examined the extent to which conditioned responses were developed over 20 repeated test sessions. On alternate days, participants were provided with novel tasting preloads prior to a test meal. Each energy variant of the preload was paired with a different flavour. After 20 sessions, the flavour-nutrient pairings were reversed, and 2 further test sessions were completed. Participants displayed no observable improvement in compensatory ability over the 20 test sessions, and were not observed to display accurate learned associations. Whether children and adults learn associations between flavours and visceral cues associations at equal rates is yet to be fully investigated, and it could be argued that it may be harder to condition adults in this way as they have had much more extensive experience with food, and therefore may require longer to override their own conditioned responses towards experimental foods (as argued by Birch and Deysher, 1985).

In this thesis, it was proposed that participants' eating behaviours during laboratory-based preloading experiments were being influenced by participants' prior experiences with the types of food used in the experiment. If participants had consumed similar foods previously, learnt associations may have been affecting participants subsequent eating behaviours. As the energy level of the preload varied with test condition, while the sensory properties remained the same, it was predicted that participants may be using sensory information to guide their intake during a test meal, rather than the satiative sensations generated by the actual energy content of the preload. Thus learnt associations between the preload and its effect may have been

inhibiting accurate compensation. In these experiments, appetite is assessed via subjective ratings throughout a test meal, and covert measuring of the amount eaten during this meal. As can be seen from the type of measurements taken, these experiments were specifically concerned with processes of satiation rather than satiety, as eating behaviours within a meal were being considered.

Of particular interest to this thesis was whether humans could create associations between explicit information such as nutritional labelling, or whether only the more basal information gained from sensory feedback is able to influence intake in this way. Furthermore, could changing the labelling of a food create a strong enough change in perception of the food to interfere with these associations?

### **1.1.3 Portion size manipulations**

One way in which participants can be observed to respond to external cues rather than internal visceral cues is via changes in food portion sizes. A study by Wansink (1996) concluded that for a variety of foods, increasing package sizes led to a corresponding increase in desired portion size when asked to illustrate the amount participants would choose to eat. Another study noted a similar effect with food intake, with visitors to a cinema eating more popcorn when initially served with a larger portion (Wansink & Park, 2001). Interestingly, when served in a larger portion, the popcorn was perceived to be less healthy, and participants reported being less able to judge how much they had eaten. This indicates that participants' evaluation of the popcorn varied with portion size, which could support the argument that the information obtained from the food is influential in appetite regulation. Due to the naturalistic setting of this study however, tight controls over participant mood and prior eating were not possible. The participants for this experiment were based on an opportunity sample, and so included male and female participants with a 11-89 age range. The authors also do not specify whether every person entering the cinema took up their offer of free popcorn and beverage, and consequently, whether it can be ascertained whether some participants shared their food. An alternative explanation for this finding could be that participants were more willing to share when provided with the larger portions, thus creating this portion size-intake relationship. As such, the conclusions that can be drawn from this study are limited.

More recently, a series of more tightly controlled laboratory-based experiments have examined how portion sizes affect intake, using a variety of foods including pasta meals (Rolls, Morris & Roe, 2002), sandwiches (Rolls, Roe, Meengs & Wall, 2004) and potato crisps (Rolls, Roe, Kral, Meengs & Wall, 2004). These studies incorporated within-participant designs to examine how changing the portion size of a meal affected meal intake, with all three replicating the finding that a larger portion size leads to increased intake. Kral et al., (2002) expanded upon this finding by examining intake over a series of meals in a two day period, and found that the increased intake was not compensated for in subsequent meals, leading to an increase in overall energy intake when provided with larger portion sizes. These latter studies provide more convincing evidence of the association between portion size and food intake, as the within-participant designs will have reduced the likelihood that the effect was created by individual differences between participant groups.

One potential explanation for the observed relationship between portion size and intake relates to the tendency many people have to finish the portion they are given. Specifically, it is possible that the differential is simply created by ceiling effects. Participants manage to finish the smaller portion, and so end their meal sooner, creating the observed effect. However, this cannot explain the result entirely, as the effect still persists in the studies by Rolls et al., (2002) and Rolls et al., (2004) even when data from participants who finish the portions are excluded. An alternative method employed by Wansink, Painter & North (2005) provides further evidence of the effect of visual cues upon eating regulation. Here, 54 participants were presented with bowls of soup to consume. Using self-refilling bowls, some participants were given larger portions to consume by covertly refilling the bowl during the meal. Despite consuming 73% more soup in this condition, participants were unaware of consuming any more, and were no more sated than participants who had consumed normal portions. Thus, this experiment suggests that the development of satiety depends at least partly upon cognitive metering of food intake guided by visual cues. Taken together, these studies provide further evidence that humans can be observed to respond to learnt external cues when regulating their energy intake.



#### **1.1.4 Attention to and memory of food cues**

So far, it has been suggested that participants may be influenced by a variety of forms of external information when regulating their energy intake. If this is the case, the focus of an individual's attention may also affect this process. For example, if a person does not think about the food they are eating, will this diminish these influences? And conversely, if they concentrate upon the foods to be consumed will they be able to maximise its effectiveness? An anecdotal example of this may be the situation when due to a particularly engrossing activity, we 'forget to eat' and pass through normal meal times without the usual hunger. Herman, Ostovich & Polivy. (1999) suggest two alternatives as to why this might occur: Either attention to hunger may be overridden by a more compelling focus, or possibly that hunger can be displaced by other attentional focuses due to human consciousness only having a limited capacity and the ability to attend to a certain number of cues.

##### **1.1.4.1 Distraction from food cues and appetite**

Herman et al. (1999) examined the effect of directing subjects' attention towards or away from food via video cues of food-related or non food-related topics. Herman et al contrasted these conditions between food deprived and non-deprived dieters. The food cue was found to increase rated hunger in all the subjects, while the 'interesting' non-food cue was only found to reduce hunger in deprived subjects. The authors propose that this may be due to the non-deprived subjects already being in a state of repletion, and so cannot have their hunger reduced anymore. Rogers and Hill (1989), Jansen & van den Hout (1991) and an earlier study by Ross (1974) all found distracting cues to reduce subjective hunger and fullness ratings. In a later study by Fedoroff (1997), the authors compared restrained and non restrained eaters by exposing them to differing food cues, by either exposing subjects to the smell of food, instructing them to think about food, or giving them no cue. There were no differences seen when there was no pre-exposure to the food cues, but restrained eaters saw significantly greater intakes after exposure to either of the cues.

Bellisile & Dalix (2001) examined the effects of distraction from or attention to food cues by playing audio tapes to subjects during a test meal. The results showed a significant increase in the amount eaten during the distraction condition, and also a significant correlation between level of restraint and the increase in intake over baseline levels. The correlation showed that a 50kj increment of food intake was seen for each additional point score on the TFEQ. It is also worth mentioning that while the distribution regressed to the equation  $y = 50x - 119$ , (thus indicating that for very unrestricted subjects, the results predicted a negative effect of distraction upon intake) only six subjects exhibited a decrease in intake due to distraction, of which two may have been considered outliers. Taking this into consideration, this data may not adequately argue a case for a null effect of distraction upon low restrained eaters.

#### **1.1.4.2 Memory of recent eating**

Higgs (2002) examined whether participants' memories of their recent eating influenced their intake at a biscuit taste test. This was conducted by asking subjects to focus their minds on the lunch that they were provided with 2 hours earlier (pizza), and comparing their intake with other subjects who had been given the cue of thinking about the previous days lunch or no cue at all. The group who had thought about their recent lunch intake were shown to eat significantly less at the test session, which involved eating biscuits and was disguised as a taste test. Hunger, fullness and preference ratings of the foods failed to show any features which would indicate confounding effects of the mental visualisations or contrasts in palatability between the two types of food. A further experiment observed that this result could not be elicited by thinking of food intake on a previous day, which indicates that the effect was not just a response to the memory of any food. It is unclear in whether a 'peer pressure' effect may exist in this data – the subjects know that the experimenters know what they have eaten previously that day, and so they may limit their intake to avoid appearing greedy. The statement 'think about what you have eaten at lunch today' may make subjects think that the experimenters are hinting that they have already eaten a lot, and so may restrict further intake accordingly. This may be especially relevant for restrained eaters who are conscious about their weight and how

their eating habits may appear to others. Although this study was not examining the effect of attention directly, it could be argued that a memory effect may act via an effect on participants' attention towards the food they have consumed. It is possible that by reminding participants of their recent eating, Higgs (2002) was drawing their attention to the food, and the various forms of information gathered during this eating episode.

The apparent effects of attention towards and distraction away from foods upon eating behaviours is relevant to this thesis because it provides further evidence that human food intake is influenced by external information sources. The potential effects of attention and information are closely linked, as is it is plausible that it is the attention to, or distraction away from the information about the food that is influencing appetite.

#### **1.1.5 Explicit information sources**

While the evidence highlighted above illustrates how information can influence appetite, how this relates to providing overt nutritional labelling has not yet been established. The question at hand changes when considering this issue, as an additional factor needs to be considered. Specifically, where nutritional labels are added to foods, the extent to which individuals take note of and believe the information is critical in determining their effectiveness. Several laboratory-based experiments have examined the effectiveness of providing nutritional information with test foods, but results have been mixed. The previous studies in this area are reviewed below, and the reasons why further research is of value will be explained.

Table 1.1 Summary of studies examining how information about test food can influence subsequent appetite and food intake. P refers to Participants, ED refers to Energy Density

	Paper	N	Participants	Design	Outcomes	Relevance
1984	Eiser, Eiser, Patterson & Harding	247	106 male, 141 female, all aged 13 – 14	Children were asked to rate foods either with no info or info regarding nutrient content	'Good for you' ratings followed info, but 'pleasant did not'	Illustrates how information about a food may not influence perceptions and desire to eat it i.e nutrient info may not influence perceived palatability and subsequently appetite
1987	Wardle	10	Normal weight, non-dieting women Mean age 43.8yrs	Energy content & information crossover design	Appetite of P sensitive to actual energy and deprivation time, but not caloric beliefs	Utilised nutritional labels to manipulate beliefs.
1990	Ogden and Wardle	20	10 restrained and 10 unrestrained normal weight women, mean age 20.3 yrs.	Energy content & information crossover design	All P sensitive to actual content, restrained P sensitive to labels	Utilised nutritional labels to manipulate beliefs.

	Paper	N	Participants	Design	Outcomes	Relevance
2001	Yeomans, Lartamo, Proctor, Lee & Gray	16	Unrestrained male participants, aged 18-30 (mean 23)	Energy content & labels used in crossover design in unrestrained men	No effect of information, P followed actual energy values	Possible limitations to this study. Utilised nutritional labels to manipulate beliefs.
2002	Kral, Roe & Rolls.	40	Normal weight women, of varying restraint levels. mean age 21.1	P were provided with ad libitum meal varying in energy density, and some were provided with ED labelling (rather than Energy content or fat content)	P followed same pattern of intake across the info/no info groups, and intake was related to actual ED	Lack of effect of labelling doesn't support a perception-based theory, but misleading labelling was not used. Also to what extent does information about energy density affect perception about a food?
1969	Jordan	4	Normal weight male students, aged 20-22.	P had control over intake via oral or intragastric routes, and could eat as much as desired	Little effect was seen of calories on amount consumed intragastrically	Supports perception-based theories

	Paper	N	Participants	Design	Outcomes	Relevance
1972	Wooley, Wooley & Dunham	14.	7 Obese and 7 normal weight participants, 9 female, 5 male. age range 22 – 50.	P asked to guess whether meals were high or low calorie after consumption	P showed little ability to discriminate, with hunger reported more in accordance with initial beliefs about calorie content	Suggests perception of energy is important
1972	S Wooley	32	16 obese and 16 non-obese participants. Equal male/female split, aged 19-24.	Preload manipulated to appear high or low calorie	Intake not affected by calorie change but altered by beliefs about calories	some concerns about the methodology used.
1989	Heatherton, Polivy & Herman	129		P given placebo, and told either nothing, or that the pill had made previous P feel hungry or full	Information given to P affects food intake, although the opposite effect was seen for unrestrained P	Suggest an effect of info on intake, but could it be attributed to social norm effects?
1989	Mattes	24	Normal weight adults (12 male, 12 female) mean age 22.6	P were given cereal sweetened with sucrose or aspartame for 5d. Intake and hunger monitored.	24h Energy intake tended to be more strongly influenced by perceptions of energy of the breakfast	

	Paper	N	Participants	Design	Outcomes	Relevance
1989	Rolls, Laster & Summerfelt	40		P given high or low calorie (sweetened with aspartame) deserts and told to eat ad libitum. Some given info about calories	Similar weights of food were eaten in both conditions. Awareness of calorie difference did not influence intake	Despite lack of effect of labelling, the fact that the sweetness of both conditions was the same may suggest that P perceptions for the two conditions were similar
1992	Solheim	347	Opportunity sample of shop customers. No further info given.	Labelling of high and low fat sausages was manipulated. P gave rated liking for them.	When Sensory qualities were similar across fat contents, information affected ratings	Link between perceived palatability and intake, thus indicating that this supports theories about perception
1993	Caputo and Mattes	17	12 female, 5 male normal weight participants. mean age 21.7 (SD 0.9)	Following a baseline period, participants were told that a test meal provided for 12 consecutive days was either high or low in fat	Participants increased their daily intake when told the meal was low in fat	
1995	Shide and Rolls	48	24 restrained, 24 non restrained women, mean age 26.3yrs	Info manipulated about equicaloric preloads	P ate more after low fat labelling then after high fat	Suggests that perception can alter food intake.

	Paper	N	Participants	Design	Outcomes	Relevance
1995	Chapelot, Pasquet, Apfelbaum & Fricker	16	8 restrained and 8 unrestrained normal weight women mean age 20.2yrs	Energy content & information crossover design	Both actual and perceived levels of calories affected intake in unrestrained and restrained eaters.	Some support for the theory, although unrestrained subjects were not influenced as expected.
1998	Miller, Castellanos, Shide, Peters & Rolls	95	51 male, 44 female, restrained and unrestrained participants, mean age 23.1	P given an ad libitum snack of high or low fat potato chips. Some were provided with info, some not.	Restrained P ate more when low fat label was provided. labels were not used incorrectly	No effect on unrestrained P
2003	Bowen, Green, Vizenor, Vu, Kreuter & Rolls	192	Women with a mean age of 64 (SD 10.2) A sub - section of the WHI study.	Actual and expected fat content used in a crossover design using milkshakes	Intake was determined by fat content, with more of the high fat variety being consumed. Preferences were shown to be influenced by expectations	Despite intake result, the fact that preferences were influenced by expectation infers that perception of the shake was influential at some level



Research into eating behaviours using labelling techniques has been conducted since the late 1960's and 1970's when studies were presented by Jordan (1969) and Wooley et al., (1972) which challenged the theory that short-term hunger and satiety were governed solely by the actual energy contents of foods, suggesting that cognitive factors may be influential in the subjective sensation of these feelings.

Jordan (1969) examined the effects of combining oral and intragastric feeding, varying the amount and dilution of the infused portion of the food to examine how voluntary oral feeding was influenced. It was observed that not only were the participants unable to discriminate between the infused food and infused water, but they were also unable to reduce their oral intake sufficiently when the amounts of infused food was altered. Evidence that participants' evaluation of the foods influenced energy intake regulation was also observed by Wooley et al., (1972), who provided participants a preload in two different energy levels over several days. After consumption of each meal, participants were invited to guess whether it was a low or high-energy preload. Generally, participants were poor at distinguishing which preloads were low-energy versions. It was also noted that subjective hunger ratings after the preload were determined by the participant's estimate of the preload, with greater subjective hunger consistently reported after a perceived low-energy preload, regardless of its actual content.

In another study by Wooley (1972), preloads designed to appear high- or low-energy altered subsequent hunger in participants by their perceived rather than actual energy contents. While this study potentially supports the findings of Wooley et al., (1972) and Jordan (1969), its findings must be judged with some caution, as the manner in which the appearance of the preload was altered may have confounded results. Methylcellulose was used to thicken the drinks designed to be high-energy, and while this may have created the desired effect, viscosity has since been shown to influence hunger and satiety independently of energy content (Mattes & Rothaker, 2001). It could be argued therefore that the increased satiating ability of these preloads may have arisen due to physiological responses to the thicker liquids, rather than a psychological response to the appearance of the soup.

However, research examining the extent to which participants' perceptions of the foods they are consuming have an influence on intake regulation is far from unanimous, with some studies suggesting that participants are unaffected by cognitions about foods, and that hunger and satiety are governed primarily by the nutritional properties of the preload and not by appearance.

Wardle (1987) used nutritional labels to inform (or misinform) participants about the calorific value of an orange juice preload provided two hours before a test meal. The results from this study did not support the findings of Wooley et al., (1972) or Jordan (1969), as a variety of subjective measures were all sensitive to both the length of food deprivation and the energy content of the preload, but were insensitive to the effects of labelling. Although the test meal administered two hours after preload consumption failed to show any difference between any of the conditions, overall this study provides support for the argument that beliefs are not the primary determinant of intake regulation.

Ogden and Wardle (1990) used a similar methodology in a subsequent experiment, with the inclusion of a measure of dietary restraint in the form of the restraint scale of the DEBQ (Van Strien et al., 1985). In this study, the authors again found participants to be responsive to the actual variations in energy content of the preloads, in terms of the subjective ratings taken in the preload – test meal interval. While unrestrained participants were again seen to be unresponsive to the effects of the label manipulations, the restrained participants were found to feel significantly more full and less hungry after preloads labelled high-calorie, regardless of actual content. The study failed to highlight any differentials in intake at the test meal across the actual or labelled preload conditions, which concurs with Wardle (1987).

In support of Wardle (1987) and Ogden and Wardle (1990), it can be argued that the earlier work by Wooley, Wooley and Dunham (1972) may have inherent methodological problems. The criticism levelled at the study is that as participants guessed how energetic a beverage was after consuming it, this estimate was likely to be based on visceral sensations of hunger and fullness, and so is it unsurprising that a perceived high calorie preload will be correlated with lower hunger scores. This

criticism does not however, account for why no difference in hunger ratings was seen between the actual high- and low-energy preloads, which may have been predicted due to the relatively large manipulation of calories across the test days (the drinks varied in energy approximately by a factor of 2). Whilst these limitations should be considered, and raise some questions over the results seen here, other more recent studies have also found beliefs to influence short-term eating regulation using different methodologies. For this reason, Wooley et al. (1972), should not be completely disregarded at this point.

In summary, although disparity exists in the findings of these studies, there is considerable evidence to suggest that nutritional information that participants receive about foods may influence their eating behaviours. Presumably, this information will act to alter participants' beliefs and expectations about the food they are about to consume. Further research would be of use to further elucidate whether, in a laboratory environment, the beliefs that a participant has about a food can influence their appetite.

In order to better understand why the previous studies examining this issue exhibit contrasting findings, a more detailed examination of the employed methodologies is required. A variety of methodologies have been employed to examine the potential effects of beliefs, and while this helps to determine whether results can be explained by methodological factors, it can make comparisons between studies more difficult. For clarity, the studies have been grouped together depending on their respective methodologies.

#### **1.1.5.1 Nutritional labelling**

This technique is commonly used to manipulate beliefs about foods, so that cognitive and physiological effects can be examined independently. Generally, this method requires the foods used to be matched for sensory properties to eliminate effects arising from varying palatability or other sensory properties of the foods. This technique has been used by the previously-mentioned studies by Wardle (1987),

Ogden and Wardle (1990), as well as Solheim (1992), Chapelot et al., (1995), Shide and Rolls (1995), Miller et al., (1998) Yeomans et al., (2001), Kral et al., (2003), and Bowen et al., (2003). There is also considerable variation between the methodologies used in this group. Two studies have monitored the effects of labelling a single food (Solheim, 1992, Miller et al., 1998,), whereas the rest of the studies mentioned have all used preloading paradigms and so probably bear the most similarities to this thesis. Other distinctions can also be made between these studies, and these will be discussed later in this review.

#### **1.1.5.2 Labelling of a single food**

Of the two studies highlighted here, the earlier, by Solheim (1992) does not directly examine the role of labelling on appetite. In this study, sausages labelled high- or low-fat were tasted by participants, and rated for their palatability and sensory properties. The study found that the provision of labels could influence these ratings, with increased palatability ratings after tasting the sausages labelled high-fat. Miller et al., (1998) examined the effects of providing normal and reduced-fat crisps with or without nutritional labels on both energy and fat intakes. Although participants ate significantly less fat and energy following the low-fat crisps, 24-hour intake showed no significant differences in energy intake. The provision of nutritional labels was only seen to influence restrained participants, who ate significantly more of the low-fat crisps when nutritional labels were provided. This study should be considered separately as subsequent appetite or intake was not measured, as would be in preloading paradigms.

#### **1.1.5.3 Labelled preloads**

The potential influence of information upon appetite has also been examined using a preloading paradigm. Here, nutritional labels are added to preloads to manipulate how participants perceive the preloads they are consuming, and how this affects

subsequent appetite. This technique can be used to examine how the labelling of one food can influence intake of subsequent food more accurately than may be achieved by use of 24-hour food diaries or retrospective questionnaires. As noted previously, even within this group, considerable variation in methodologies exists. The types of labels used varies, as some studies have used high- and low-fat labels (e.g. Shide and Rolls 1995, Bowen et al., 2003), some have used labels referring to energy content or density (Wardle, 1987, Ogden and Wardle 1990, Kral et al., 2002). Another technique employed by Yeomans et al., (2001) involved using fictitious brand names to elicit different perceptions of richness and energy content. The argument that intake is influenced by beliefs and perceptions of foods is supported by a study by Shide and Rolls (1995), who found that identical preloads could produce differing effects on appetite when labels were manipulated. This finding echoed the results of an earlier study by Caputo and Mattes (1993). In particular, this study also involved using labels to convince participants that identical energy loads actually varied in energy content. Although it employed a relatively small sample size of 17, a repeated measures design allowed each participant to be tested 12 times on consecutive days. In this study, participants were provided with a test meal, which they were informed was either low, moderate or high in fat. In reality each of the test meals was identical. Diet records were then completed by the participants for the remainder of each day. The authors found that the different labels on the test meals did have an effect on daily intake, and in particular, the low fat labels increased daily intake relative to baseline values.

More recent studies (with the exception of Bowen et al., 2003) have failed to find an effect of nutritional information on appetite or intake, with the results obtained being determined by the actual energy levels of the preload, regardless of the labels. Bowen et al., (2003) provide somewhat ambiguous results, as although the authors fail to report an effect of information on subsequent energy intake, preferences for the preloads were found to be influenced by their expectations. Although in this study intake was not observed to be influenced by expectancies generated by labels, their influence on palatability ratings does suggest that the information was influencing participants eating behaviours, and so may have implications for intake in other studies.

Yeomans et al., (2001) and Kral et al., (2003) are two of the most recent studies to examine this specific question of providing nutritional labels, both of which fail to show any influence of the information provided. In order to justify why further investigation into this research question is warranted, these two studies will now be examined in greater detail.

#### 1.1.5.3.1 Yeomans et al., (2001)

Yeomans et al., (2001) found unrestrained male participants to be insensitive to manipulation of labels presented with a soup preload. Several concerns can be raised about some of the methods employed here, and some of the assumptions made. This study involved the use of fictitious brand names to convince participants that the soup preloads provided were either high- or low-energy products. The use of such a design is understandable – in a real environment, individuals will be likely to form their opinions about products based upon the appearance of the product and its packaging. Providing these fictitious brands will also remove some of the problems associated with nutritional labelling as it encourages participants to form their own judgements about the test foods, rather than force feeding participants with information about the content of the food, which may arouse suspicion. However, the use of such brands must be believable and in order for the manipulation to maintain its validity, their effects on participants' perceptions must be quantifiable. Yeomans and colleagues validated this manipulation by means of a separate test, where a different group of participants were asked to rate how they would expect soups to taste if they were presented with each of the fictitious labels. This method of validation may have inherent problems as the soup used in the study was not actually presented along side these labels, and so it cannot be determined whether these labels were believable, given the actual appearance and taste of the soup they represented. If, for example, a soup which appeared and tasted weak and watery was purported to be 'luxurious' and 'creamy', participants may begin to question the meaningfulness of the labels.

The use of fictitious labels in this study raised another potentially serious consideration related to the within-participant element of this study's design. On four occasions, participants were provided with a soup preload, labelled differently each

time, but actually consisting of the same soup. It is hard to believe that by the end of the fourth visit, the participants would not have realised that the food served was the same (or at least similar) each time, despite a label suggesting it should be considerably different. While it is acknowledged that the order of presentations of these preloads were counterbalanced, and represented a better alternative compared to a between-participant design, this design may have still created some problems. The criticism of this method is not that a bias would be created towards one condition or another, but rather that the diminishing effectiveness of the information manipulation across the four test conditions may have artificially created the null result observed in this study.

#### 1.1.5.3.2 Kral et al., (2002)

One of the most recent studies employed to examine the effects of nutritional information upon food intake was conducted by Kral et al., (2002). While this study did not reveal any effects of the nutritional information upon appetite and eating behaviours, several potential limitations are evident within the study methodology. In this study, a mixed model was employed to investigate the relative effects of foods varying in energy density (within-participant), as well as the provision of information regarding the energy density of the food (between-participant). On three occasions, 40 participants of mixed dietary restraint levels consumed an entrée containing 5.23, 6.28 or 7.32KJ/g. The entrees were consumed ad-libitum. Energy intakes for lunch and dinner were also recorded. Half of the participants were given information regarding the energy density of the entree they were consuming. Decreased energy intakes were observed following the low-energy entrees relative to the high-energy equivalent, while information about the entree energy density was not seen to alter the results between groups.

The study by Kral and colleagues (2002) does not support the theory that individuals' expectations about a food will influence their ability to regulate intake of subsequent foods. The explanation for this could lie in the methodology employed and in particular the fact that participants consumed the different entrees ad-libitum. As any

effect of expectations upon intake would be likely to be relatively subtle when compared with the physical properties of the entree, the differences in volume consumed on these different test days may have masked any influence of the nutritional information. There are also some reservations about the methods used for the provision of information in this study. In this study, participants in the information group were given a training session by a registered dietician about energy density and how to derive it from nutritional labels. During the test sessions, this group of participants were then provided with nutritional labels alongside each entree which informed the participant of the energy density and its relative level (low, med, or high).

However, the extent to which this influenced participants' beliefs of and expectations about the entree is unclear. The authors use questionnaires at the conclusion of the experiment to prove the effectiveness of this manipulation, and it is the results of this questionnaire that raise concerns. Despite receiving no information about the entree contents, three of the no-information group were able to identify that the proportions of ingredients varied across test conditions, and a further nine were able to identify sensory differences between the test days. This is of concern because it creates the possibility that sensory differences may be creating the observed effects by providing the participants with implicit information about the properties of the entree, rather than a purely physiological effect arising from energy density differences. The authors admit that participants may have been influenced by taste differences as rated liking of the entree (the only rating taken) may not have been sensitive enough to detect subtle taste differences. As the taste of a food will obviously have an influence on its consumption, it could be argued that this is an important factor which may deserve more consideration as it may change the whole interpretation of these results.

The way in which the authors ascertain that the no-information group had less knowledge about energy density than the information group is also a little ambiguous. The authors rely on the fact that when completing a four-question quiz about energy density, 17 participants in the information group answered all the questions correctly, while in the no-information group only 10 participants were able to do this. The other participants were reported as having answered 3 or less questions correctly. However, while more participants in the information group scored 100% in this quiz, when you



consider that half of the participants who had received no energy density training also managed to answer all four questions correctly, the validity of this claim comes into doubt. The remaining 10 participants in the group may have also answered three out of four correctly, as no further breakdown of the results of this quiz are given.

Participants were also asked about their knowledge of energy density, and all of the 20 participants in the no-information group reported having little (9 of 20) or no knowledge (11 of 20) of energy density. Again, on face value this appears to confirm the authors claims that the no information group had little knowledge of energy density. However, this result should be viewed with caution as no equivalent result for the information group is provided. The way in which this question was asked may have influenced the participants' answers to it, as energy density is a scientific term not readily used in supermarkets, food advertising etc. It is quite possible that these participants had a good understanding of the underlying issues but were just not familiar with the specific term, or they were being overly cautious given the environment (surely few participants would walk into a scientific laboratory and tell the researcher they were already experts in the subject). The lack of an equivalent result for the information group also suggests that even this group reported having little knowledge of energy density which may be a reflection of this cautiousness.

These final questionnaires have been examined in so much detail because taken together, they were used by the authors to prove that they had created an observable difference in knowledge between the two groups without influencing eating behaviours. Thus this finding is used to support the proposal that information did not influence appetitive responses to the entrees. From the discussion above, it can be seen that there is a possibility that the observed results may actually be due to a number of factors not considered in the report of this experiment, and to determine that the null result observed regarding information provision means that it is not an influential factor may be premature.

In summary, while the most recent studies have produced results which refute the ability of nutritional labels to influence participants short-term energy regulation, when these experiments are examined in detail several methodological limitations exist which may explain why these studies have produced nul results. This, taken

together with earlier findings such as those by Shide and Rolls (1995) and Caputo and Mattes (1993) suggest that further investigation of this question is desirable.

### **1.1.6 Implications for longer timescales**

If the wider context of these issues is considered, how these processes may influence eating behaviours in the medium to long term becomes more obvious. If for example, consumers buy a traditionally high energy product developed to contain very little energy, initially processes such as learnt satiety may aid weight loss as participants are using the memory of the high – energy product to guide their intake. However, with repeated exposures to the food the benefits offered by learnt satiety would diminish, as intake would gradually be adapted to the actual energy content of the food. As such, the information provided about the food becomes of lesser importance over a longer time period, as learnt associations are eventually formed about the food and the satiety responses generated by the food, regardless of the information provided with it.

It is possible that human regulatory responses such as learnt satiety have been hindered by modern foods and diets. While originally, any given food was only available in one form, modern manufacturing processes now allow many different permutations of food types and energy content. It is plausible that this may have limited the effectiveness of processes such as learnt satiety, as an individual's ability to learn associations between foods and their properties may be impaired when foods are available in a variety of different energy contents. If eating behaviours could be examined without the influence of informational cues such as learnt satiety, some indication of their influence could be gained. If participants could be observed to become more sensitive to the energy contents of foods when information cues about the food are restricted, it would provide some indication that the process of learnt satiety is hindering humans' intake regulatory responses.

### 1.1.7 Summary

Evidence has been presented that implicates information gained by the individual being influential in short-term energy regulation. This information may take the form of nutritional labelling, or more indirect sources, such as the appearance of the food, or the size of packet it is served in. While some studies have failed to observe such relationships between information and eating behaviours, there are often methodological reasons why this may be the case.

Thus the aims of this thesis are as follows:

- To further investigate, with particular reference to dietary preloading studies, how providing information about a food will influence a participant's dietary response to its consumption. Can manipulating information about a preload given to unrestrained participants exert an observable influence on their ability to compensate for the energy it contains? Existing research that examines the influence of information upon preloads often leaves uncertainty regarding the effectiveness of information manipulations due to potential demand effects, and this thesis aims to approach this problem from a novel perspective.
- To develop a suitable methodology with which to test the above question. The suitable methodology will allow the potential effect of information to be investigated while controlling variables relating to the physical form and content of the test foods as well as the methodological factors that have been highlighted as potential confounders. A review of the physiological (rather than psychological, as have so far been considered) factors that influence compensatory ability is needed to identify these factors.

Below is a summary of the objectives of each of the eight experiments presented in this thesis, to illustrate how each contributes towards addressing these two main aims. The eight experiments conducted here can be split into four different parts.

The first part was concerned with the development of an experimental paradigm, and began to examine how information can be important in this type of study.

Experiment 1. To develop a vehicle suitable for use in preloading studies and to incorporate this vehicle into a preloading paradigm sensitive enough to observe short-term energy compensation in unrestrained, adult participants.

Experiment 2. To determine whether the adjustments made to the initial experimental design are effective. To investigate whether learnt associations between the food and its satiating effect are limiting participants ability to compensate in preloading studies.

The second 2 experiments expanded on this question further with two different experiments that investigated how participants initial beliefs about a preload were related to their appetite and eating behaviours shortly afterwards.

Experiment 3. To assess whether participant's initial beliefs and uncertainties about a preload are related to participants eating behaviours at a test meal

Experiment 4. Can the findings of experiment 3 be replicated using a methodology that will not be at risk from bias caused by baseline hunger levels and demand effects of the questions posed to participants?

Experiments five and six moved away from preloading studies, as these studies were concerned with the development of a psychophysical task with which to assess participants beliefs about foods, with a view to incorporating such a measure into the preloading design.

Experiment 5. The development of a measure based upon existing psychophysical theory that can be used to assess participant beliefs and uncertainties about a food in a way that can be incorporated into a preloading experiment.

Experiment 6. To develop further the techniques introduced in experiment 5 using adaptive psychophysical procedures to create a task that is both reliable and practical to use.

The final experiments of this thesis revisit the preloading paradigm, and sought to establish the mechanism behind the observed associations between preload expectancies and compensatory ability.

Experiment 7. To begin to examine whether participants attention towards or away from a food may be mediating their sensitivity to the energy content of the food. This experiment was planned as a preliminary experiment before a larger experiment that incorporated the psychophysical measures.

Experiment 8. To utilise the psychophysical measure developed in the previous experiments to re-examine the observed association between beliefs, uncertainties and compensation using these measures. These experiments also aimed to test whether evidence could be observed that would support the theory that attention was mediating the observed associations.

# Chapter 2    **Methodological considerations**

## **2.1 Methodological considerations: The assessment of short – term energy regulation in humans**

This thesis is primarily concerned with the potential effects of information gained by the participant upon eating behaviours, with specific reference to laboratory-based preloading experiments. As such, the focus of the experiments presented here will be very much psychologically-based.

However, when designing experiments that can examine this issue, it is important to at least consider other factors that will also influence this type of study. Although the factors which are discussed below will not be tested in the experiments of this thesis, their influence will need to be considered across different test conditions in order to prevent confounding influences. The initial choice of methodology will then be introduced, along with the adaptations made to it following initial testing.

### **2.1.1 Dietary preloading studies**

The experiments of this thesis were based around a dietary preloading paradigm. Preloading experiments are widely used in the field of ingestive behaviour, and are suited to short - duration, laboratory – based experiments. A dietary preloading study examines the effects of a particular food upon subsequent appetite and intake. A preloading study is used to examine the effects of consumption of a particular food upon subsequent eating behaviours. In such studies, participants are asked to consume the preload, and after a pre-determined time period, their appetite is measured, often via calculating the amount eaten at an ad-libitum test meal. Test meal consumption can be measured in a number of ways, either by using food items which can be easily measured (e.g. biscuits, as in Higgs, 2002), or by covertly weighing the food present before and after the meal to determine how much has been consumed (e.g. Yeomans et al., 2001).

The extent to which a preload suppresses appetite and affects subsequent intake is of particular interest to researchers. Often different test conditions are used within experiments to compare the suppressant abilities of preloads varying in energy or macronutrient content. The reduction in intake following preloads of different energy content is termed 'dietary compensation'. This process of energetic compensation is central to the issues of energy regulation and ultimately obesity, as it explores how individuals are able to cope with variability in their diet and detect when extra energy is consumed. Often, the compensation seen in this type of experiment is incomplete, as the reduction in intake at the test meal is less than the extra energy ingested during the preloading stage of the experiment.

Preloading studies often utilise visual-analogue scales to obtain participant's subjective feelings of sensations such as hunger and fullness. These rating scales consist of a horizontal line (often 100-mm long) anchored at each end with opposing statements such as 'extremely hungry' and 'not at all hungry'. Feelings of hunger and fullness are kept separate – i.e. being full is not considered the opposite of being hungry, as the two feelings do not always show a reciprocal relationship (Rogers and Hill, 1989).

Although studies that examine people's eating behaviours in real-life situations are undoubtedly useful for the understanding of eating behaviours, they are not perfect for every experimental design, and there are many situations in which the sort of paradigm described above represents the best solution. One of the main reasons for studying eating behaviours outside of a laboratory is that it has been argued that this does not provide a realistic illustration of people's eating behaviour in the 'real world' (Meiselman, 1992). This statement is not without foundation, as there are several ways in which it is possible for an artificial laboratory environment to influence a participant's eating behaviours. However, whether a 'real life' experimental design solves all of these problems is less clear. Firstly, one of the difficulties with these types of experiment is that by their very nature it is impossible to control potentially confounding variables that will influence participants' food choices and intake at any given meal. If, for part or all of the study, participants deviate from their 'normal' routine or environment, this may create error in the measures taken.



Error may also arise from the measurements themselves. There will often be some doubt over the reliability of measures taken without the experimenter present, such as food diaries. Participants have been shown to bias their dietary reporting to a perceived norm, with participants who eat less tending to over-report, and participants who eat more tending to under-report (Stunkard, 1981). Apart from questions about the accuracy of measures taken outside of the laboratory, there are also other considerations regarding their use. The mere knowledge that a participants' diet is being monitored may influence their eating behaviours. While this may be true of all ingestive behaviour experiments using humans, it highlights the fact that even experiments conducted in 'real life' situations often cannot be considered as entirely ecologically valid. The extent to which conducting eating behaviour experiments outside of a laboratory will provide more naturalistic eating settings is also unclear. Humans eat in an infinitely varied manner, and so identifying a 'real' eating situation may not be as simplistic as moving the experiment outside of a laboratory. A study conducted by Peterkin, Rizek, Posati & Harris (1987) highlighted that in middle-aged Americans, a third of eating occurs while alone, while in older Americans (Davis, Murphy & Neuhaus, 1988) the likelihood of eating alone was strongly associated with the living arrangements of the participants (i.e. living alone vs. living with a partner). Therefore, how realistic an experiment is will depend on the participants as much as it depends on the experimental setting.

Kissileff (1992) proposed that laboratory-based ingestive behaviour studies are useful when asking questions such as '*What controls how much people eat, and when they stop eating?*' rather than questions such as '*What controls when we eat, what we eat and why we eat?*' If the benefits of this type of study are considered, Kissileff's reasoning becomes clearer: Conducting experiments in a laboratory allows experimenters to control as much of the environment as possible, which may include external cues such as the eating environment as well as the exact timing and nutrient content of the eaten food. In particular, this type of methodology allows us to examine the acute effects of manipulating a specific element of a meal, as it allows the greatest control over other, potentially confounding variables. While artificial environments and forced meals choices may not directly inform us about participants food choices away from the laboratory, they may be able to give us an insight into the individual

processes which contribute (along with other factors) into making those decisions. This argument is illustrated by Kissileff (1992), who compares the mechanisms controlling eating to the mechanisms controlling cardiovascular function. While an athlete's cardiac output may vary from one situation to the next, it is likely that mechanisms controlling this response remain the same from one situation to another.

Within a preloading paradigm, there are many different experiments that have been carried out, examining a variety of factors. Unfortunately, this has meant that a large range of study protocols exists, which can make between-study comparisons difficult. This heterogeneity also extends to the results obtained from these studies, with many conflicting findings. Debates such as the satiating efficacy of the different macronutrients, and whether the volume or energy density of a food is more efficient at invoking satiation have all been examined numerous times without a definitive conclusion. The differences in the findings of these studies have also been partly attributed to the variations seen in the design of experiments (Poppitt & Prentice, 1996), (Rolls & Hammer, 1995). The factors that have been highlighted as contributing to the variance seen in preloading experiments are reviewed below.

#### **2.1.1.1 Preload – test meal delay**

The interval between preload consumption and test meal has been suggested to be an important factor in determining the level of compensation seen (Porrini, Santangelo, Croveti, Riso, Testolin & Blundell. 1997) (Rolls, Castellanos, Shide, Miller, Pelkman, Thorwart & Peters. 1997). Rolls, Kim, McNelis, Fischman, Foltin, Moran, (1991) examined the effects of preloads at varying time points before a buffet-style test meal. Accurate compensation was seen when the preload was administered to participants 30 minutes before the meal, whereas lesser compensation was noted in response to preloads provided 90 and 180 minutes before, respectively. Exactly why this pattern was observed is somewhat unclear. It may be argued that physiological factors influenced this effect, as different satiety mechanisms work along different timescales. Immediately after consumption afferent signals from the mouth send the first signals to the brain to act as a negative feedback mechanism, in response to the actions of chewing and swallowing. After the food is consumed, gastric distension is

thought to produce satiety signals initially, until the food passes into the intestine, where nutrient receptors also contribute to satiety. The fact that both fat and carbohydrate-based preloads produced the same pattern of results suggests that this may not be an effect dependant upon transit times or absorption rates, as fat and carbohydrate have been shown to be digested and absorbed at different rates.

30 minutes is an often-used interval between preload and test meal when wishing to examine the within-meal aspects of satiety, while using intervals greater than 30 minutes begin to look at the post absorptive mechanisms, as the food is passing through the gut and has begun to be digested (Rolls & Hammer, 1995).

#### **2.1.1.2 Solid vs. Liquid energy**

One area which has received particular attention in recent years is the question of how well energy in liquid form evokes satiety responses. This has arisen due to the findings of several epidemiological studies that have observed correlations between soft drink consumption and the increasing prevalence of obesity (Flegal, Carroll, Kuczmarski & Johnson., 1998; Harnack, Stang & Story 1999; Ludwig, Peterson & Gortmaker, 2001; Liebman et al., 2003, DellaValle, Roe & Rolls, 2004). These results were supported by a intervention study where 644 school children were discouraged from consuming carbonated drinks (James, Thomas, Cavan & Kerr, 2004). Over the course of a whole school year decreases were observed in both carbonated drink consumption as well as levels of overweight and obesity, when compared with control groups.

In short term regulation experiments, there have also been several instances where solids have been found to be more satiating than liquid energy loads (Dimeglio & Mattes 2000; Mattes, 1996; Haber et al., 1977). However, some recent research has emerged which questions these findings (Truchiya, Almiron-Roig, Lluch, Guyonnet & Drewnowski, 2006; Almiron-Roig, Flores & Drewnowski 2004). Further complexity is added to this issue with the observation that in some studies, soups in particular are able to invoke satiation as well or even more than solid or other liquid loads (Mattes, 2005; Himaya & Louis-Sylvestre, 1998).

### **2.1.1.3    Macronutrient Composition**

Dietary composition has been examined as a potential cause of overeating and subsequent weight gain, and the relative satiating efficacies of carbohydrate (carbohydrate), fats and protein is key to the behavioural responses seen after a preload. Dietary fat is the nutrient most often linked with over eating and the problems associated with the ensuing positive energy balance, and much of modern weight control advice is based around the principle of trying to reduce the levels of fat in the diet. The reasons why fat is thought to be most influential in hyperphagia are that it is a highly palatable nutrient, and also that it provides a high level of energy per unit volume, making over consumption easier. There is also evidence that the different macronutrients do not provide the same levels of satiation per unit of food, and there have been several studies examining the satiation hierarchy in order to determine which of the nutrients is most efficient at evoking satiety signals, and is the least.

It has been suggested that protein is the most satiating of the macronutrients, and there have been several findings which support this theory. A study by Poppitt, McCormack & Buffenstein (1998) recruited 12 women to participate in an experiment which aimed to examine the satiating hierarchy of fat, carbohydrate, protein and alcohol. Protein was found to significantly reduce short-term hunger, and also energy intake during the test meal. No significant differences were found between the fat and carbohydrate preload conditions in either rated appetite and hunger, or energy intake during the test meal.

While most authors agree on the effect protein has on the development of satiation, there is more debate over how carbohydrate and fat fit into the hierarchy. The lack of any significant difference between the fat and carbohydrate conditions in Poppitt et al. (1998) is a result that has also been seen in other studies. Despite much interest from various authors, research into this relationship has not yielded conclusive results. Several studies have found carbohydrate to be more satiating, and several, like the study in question have found them to have similar effects. If only iso-energetic protocols are considered, Cotton, Burley, Westrate & Blundell (1994), Green, Burley

& Blundell (1994), Lawton, Burley, Wales & Blundell (1993) & Rolls, Kimharris, Fischman, Foltin, Moran & Stoner (1994) all found fat to be less satiating than carbohydrate. Research by Woodend & Anderson (2001) has showed that infusions of sucrose were more effective at depressing food intake than safflower oil infusions of the same energy density. This result is not a unanimous finding however, as studies by De Graaf, Hulshof, Westrate & Jas (1992) Foltin, Fischman, Moran, Rolls & Kelly (1990) Foltin, Rolls, Moran, Kelly, McNelis & Fischman (1992) & Stubbs, Harbron & Prentice (1996) have all found fat to be as equally as satiating as an iso-energetic amount of carbohydrate. To try to solve this debate, research has also begun to examine different areas which may be responsible for these results, such as the relationship between macronutrient type, food volume and energy density.

#### **2.1.1.4 Volume**

While the composition of the preload has often been considered as an important variable in satiation studies, the observation that appetite and satiety can be influenced independently of this, namely via the volume of preload given, has also been considered by some. The stomach contains mechanoreceptors that respond to changes in tension in the tissue around them. As food is ingested and passed down into the stomach, the stomach is stretched, thus stimulating the mechanoreceptors to signal satiety. Some research (e.g. Cecil, Francis & Reed; 1998) has indicated that signals arising from gastric distension play a more important role in regulating gastric emptying rates rather than termination of feeding, but it is still unclear the extent to which these signals may indirectly influence eating behaviour. Some of the earlier work that examined the effects of volume looked at providing water with a meal to see if the added volume (but not energy content), affected rated appetite and hunger. Lappalainen, Mennen, Vanweert & Mykkanen (1993) for example, examined the effect of 400ml of water provided with a breakfast consisting of cheese & tomato rolls, yoghurt and orange juice. While the results showed an influence of the water on rated satiety and hunger during the breakfast, there were no significant effects of the water on post breakfast ratings, indicating that subsequent intake may not have been reduced by the additional volume. Another study by Rolls, Bell & Thorwart (1999)

also shows that when a similar amount (356g) of water was provided with a meal, there was no conclusive evidence of subsequent intake reduction. A recent study by Norton, Anderson and Hetherington (2006) was also unable to find any effect of preload volume upon subsequent intake, despite significantly different subjective responses following the different volume soup preloads.

The way in which water is added to test foods may be influential in determining the subsequent effects upon satiety. In the two studies above water was provided with a preload, and no effect was seen, but in Rolls et al. (1999) a significant difference was seen when the water was incorporated into the meal, with decreased ratings of hunger as well as decreased intake at the test meal provided. Earlier studies by De Graaf & Hulshof (1996) and Rolls, Castellanos, Halford, Kilara, Panyam, Pelkman, Smith & Thorwart (1998) have also displayed results that support this observation, as both mixed water with the preload in order to increase its volume. In these studies, a significant effect of the larger volume preloads were seen, and as with the study by Lappalainen et al. (1993), the energy content of the larger volumes was also matched with the other smaller volume conditions. This evidence supports the notion of incorporating water into the meal being important if satiety is to be affected.

Why there is a discrepancy between ingesting water *with* a food and ingesting it *in* a food may be due to cognitive influences; a subject drinking water along with a preload may subconsciously discount the water as having any satiating effect, whereas a seemingly larger volume of an energy containing preload (even if the extra volume does not actually add any calorific value) may make the subject think they feel more satiated (DeGraaf & Hulshof, 1996). Alternatively, the observed differences may have links to the process of gastric emptying, as when solid and liquids are ingested separately the liquid will remain largely separate from the solid, while if the foods are mixed together prior to ingestion, they will be more evenly dispersed throughout. This is significant because it has been shown that if the liquid component of the meal is nutritive, not only is the liquid phase emptied more slowly, but there is also a retarding effect on the solid component as well (Collins, Houghton, Read, Horowitz, Chatterton, Heddle, & Dent; 1991). Therefore, if a preload has water thoroughly mixed with it, gastric emptying by the stomach will be slowed, which in turn will prolong gastric distension. This criterion of having nutrients thoroughly mixed with

liquids has made soups one of the most eligible forms of foodstuff to be used as a preload.

The enhanced efficacy of soups rather than food and water to create satiation has also been examined by Himaya & Louis-Sylvestre (1998). In this study the authors tested the differences between preload of vegetables given whole, as chunky soup or as strained soup on subsequent eating of a test lunch and dinner. The results of this test showed that chunky soup was the most satiating, and producing a significant difference against the whole vegetable preload. The findings of this and the other studies mentioned indicates that the form of the preload is an important factor when trying to manipulate dietary variables, as the body responds differently to water when its mixed with nutrients compared to water merely consumed at the same time.

In summary therefore, it has been shown that several studies have found volume of food eaten to be determinant of hunger and appetite, but only in conditions where the actual food is responsible for the increased volume - simply drinking water does not have the same effect. The fact that drinking water does not produce the same effect shows that volume cannot be the only mechanism at work, and there must be other influences, possibly from nutrient receptors in the gut, oro-sensory feedback, or even a combination of such factors.

#### **2.1.1.5 Energy Density**

The energy content of food, and more specifically, the energy density of food have been identified as major determinants of a foods satiating ability. Energy density can be defined by the energy content of the food (kJ), divided by its mass (g). This aspect of food was first considered in response to the finding that in natural situations, humans generally eat a constant weight of food. Some recent studies that have examined how different macronutrients influence satiety in a preloading paradigm, whilst controlling for energy density. Both Rolls et al., (1991) and Raben, Agerholm-Larsen, Flint, Holst, Astrup (2003) provided participants with preloads with the same energy density, but varying in macronutrient content. In each study, appetite was not seen to vary significantly following the different preloads, suggesting that the

differences in satiating efficacy of the preloads was actually due to the energy density of the macronutrients, rather than the macronutrients themselves. This was also observed by Shide, Caballero Reidelberger & Rolls (1995) when preloads were infused into participants intragastrically.

Difficulties often arise when trying to separate the potential effects of energy density and volume, as manipulating one often also changes the other. The results reported by Lapalainen et al., (1993) and De Graaf & Hulshof (1996) could both be attributed to decreases in energy density of the food, rather than increases in volume. This is also the case in the study previously mentioned by Rolls et al., (1998) who varied the volume of milk based preload by adding water to them. From this study, it cannot be deduced whether the effect is due to the change in volume, energy density or both. However, a subsequent study addressed this issue, and indicated that this result was not solely due to an energy density effect, when Rolls, Bell & Waugh (2000) again compared the satiating actions of milk-based drinks of varying volumes upon subsequent appetite. For this study, in order to manipulate volume independently of energy density, air was whipped into the mixture (rather than adding water), to create the different volumes of 300, 450 and 600ml. As before, the different preloads were served to participants on different days, and subsequent appetite was monitored both objectively and subjectively. When the energy from the preload breakfast was excluded from the analysis, a significant effect of volume was seen, with the 600ml preload causing a 12% greater reduction in intake at the test lunch. This study is not free from limitations however, and as participants could see the different volumes of drink being served as a preload, some uncertainty exists about whether cognitive factors may have influenced participants' behaviour.

Gray, French, Robinson & Yeomans (2002) also examined the relationship between volume and energy density, in an attempt to dissociate between the two. In this study a preload was given in the form of a soup and was eaten normally 30 minutes prior to the test meal, which consisted of pasta with a tomato based sauce. The study employed a within-subject crossover design, and employed four preload conditions. The preloads varied in volume (150 and 450ml), and energy density (1.4 and 4.1kJ/ml). The study found that the high volume preloads reduced rated appetite



before the test meal with no difference between the low and high energy density variants. Unexpectedly, the only difference upon actual test meal intake was found in the high volume, high energy density variant with no difference between any of the others - indicating an effect of total energy, but not energy density or volume. While in this study, the authors created high and low energy density variants that were reported to have the same sensory qualities, this study suffers from the limitation of the subject being aware of the amount of soup that they are consuming, as this cannot be easily disguised when the subject has to eat a food orally. Gray et al., (2002) suggest that the effects of the preload volume in addition to cognitive processes relating to volume may have resulted in the masking of any energy density effect, which would explain why the only significant difference was seen in the high volume, high density variant. Here both volume and energy density will be working synergistically, while in the low volume high density variant, cognitive effects relating to volume may mask the effect of the energy density.

#### **2.1.1.6 Palatability**

There are several definitions of the term palatability. In a review, Yeomans (1998) suggests that palatability should be defined as the hedonic evaluation of oro-sensory cues under standardised conditions. Hyde & Witherly (1993) propose that any sensory characteristic of a food can contribute towards its perceived palatability; It is not solely a function of the taste of the food. Palatability is usually assessed via VAS rating scales, and in experimental situations palatability ratings are often made at the start of the experiment during a 'taste test'. Such taste tests involve consuming as little of the food as necessary to determine its palatability, to prevent participants becoming sated or bored of the food during the taste test.

Experiments examining intake of a single meal varying in palatability have found that often, increased palatability increases intake (Yeomans 1996; Yeomans, Gray, Mitchell & True., 1997; Yeomans & Symes, 1999). In addition to this, other studies have examined the effect of varying palatability Bellisle, Lucas, Amrani & LeMagnen (1984), levels of preferred and non-preferred test meals. Bellisle & Le Magnen (1980,

1981) all found that using this experimental design, increases in palatability only increased intake of a preferred meal, whereas the intake of the lesser preferred meals was unaffected by changes in its palatability. The influence of palatability upon appetite is also often examined via use of a dietary preloading experimental design. By administering a food that varies in pleasantness in different test conditions, how this affects subsequent eating and hunger can be observed. De Graaf, De Jong & Lambers, (1999) observed that intake of an ad libitum preload increased when it was served in a high palatability variety, without influencing intake at a subsequent test meal. This finding of increased overall energy intake was contrary to previous findings by Rogers & Blundell (1989), and Warwick, Hall, Pappas & Schiffman (1993), who were not able to demonstrate a change in test meal intake when fixed preloads were served in high- and low-palatability versions. The finding that exercise can increase the subjective rated palatability of a food (Lluch, King & Blundell, 1998) also suggests that the more hungry a person is, the more appealing food will be. However, this is only partially supported by other studies. Johnson & Vickers (1993) and Kim & Kissileff (1996) both saw reductions in test meal palatability following high-energy preloads, whereas Drenowski, Massien, Louis-Sylvestre, Fricker, Chapelot & Apfelbaum, (1994) and Yeomans, Gray & Conyers (1998) saw no such effect.

It can be seen therefore that the palatability of foods may have a definite influence on appetite in experimental situations, and therefore it is important that the pleasantness of the experimental foods is controlled if it is not to confound results.

### **2.1.2 Summary – factors affecting a preloading paradigm**

It can be seen therefore that there is a body of evidence that indicates that several factors associated with the physical form of a preload can influence the satiation it evokes. The timing of experiments is also important, as preloading experiments over markedly different timescales will not necessarily be examining the same processes. Although these factors are not to be directly tested in the experiments of this thesis, adequate control needs to be exerted over them to avoid un-interpretable results. How these factors inform the choices made for the experiments designed in this thesis will be discussed in the following chapter.

## Chapter 3 General methods

In order to investigate the potential effects of nutritional information upon eating behaviours, a preloading paradigm was developed for use in laboratory – based experiments. By establishing a basic experimental design, information – related manipulations could be introduced to the experiments in order to allow investigation of their effects. The nature of this framework is described below, and the adaptations made to this basic design are introduced.

### 3.1.1 Preload formulation

Initial testing, along with previous experience of experimental protocols incorporating preload vehicles helped to guide the choice of experimental design towards using tomato soup as a preload. This food was chosen as extra energy (in the form of maltodextrin) could be added to it without dramatically changing its sensory profile. soup also proved to be a convenient vehicle, as it had a relatively long shelf life, and could be prepared quickly. Dried packet soup mix was also relatively inexpensive, and so was feasible given the limited resources of the project.

Several laboratories have utilised soups for preload vehicles, in particular, several studies conducted by the ingestive behaviour research group at Sussex University seemed to provide useful models of experimental paradigm. Here, low-energy instant soup mixes were combined with differing levels of maltodextrin to produce low and high energy preloads to be used in laboratory-based studies with each test condition taking place over a single meal time. Yeomans et al. (2001) incorporated this design into a study examining the effect of nutritional information upon appetite, which made examining this methodology even more relevant. Subsequently, using these methodologies as a starting point, an experimental paradigm was developed for the current series of experiments. The designs for these experiments aimed to allow examination of the potential effects of information upon appetite, while adequately controlling factors that are in part controlled by biological determinants. The basic preloading paradigm to be used in the initial experiments of this thesis is outlined below.

Following preliminary tests, two tomato soups were formulated in the laboratory with matching sensory properties, but considerably different energy contents. Per litre, each soup contained 2 vegetable stock cubes (Oxo), 15g of Vegetable Bouillon (Marigold), 15g of vegetable puree (Gia), 5g of medium peri-peri sauce (Nando's) and 90g of sieved tomato passata (Tesco). These ingredients provided 518kJ/l. To make the high-energy soup, 160g (2508kJ) of maltodextrin was added to the soup. A form of maltodextrin was used that had previously been selected for its minimal sweetening and thickening properties (Cerestar C\*DRY 01910 - Gray et al., 2003). To make the low energy version, 0.75g/litre of aspartame-based sweetener (Canderel) was added to the basic ingredients to compensate for the mild sweetening effects of the maltodextrin. For each preload, the ingredients were measured into a beaker, and then water at 55-60°C was used to bring the soup volume to the correct level. The soup was then stored in a thermos flask until required.

### **3.1.2 Design**

A within-participant design was utilised with each participant visiting the laboratory twice. The energy contained in the preload was covertly manipulated across the two test days (259kJ and 1514kJ), and following consumption of each, participants' appetitive motivations were monitored for an hour. A within-participant design reduced the problems caused by variation between participants, as each participant was acting as their own control. Due to the facts that palatability has been highlighted as an influential variable in ingestive behaviour experiments, and that the rated palatability of a food will vary individual to individual, between participant comparisons would not be suitable.

### **3.1.3 Participants**

Male participants between the ages of 18 and 35 were required for this design, and were recruited via university notice boards. Participants were required to have a body mass index (BMI) of between 20 and 30, and were required to score 2.0 or less on the restraint scale of the Dutch Eating Behaviour Questionnaire (DEBQ). This questionnaire assessed the degree to which participants attempted to control their food

intake in response to body image and body weight concerns. Although individuals exhibiting high levels of dietary restraint may well be sensitive to the effects of information about a preload, this thesis is not intended to focus on influences brought about by dieting or weight concerns. This thesis aims to investigate potential mechanisms that relate to individual's learned associations between foods and its effects, and for this reason individuals who attempt to control their intake cognitively and override their visceral hunger and satiety cues due to weight concerns would not be suitable for these investigations. The studies were limited to male participants in order to reduce between-participant variability as much as possible, coupled with the fact that it is generally easier to find males who score below 2.0 on the DEBQ restraint scale. Participants were also screened for any aversions to the foods used in each experiment, and were asked about their daily routines regarding eating behaviours and physical activity. Any participants who expected to deviate markedly from their normal habits (e.g. were about to embark upon a fitness program or a change in eating habits) were excluded from the experiment. Other exclusion criteria were prior knowledge of ingestive behaviour research, the taking of any medication known to influence appetite and recent illness that disrupted normal eating behaviours.

#### **3.1.4 Measures of subjective appetite**

Subjective ratings were to be used throughout the experiment to assess participants' appetitive motivations. At various points throughout the experiment, participants were instructed to complete a set of subjective ratings. Each set was presented on a sheet of A4 paper. Identical ratings were taken at each timepoint, and consisted of VAS ratings of hunger and fullness, as well as two prospective consumption measures. The VAS consisted of a question, with a 100-mm scale underneath. For the hunger ratings, participants were asked: 'How HUNGRY do you feel right now?' The 100-mm scale underneath was anchored with 'NOT AT ALL hungry' to the left of the scale and 'EXTREMELY hungry' to the right of the scale. The fullness rating took exactly the same form, but with the question: How FULL do you feel right now? Stubbs et al.,

(2000) argued that VAS could predict amount eaten in controlled experimental situations with good level of reliability when used in a within-participant design. As the experiments of this thesis employed laboratory – based experimental designs with repeated measures designs, these scales were deemed appropriate.

Two novel prospective consumption measures were also incorporated into each bank of subjective responses. The prospective consumption measures each asked how much of a particular food participants felt they would want to eat at that moment, and as such were a different method of assessing participants' hunger. For these measures, participants were asked how big a slice of pizza or quiche they would like to eat. Participants were shown a picture of each food, and a graphical representation of it divided into twelve segments. Participants then estimated how large a slice of each food they would choose to eat, by responding 1 – 12. Provision was also made for participants to choose more than a complete pizza or quiche if desired. Pizza and quiche were selected as the two foods to be used in these estimates as they are both typically presented in circular portions which could be approximated using the above method. They also provided an estimate for a palatable food (pizza) and a relatively bland food (quiche). This would hopefully accommodate for uncertainty as to whether a high palatability food will be unable to provide reliable prospective consumption estimates due to its propensity to bring about over-consumption.

### **3.1.5 Measures of food intake**

An intake measure was also taken at a test meal 30 minutes after consuming the preload. In experiment one, participants were provided with a meal of cheese and tomato pizza. Eight individual pizzas, approximately 18cm in diameter were freshly cooked during the experiment, cut into quarters, and served to the participant on a large plate. A set amount of 800g was initially served. This amount was intended to be in excess of what would be consumed, although more was available if necessary. The pizza provided 4.2KJ/g of energy. Subsequent experiments used a tomato and herb pasta dish in place of the pizza. The pasta was freshly cooked during the experiment, and served to participants in a self-heating container. Initially, 1400g was served to participants, with more available if necessary. The pasta used were dried

conchiglie pasta shells, while the pasta sauce consisted of one jar of pasta sauce blended together with one tin of plum tomatoes and 0.5g of oregano. This mixture was cooked for 20 minutes before being added to the cooked pasta. Together the pasta and sauce contained 3.33KJ/g of energy. After participants had finished eating the test meal, the amount of food that remained was covertly recorded.

### **3.1.6 Videos**

To direct participants' attention during the interval between preload and test-meal consumption, participants were asked to watch 20-minute videos during this time. The videos consisted of two wildlife documentaries into which pauses were edited every five minutes. During each of the pauses, a message appeared on the screen to complete a set of subjective ratings. The two videos were used in a counterbalanced order. The subject matter of the videos selected by the criteria that they were unlikely to create strong positive or negative moods, which may influence eating behaviours.

### **3.1.7 Procedure**

Upon acceptance to the experiment, participants were instructed not to eat or drink anything for three hours prior to the test sessions, and to only eat 'a light breakfast' which was qualified as toast or cereal, not a cooked breakfast. Participants were also asked to refrain from consuming alcohol on the day before the test session or on the test day itself.

Participants arrived at the laboratory at the agreed time. After a verbal questionnaire verifying compliance with the study requirements, participants were shown to a test cubicle. The cubicle contained a tv/video combination unit, and the questionnaires that were to be completed during the trial. Also in the cubicle, was a thermos flask containing 500-ml of either the high or low-energy variant of the soup preload, and a mug.

After initial baseline subjective ratings were taken, participants consumed the soup in the thermos, using the mug. Participants were instructed to consume all of the soup within ten minutes (a stop clock was provided as a reference), and were asked to (as

far as possible) try to spread their consumption over the ten-minute period. If the soup was consumed in less than ten minutes, participants were asked to wait for the remaining time before continuing with the study. At the end of this ten-minute period, the second set of subjective ratings was taken.

The participants then watched the 20 minute video, and were asked to follow the on screen instructions. Immediately after the video, the test-meal was served to the participants, and they were invited to '...eat as much as you like, and feel free to ask for more.' Upon termination of eating, volunteers completed a final set of rating scales, as well as pleasantness ratings for both the preload and the meal. After the end of the test, the remaining food was weighed to determine how much had been consumed.

Participants' second visit to the laboratory was scheduled to be between 24 hours and one week of the first visit. Both test sessions followed identical protocols, with the exception that participants were provided with a different preload on each occasion, so all participants were tested once with each variant of the soup. The ordering of the preload presentation was counterbalanced across participants. Upon successful completion of the experiment, participants were given a brief questionnaire relating to the perceived objectives of the study, after which they were fully debriefed and compensated for their time.

This basic framework was to be used for all the experiments of this thesis that utilised a preloading design. In response to observations during each experiment, adaptations were made to some of the details of the design in later experiments, the most obvious of which being the switch from pizza to pasta as a test meal. The exact details of the adaptations and the reasons why they were made are given in the methods section of each experiment.

### **3.1.8 Assessing the influence of information: How can a participant's beliefs be measured?**

In addition to the basic preloading paradigm, the experiments of this thesis incorporate several different measures to investigate the effects of information about a preload upon subsequent short-term energy regulation. Previous studies examining



this issue have tried to manipulate participants' expectations of foods by providing information in the form of nutritional labels presented on or alongside the food (e.g. Shide and Rolls, 1995). As has been discussed in the opening chapter of this thesis, one of the problems inherent in this approach is the difficulty of knowing how the supplied information has actually altered the participant's beliefs about the preload.

The third and fourth experiments of this thesis circumvented this problem by assessing participants' initial beliefs about a preload, rather than by trying to manipulate them. Here, novel measures were employed to obtain an indirect estimate of the participants belief of the satiating efficacy of the preload, and their uncertainty about this belief. In both experiments, the measures were conducted immediately prior to the preloading paradigm already introduced, just after baseline ratings of appetite were taken. while these methods are described in detail in the corresponding chapter, an outline of the measures used in these experiments is presented below.

#### **3.1.8.1 Experiment 3**

The measure employed in experiment 3 incorporated 8 bowls of cereal ranging from 30 – 250g in weight. Participants were asked to taste the preload they were about to consume, and were shown the amount they would be asked to drink. They were then asked to give three estimates. Initially, participants were asked to estimate the size of bowl of cereal they would want to eat after consuming the preload in order to satisfy their hunger. They were then asked to estimate the smallest portion size they would be confident that they would want less than, and the largest portion size they would be confident they would want more than. Thus, the participant provided estimates of the amount they expected to want, and their confidence in this estimate can be determined by the distance between the second and third estimates.

#### **3.1.8.2 Experiment 4**

Experiment 4 utilised an alternative method that involved a more abstract judgement about the satiating effects of the preload to reinforce and improve upon the results of the previous experiment. In particular, concerns were raised that directly asking a

participant how hungry they thought they would be after drinking the soup preload would introduce demand effects. In experiment 4 three different foods were used, one of which was the soup preload. Participants had to provide an estimate of how much of one food would be equivalent to a pre-determined quantity of another to assess relatively how filling the food was expected to be. Estimates were made with each of the foods against each of the others so that average estimates of the expected satiating ability of each food could be obtained. This method represented an improvement over experiment 3 as at no point during the experiment were participants asked to estimate how much they expected 500-ml of preload would reduce their hunger. The manner of the questions was also less direct; asking participants 'is food 'a' a larger or smaller portion than food 'b' reduces the risk of demand effects as it is not asking participants to predict subsequent eating episodes which may in turn influence actual eating behaviours.

Similarly to the measure used for experiment 3, in order to obtain uncertainty estimates, participants also estimated the amount of food 'a' that would be definitely more than and definitely less than the pre-determined amount of food 'b', in terms of their hunger-reducing properties. the distance between these two estimates provided an indication of each participants certainty about their initial estimates.

### **3.1.8.3 Experiments 5 and 6**

These two experiments sought to find previously-established methods which could be applied to the measurement of participants' expectancies about preloads in order to confirm the earlier findings. Psychophysical analysis was highlighted as offering an alternative solution to this problem. This type of analysis has been used extensively in the in fields such as auditory acoustics, and often involves tasks that seek to determine relative levels at which participants subjectively rate different stimuli as equal. This could be applied to the measures used in experiment 4, where the subjective hunger-reducing properties of one food were expressed in terms of another. A computer-based task allowed repeated comparisons of different portion sizes of different foods, so that the exact portion sizes at which the foods were considered equal could be determined. Subsequently, the participant's expectancies of the preload (relative to the

other foods) could be ascertained. Statistical analysis of the set of responses given by the participant also allows estimates of their certainty to be obtained. The two experiments utilised two different methods of achieving this data. Experiment 5 utilised a traditional, simple psychophysical technique, which proved inefficient for the present purpose. in response to this, experiment 6 utilised a more complex technique which required a greater degree of computer programming, but provided more accurate data from fewer responses.

## **Chapter 4    Developing a paradigm by which to investigate the role of information in dietary preloading studies**

#### **4.1 Experiment 1: Developing a vehicle for use in dietary preloading studies**

Dietary preloading studies often attempt to match sensory properties of actually different preloads. If preloads are matched it is argued that participants' behaviours will not be influenced by differing cognitions about the preloads they consume. It is also assumed that any effects seen across preload conditions must therefore be due to the chemical or physical property of the food that had been manipulated. Problems arise in this type of protocol when preloads are not adequately matched. If participants are still able to distinguish between the preloads, either by taste, appearance, or prior knowledge of the food used, then dissociating the effects of cognition from the physiological effects of the food is impossible (Rolls and Hammer 1995). Therefore, if the cognitive effects of information about a preload are to be investigated, it is essential that a suitable preload vehicle is developed. If preloads are to be varied in energy content across test conditions, then the different energy variants must be adequately matched to prevent participants being able to systematically identify any physical difference between them. This will prevent any results obtained becoming contaminated by participants responses to physical differences of different preload variants.

In addition to preventing the dissociation of cognitive and sensory effects of the preload, perceptually different preloads may potentially influence result validity in another way. For example, participants' eating behaviours will be influenced by variations in preload palatability, as palatable foods can stimulate consumption independently of hunger (Yeomans 1999). A participants' subjective evaluation of the consumed food may also be influenced if in different test conditions, there is a perceivable taste difference in the foods used. If the participant perceives the preload to be similar to a food eaten previously, the satiating valance of the preload may be influenced by the memory of that food, and its properties. Subsequently, across-condition differences in the sensory profile of preloads raises the possibility that one preload will be associated with different memories from another.

Matching nutritionally different preloads can be a difficult task, and somewhat unsurprisingly some studies fail to accurately disguise the differences between preload variants. This can often be seen in the form of significantly different scores in sensory characteristics ratings of the preload. Studies by Hulshof et al., (1993), Yeomans et al., (2001), De Graaf & Hulshof (1996), Rolls et al., (2000) and Gray et al., (2002) have all reported at least one significantly different sensory rating between different preload test conditions. Others, including Porrinni et al., (1995), Rolls et al., (1988) and Himaya and Sylvestre (1998) have utilised overtly different foods as preloads, which obviously creates even greater differences between preload variants. Although the methodologies of these studies undoubtedly suit their specific purpose, variation of this type can often make across – study comparisons difficult. As cognitively-induced satiety effects may not be completely dissociated from physiologically-induced effects due to these sensory differences, their relevance to the present research question must be viewed with caution.

As mentioned, many authors acknowledge the potential problems of discriminable preloads, and try to match the sensory properties of preloads that vary in energy or macronutrient content. Often, the chosen method of testing the similarity of different preloads is to ask a series of questions about the sensory profile of the preload, answered via 100-mm visual analogue rating scales (VAS). These scales are anchored at either end with opposite sentiments towards a specific characteristic of the preload (e.g. the question ‘How salty is this soup?’ may be anchored with ‘NOT AT ALL Salty’ and ‘EXTREMELY Salty’). Participants are instructed to treat the scale as a continuum between the two anchors, and consider where they would place themselves on this continuum. Participants then indicate their response by placing a vertical mark through the scale at the desired point. Thus, by asking a series of questions relating to different properties of the food, an indication of the participant’s perceptions of the preload can be obtained.

Rolls et al., (1998), Yeomans et al., (1998) and Yeomans et al., (2001) have argued that insignificant differences from this type of rating indicates that no differences were perceived between the preload conditions. However, the suitability of rating scales to assess similarities in taste has not been verified, and therefore questions may still be raised regarding results that are reliant on this assumption. French (1994)

suggested that VAS may not be sensitive enough to highlight subtle differences in taste. Another potential problem of using VAS to assess preload similarities relates to the specificity of the questions asked. Will merely asking questions about pleasantness, sweetness, saltiness etc. cover the entire range of potential differences between preloads? The exact questions that need to be asked in order to ensure all potential sensory differences are considered is another issue that, as yet, has not been properly investigated.

Problems also arise when using VAS to assess preload similarities if between-participant designs are used. The findings of Bartoshuk et al., (2003) highlight the potential limitations if using this approach, due to across-group differences in perception of sensory characteristics. For example, 'Extremely Sweet' may not have the same implications to all participants, and so by using VAS to compare one participant's rating with another, it is possible that scales with perceptually different anchor points will be compared.

An alternative method of assessing the perceptual similarity of preloads is via the use of discrimination tests. A triangle-test or a two alternative forced-choice test would provide a more definitive answer to the question of whether perceptual differences exist between different preload conditions. However, to my knowledge, no studies have reported using this method to assess the similarity of the food used as preloads. What these tests consist of, and how they may benefit the questions at hand are described below:

#### **4.1.1.1 Two-alternative, forced-choice (2AFC) tests.**

Rather than asking participants about each preload variant independently, discrimination tests such as 2AFC tests present both sample types at once, and ask participants to choose between them. Typically, participants are asked to choose the sample which fits a specific criteria set by the experimenter. This criteria may relate to a specific sensory characteristic of the samples (e.g. Which soup is the most creamy), or may involve evaluation of multiple sensory characteristics (e.g. Which soup do you think has the most calories). 2AFC techniques will address the problem of sensitivity, as unlike typical repeated-measures preloading designs, participants are

presented with both samples simultaneously, rather than one at a time, separated by several days.

#### 4.1.1.2 Triangle tests

Triangle tests are used to determine whether an *unspecified* difference exists between two treatments, which in the present context, would be the different preload variants. This potentially offers a more powerful assessment of their similarity, as there are undoubtedly numerous ways in which the energy difference may create a sensory differential between preloads. The aim of discrimination tests is to merely establish whether participants can reliably distinguish between the two samples, rather than to actually identify what the nature of the difference is. Triangle tests therefore address both the problems of sensitivity and specificity.

In triangle tests, participants are presented with three samples to taste, two samples of one variety, and one of the other. They are then asked to decide which is the odd sample. There are two possible combinations of this task (A,A,B or B,B,A), and for each combination there are three possible sequences in which any three samples can be presented (X,X,Y; X,Y,X; Y,X,X). This gives a total of six possible sequences of sample presentation, and so to ensure that each sequence is used an equal number of times, the number of trials must be divisible by six. The results of the test can then be examined, to establish whether the number of correct identifications of the odd sample differs significantly from chance. Although different methods of completing this task have been proposed, the recognised protocol (ISO, 1994) states that participants must select one of the samples, even if they cannot detect any difference. This is an important factor, as allowing a 'don't know' response will obviously influence the analyses conducted. Including this option may bias the results towards a verdict of 'no perceivable difference' as participants may select the relatively easy option of 'don't know' rather than the potentially more difficult task of choosing between the three similar samples.



#### 4.1.1.3 Pilot study aims

The aims of the following pilot studies were twofold: Firstly, a specially formulated soup was developed for use in preloading studies. High- and low-energy versions of the soup were produced (518kJ/l and 3028kJ/l), with the intention that they should be indistinguishable from one another. By conducting both triangle tests and 2AFC tests on different versions of the preload, it could be determined whether participants could discriminate between them. The second aim of the following studies was to ascertain whether this formulated soup could be used to demonstrate short-term energy compensation. By incorporating it into a laboratory-based, repeated-measures preloading study, the suitability of the soup for use as a preload vehicle could be assessed. Thus, these pilot studies tested the following hypotheses:

- Participants will be unable to reliably detect a difference in sensory characteristics between a 518 kJ / litre and 3028 kJ / litre version of the formulated soup preload, when assessed using Triangle Test and 2-Alternative, Forced-Choice discrimination tasks.
- In a preloading paradigm, participants will consistently show significantly reduced appetite for a test meal after consuming a high-energy version of the soup preload, relative to their appetite following a low-energy soup preload

## **4.1.2 Taste discrimination tests**

### **4.1.2.1 Participants**

An opportunity sample of thirty-six volunteers took part in the study. Participants were required to be non-smokers, and not suffering from a heavy cold or other illness that may influence their sense of taste or smell. 23 males and 13 females with a mean age of 20.6 took part in the study.

### **4.1.2.2 Discrimination tasks protocol**

Participants attended the laboratory on one occasion, at any time between the hours of 0900 and 1700. Upon arrival, participants were shown to a test cubicle where five samples of soup were arranged on a desk in a group of two and a group of three. The group of two soups consisted of one of each of the soup varieties, and the group of three contained two of one variety and one of the other. The ordering of the soups was randomised across participants, so each possible permutation was used an equal number of times. The soups were presented in disposable plastic beakers, with a label on each. The information on the label consisted of one or more letters, and was used to determine which sample had been chosen. There were no other markings on the beakers that could identify the sample as high- or low-energy. Approximately 10 ml of soup was poured into each beaker. The participant was also given a sheet of instructions and questions to read, and a form on which to give their responses. The instructions were as follows:

### **4.1.2.3 Instructions**

- In front of you are five samples of soup. Each sample is labelled. We will shortly ask you two questions relating to the taste of these soups.

- For the first question we would like you taste the three soups on your left, and for the second question, we would like you to taste the two soups on your right.
- For each question, Please drink the soups in alphabetical order from left to right. Please drink all of each sample provided.
- Please taste each soup only once, and try to drink the same amount from each.
- Please now proceed to question 1.

#### 4.1.2.3.1 Question 1

Please taste the three samples of soup on your right, making sure you follow the above instructions. Two of these samples are the same, and one is different. Please indicate, in the box below, which soup you think is different.

#### 4.1.2.3.2 Question 2

Please taste the two samples of soup on your left, again making sure you follow the above instructions. Please indicate, in the box below, which soup you think contains the **most** calories.

The two questions were always answered in the order shown above.

#### 4.1.2.4 Analysis

To determine whether participants were able to distinguish between the soups at levels statistically higher than chance, the observed responses were analysed against the expected performance if participants were just guessing at random. The 2AFC responses was analysed via a chi-squared non-parametric test, whereas the triangle test data could be analysed using an equation (See Equation 1.1). By entering the number of assessors and the number of correct identifications, the likelihood that the observed results may have been created merely responding at chance levels were

determined. The samples were considered as significantly different if the probability of the observed results being due to chance fell below 0.05.

$$\left( \frac{N!}{N_c! N_i!} \right) P_c^{N_c} P_i^{N_i}$$

Where:

N denotes number of assessments

N<sub>c</sub> denotes number of correct responses

N<sub>i</sub> denotes number of incorrect responses

P<sub>c</sub> denotes probability of a correct response

P<sub>i</sub> denotes probability of an incorrect response.

Equation 1.1 formula for assessing the probability that the responses made are due to chance.

### 4.1.3 Preloading study

Using the design highlighted previously, a preloading experiment was conducted using the soup as a preload vehicle. 16 unrestrained male participants took part in a two-condition repeated measures preloading study, intended to assess the suitability of the soup for use as a preload vehicle. On each session, participants consumed one of the soup preloads, and after a 30-minute interval were provided with a test meal of cheese and tomato pizza. Subjective ratings of hunger, fullness and prospective consumption were monitored at baseline and throughout the experiment, and the quantity eaten at each test meal was covertly recorded.

#### 4.1.3.1 Data Analysis

The data was entered into a Pc-based statistics package (SPSS 11.0 for windows) for analysis. Hunger, fullness, and the prospective consumption measures were examined relative to the baseline scores, and were analysed using repeated-measures ANOVAs

with preload type and time point as the within-participant factors. Post-hoc tests were conducted on individual timepoints using bonferroni-corrected paired t-tests. Energy intakes at the test meal were analysed using a paired t-test.

#### 4.1.4 Results

##### 4.1.4.1 Discrimination tests.

The results of the 2AFC and triangle tests are summarised in table 4.1. Participants did not display the ability to reliably discriminate between high- and low-energy preloads in either task, with the number of correct responses not differing significantly from chance levels.

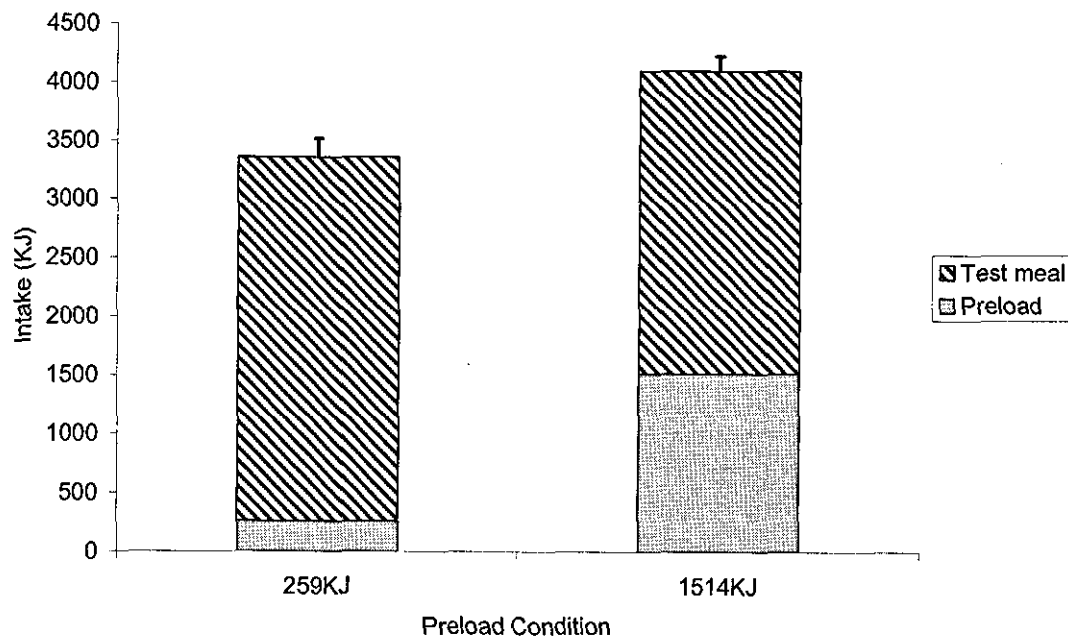
**Table 4.1** Responses to the 2AFC and triangle test taste tests.

	Triangle test	2AFC Test
Correct responses	14	20
Total responses	36	36
Significance	0.739	0.505

##### 4.1.4.2 Preloading study

###### 4.1.4.2.1 Intake

A main effect of preload energy was seen over the two test conditions  $t = 2.437$   $p < 0.05$  (Figure 4.1). The high energy preload was observed to reduce lunch intakes by a mean value of 512kJ, relative to the low-energy preload condition. Mean total lunch intake (preload + test meal) was significantly higher in high-energy preload condition ( $t = 9.397$ ,  $df = 14$ ,  $p < 0.001$ )



**Figure 4.1** Total energy intake by experimental condition. Error bars represent standard error about the mean.

**Table 4.2** Mean intake levels (kJ) for each test condition, brackets denote standard deviations.

n = 16		
	259KJ	1514KJ
<b>Preload</b>	<b>259 (0)</b>	<b>1514 (0)</b>
<b>Test meal</b>	<b>3097 (636)</b>	<b>2585 (492)</b>
<b>Total lunch</b>	<b>3356 (636)</b>	<b>4099 (492)</b>

#### 4.1.4.2.2 Dietary compensation

Participants averaged a compensation index score of 0.40, which indicates that on average when participants consumed the high-energy preload, their test meal intake was reduced by 40% of the extra energy contained in the preload.

#### 4.1.4.2.3 Hedonic ratings

Palatability ratings of both preload ( $p = 0.35$ ) and test meal ( $p = 0.756$ ) revealed no significant differences between the two test conditions.

#### 4.1.4.2.4 Subjective appetite ratings

No significant differences were observed for subjective ratings of hunger  $F(1,15) = 0.079$ ,  $p = 0.783$  or fullness  $F(1,15) = 0.375$ ,  $p = 0.549$ , or either prospective consumption measure  $F(1,15) = 3.181$ ,  $p = 0.095$ ;  $F(1,15) = 0.402$ ,  $p = 0.536$  across the two test conditions. Additionally, no systematic differences were noted between any of the time points for any of the subjective ratings, when examined individually. Figures 4.2, 4.3, 4.4 and 4.5 illustrate the mean subjective ratings at each time point.

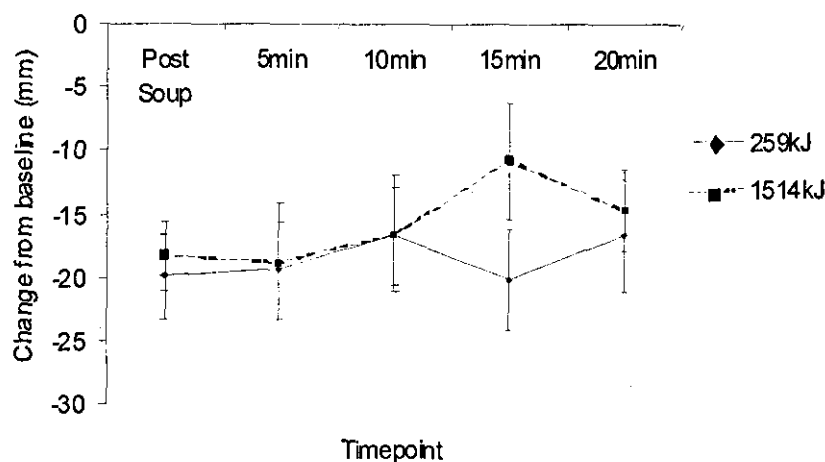


Figure 4.2. Rated hunger change from baseline following preloads of 259 kJ and 1514kJ. Error bars represent SE about the mean.

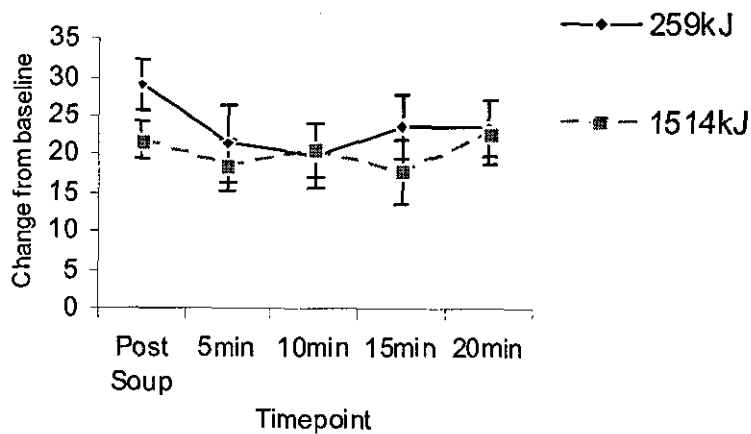


Figure 4.3. Rated fullness change from baseline following preloads of 259 kJ and 1514kJ. Error bars represent SE about the mean.

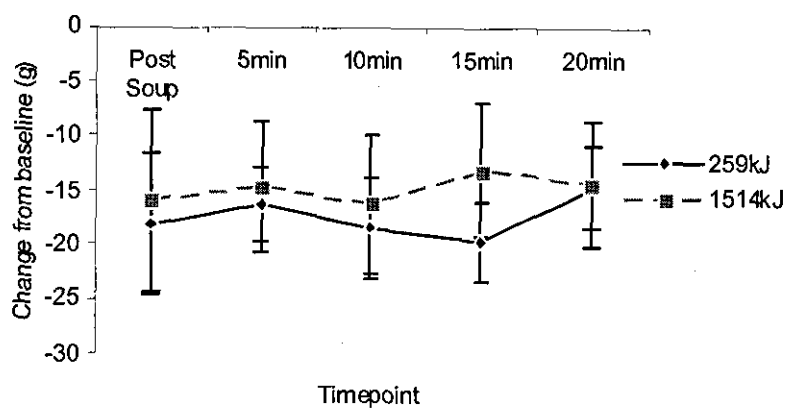
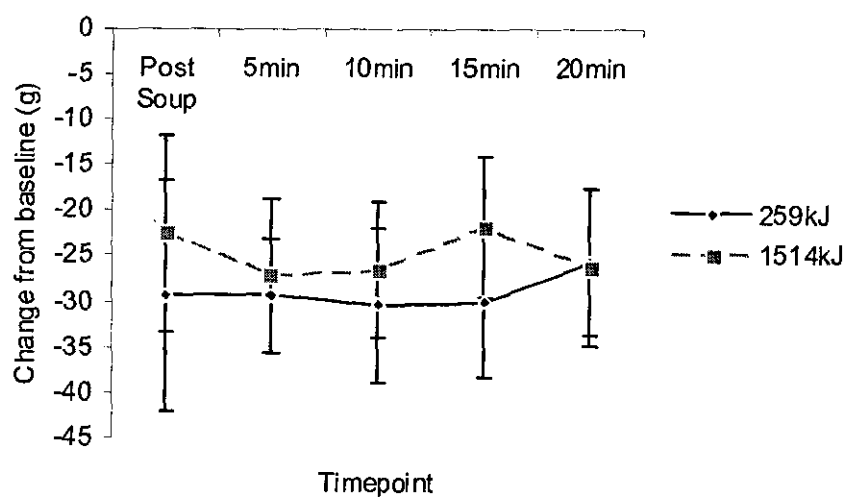


Figure 4.4. Prospective pizza consumption change from baseline following preloads of 259 kJ and 1514kJ. Error bars represent SE about the mean.





**Figure 4.5.** Prospective quiche consumption change from baseline following preloads of 259 kJ and 1514kJ. Error bars represent SE about the mean.

#### 4.1.4.3 Discussion

These two pilot studies sought to assess the suitability of a novel soup preload for use in dietary preloading studies. When tested using both 2AFC and triangle test discrimination tests, participants were unable to reliably distinguish between the soups. Some caution must be exercised when considering these two results however, as they are not directly comparable. While the triangle test is purely examining whether participants can discriminate between the soup varieties, the 2AFC is slightly different, in that it requires participants to identify which soup is more calorific. As this task requires evaluation of several properties of the soup, it may be a more complex decision to make. This approach also assumes knowledge on the part of the participant regarding what a calorific soup tastes like. If participants do not possess this knowledge, the result may be artificially biased towards the verdict of 'no difference'. For this reason it may be argued that a triangle test is a more sensitive discrimination task to use in the present context, especially as the soups are designed to taste novel. If further work were to be conducted regarding preload characteristics, an even more powerful technique may be to ask participants which preload they prefer, rather than asking them to highlight the odd-one-out. Macrae et al., (1979) found this to be a more sensitive method of assessment, and argued that this may be due to participants having to make fewer mental comparisons when just choosing the preferred sample, rather than comparing each sample against each other. For the purposes of the present research however, assessing the soups via triangle tests is already taking greater precaution than has been reported in most other dietary preloading studies.

The preloading study revealed a significant reduction in pizza intake following consumption of the high-energy preload, which suggests that this preload vehicle is suitable for observing short-term dietary compensation. Although the compensation seen at the test meal only equated to 40% of the extra energy contained in the high-energy preload, incomplete compensation in this type of study is not uncommon (Bellisle, 1998). The lack of differences in the subjective ratings is disappointing, and

this may be due to the large standard error observed when using this measure. Taking more thorough precaution to ensure that participants are familiar with this technique (most participants reported having never encountered these scales before) may help reveal more systematic differences in these ratings

A potential cause of the relatively poor compensation may be related to the type of test meal used. Yeomans (1998) reported that bland foods create a greater preload effect than more palatable ones, and it is possible that the pizzas used in this experiment were too appealing. There were also some methodological problems encountered when using this choice of meal, as cooking a sufficient quantity of pizza proved difficult at times, as was presenting enough to the participant to ensure their plate did not become empty. Participants were invited to ask for more if they wanted, but it became apparent that some were reluctant to do so. As the pizzas were cut into quarters, it may have also been too easy for participants to monitor how much they were eating on each test day. In order to be confident that these results were not merely artefacts of this experimental design, these issues should be addressed.

In conclusion, the formulated soup performed as hoped, as participants generally did not display the ability to discriminate between the high- and low- energy varieties. Also, when incorporated into a preloading study, short-term energy compensation was observed in response to the energetic manipulation. By adjusting this methodology in subsequent studies, it was predicted that a greater degree of compensation could be observed, in terms of both the intake measure and subjective ratings taken during the test sessions.

## **4.2 Experiment 2: Can information about a preload affect our ability to compensate?**

### **4.2.1 Introduction**

*Learnt satiety offers a potential mechanism that explains why nutritional information could influence participants eating behaviours in a preloading experiment. By altering participant's beliefs and expectations about the food they are about to consume, it is plausible that the association against which the test food is being compared will change. If participants are responding to pre-learnt associations between the preload and previously eaten foods, this offers a potential explanation for the incomplete compensation observed in some dietary preloading studies.*

*To begin to explore the issue of whether expectancies about a preload are influential in dietary preloading studies, the effect of restricting participants' knowledge of a preload was investigated. This could be achieved by both removing explicit information about a preload prior to the participants' consumption of it, in addition to restricting sensory feedback during its consumption, while still administering preloads orally. This included sensory cues such as sight, smell and taste cues, but also more explicit sources of information such as knowledge of what the preload contains. Efforts to restrict sensory cues may be futile unless these more explicit cues are also restricted, as the knowledge of what the preload actually is may be sufficient to evoke memories of similar foods. By comparing eating behaviours with and without sensory feedback, an insight was gained as whether a learned satiety effect is operating in preloading experiments.*

*If participants relied on learned associations rather than the actual visceral feedback generated by consuming the preload, then it would be expected that the restriction of sensory information about the preload to result in higher levels of compensation. This is because participants would not be able to rely on a conditioned satiety response as they would not know the nature of the preload they had consumed. Instead it was predicted that participants would be forced to rely on the actual visceral signals generated by the preload, thus increasing levels of compensation across the two test sessions.*

#### 4.2.1.1 Experimental considerations

The previous experiment successfully demonstrated that the formulated soup could be successfully utilised as preload in a within-participant dietary compensation study. However, several limitations of the methodology were highlighted. In order to use this preload vehicle in subsequent experiments, these limitations were first addressed. Below are listed the potential problems highlighted at the end of the last experiment, and the adaptations that made to account for them.

##### 4.2.1.1.1 Does the pizza allow participants to monitor their eating?

It has been shown previously that reminding a participant of their previous consumption can influence eating behaviours (Higgs, 2002), and so by using foods such as pizza divided into portions that can be easily counted, intake may be being influenced by memory of what was eaten previously. In this study, Higgs conducted two experiments (N=20 and N=25) during which each participant's intake of biscuits at a mock taste test were monitored. Higgs observed that intake during this taste test could be influenced by instructing participants to recall different events prior to the taste test. In particular, when instructed to remember a recent eating episode, food intake at the taste test was decreased relative to conditions where participants were instructed to recall non-food related memories.

This therefore illustrates that a memory of one eating episode can influence another. In the context of experiment one of this thesis, the findings of Higgs (2002) suggest that the memory of the previous meal may, in part at least, influence participants' eating behaviour in the second condition. It could be argued that providing a test meal consisting of discrete units (such as mini pizzas) would make it easier for participants to remember the quantity eaten, which may in turn generate a stronger memory effect.

In order to address this issue, the next study incorporated pasta as the test meal. This could be provided in large enough quantities to ensure that the participant could not accurately gauge how much they had eaten by examining how much food remained. A pasta test meal also proved more practical, as it was easier to cook large quantities at

one time, removing the risk of participants clearing their plates, and creating ceiling effects in the data.

#### 4.2.1.1.2 Was the pizza too palatable?

Yeomans (1998) noted that a stronger preload effect was observed when using bland foods. Here, on separate days participants consumed either a high or low-energy preload followed by a test meal of pasta. Between participants, the pasta was varied in palatability by the addition of oregano. Greater sensitivity to the energy manipulation of the preload was observed when participants were provided with the bland test meals. In experiment 1 of this thesis, pizza was perceived as being relatively palatable by participants, with a mean palatability rating almost three quarters of the way along a scale ranging from not at all palatable to extremely palatable (68mm along a 100mm scale). This may indicate another potential reason for the poor compensation observed. Using a pasta test meal with a relatively plain tomato-based sauce would hopefully create a test meal that participants found acceptable but not overly-palatable.

#### 4.2.1.1.3 Were the novel measures appropriate?

As discussed previously, the lack of difference between subjective ratings in the different conditions is not unique to this study. However, the prospective consumption measures devised were entirely novel to this experiment, and so their sensitivity or validity is unclear. Other experiments within the laboratory have successfully used Desire-to-Eat VAS ratings and prospective consumption measures using cheese sandwiches. It may also be argued that a prospective consumption measure using sandwiches may be more useful than the previous measures as it would be more likely to reflect an actual lunchtime meal choice. These two measures will be used in place of the two novel measures used in the first experiment. VAS ratings of hunger and fullness will still be taken, as these ratings have been used in many other compensation studies, and may represent the appetitive questions that participants will understand most readily.

#### **4.2.1.2 Summary**

There is a sizeable body of evidence that illustrates why the sensory properties of a preload are an important factor when designing preloading studies. Humans have been shown to associate flavours with the presence of nutrients, and continue to respond to the flavour, even when the nutrient is no longer present. In experiment 1, participants were observed to reduce their intake at a test meal following a high-energy preload, relative to their intake following an identical tasting, but low-energy preload. However, this reduction was incomplete, with a smaller reduction in test meal intake observed compared to the extra energy consumed in the preload. Learnt satiety offers an explanation for this observation, as according to the theory, identical tasting foods should produce the same appetitive responses, regardless of their actual energy content. Experiment 2 aimed to begin to explore whether learnt satiation may be hindering participants' ability to compensate when preloads are accurately matched for their sensory properties. Attenuating sensory information about the preload may allow the effects of learnt satiation to be observed, as learnt associations cannot be made if participants are not aware of the type of food they are consuming.

Based upon these arguments, in addition to the methodological issues raised, the next experiment will test the following hypothesis

In a dietary preloading experiment using accurately matched preloads, test meal compensation will be significantly increased when the sensory information about the preload is restricted. This is predicted because attenuating sensory information in this way will inhibit participants from relying on learnt satiety associations, which would promote a similar appetitive response following both preloads due to their identical sensory profiles.

#### **4.2.2 Methods**

#### **4.2.2.1 Participants**

32 healthy men were recruited via adverts placed around Loughborough University. Potential participants were required to be of normal weight ( $BMI < 25$ ), and display unrestrained eating habits prior to the study ( $DEBQ < 2$ ). Participants were told that they would be given pasta in a tomato and herb sauce during the second part of the experiment. As half the group would not be provided with information relating to the preload, the nature of the preload was not disclosed to participants. Instead, volunteers were asked if they had any particular food allergies or aversions, and were only told that they would be drinking 'a hot beverage' for the initial preloading stage of the study. All procedures were fully described apart from the weighing of pasta consumption during the test meal, and subjects gave their written informed consent prior to participation.

#### **4.2.2.2 Foods**

The study used two foodstuffs – a preload of tomato based soup, and tomato and herb pasta served at the test meal. The soup preloads used were identical to those served during the first experiment, and were again served in low-energy (259 kJ) and high-energy (1514 kJ) versions in different test sessions.

The pasta meal the participants were provided with during the latter stages of the study consisted of Conchiglie pasta (Tesco), tinned plum tomatoes (Tesco), and tomato pasta sauce (Tesco). A batch of sauce was made up from 800g of tomatoes and 440g of pasta sauce blended together. The pasta and sauce were served mixed together in equal quantities (700 grams of each) and were presented to the volunteers in a self-heating slow cooker. Together, the pasta and sauce provided 3.3kJ/g of energy. Both pasta and sauce were made shortly before each session.

#### **4.2.2.3 Subjective ratings**

To measure participants' feelings of hunger and fullness at time points throughout the experiment, subjective ratings were taken using visual analogue scales. Hunger and fullness VAS ratings were obtained in the same manner as described for the first



experiment. An additional VAS rating of 'desire-to-eat', and a prospective consumption measure of cheese sandwiches were also taken at each time point. The desire-to-eat scale consisted of the question: 'How strong is your desire to eat right now?', and a 100-mm line anchored at either end with the statements 'not at all' and 'extremely'. Participants placed a mark on the line to represent how they felt at that moment. The prospective consumption measure involved asking participants: 'How many cheese sandwich quarters do you feel you could eat right now?' Each set of ratings was presented on a single side of A4 paper, and consisted of one of each of the questions described above. A different sheet was used for each subsequent set of questions asked.

#### **4.2.2.4 Videos**

To control participants' attention during the interval between preload and test-meal consumption, 20-minute videos were used as in experiment 1. As before, the videos again had pauses edited into them every five minutes, although for this experiment more recent wildlife videos were used (Blue Planet, BBC 2001). The more recent videos were used to enhance the picture quality of the edited recordings. Care was also taken to avoid excerpts that contained images of or references to eating. The two videos were again used in a counterbalanced order.

#### **4.2.2.5 Design**

The study used a 2x2 mixed design to examine the effects of varying preload energy and information upon energetic compensation. The within-participant element consisted of covertly varying preload energy over two repeated test days (259 kJ and 1514 kJ), while the between-participant element compared participants who had been given explicit information about the preload (namely, that it would consist of tomato soup) with those who had not. To restrict information to half the participants, several additional steps were taken. This group of participants consumed the preload from a sealed, opaque container through an opaque straw, and they also were required to wear a nose clip during preload consumption. This not only removed the aroma of the

preload, but also attenuated much of the participants ability to taste the preload due to the interaction between the mouth and nose in this process. Participants were split into two equal groups, one of which performed the study under the restricted conditions, and the other who consumed the preload normally from a mug.

#### **4.2.2.6 Procedure**

Upon successful completion of the screening procedures, participants were given two dates upon which to attend the laboratory. The two sessions were at least 24 hours apart, and started between 12.00pm and 1.30pm, to reflect normal lunchtime eating behaviours. Participants were instructed not to eat after 11pm on the night before a session, and to have a light breakfast at least 3 hours before testing on the test day itself. Participants were also asked to try to maintain a similar routine for both test days.

Apart from the different subjective measures and test meal, the experimental protocol was identical to the first experiment. When the test-meal of pasta was served to the participants, they were again instructed to '...eat as much as you like, and feel free to ask for more.' The amount provided (1200g) was intended to be in excess of what would be consumed, although more was available if necessary. Participants were supplied with a bowl, a spoon and a serving spoon to enable them to take as much pasta as they wanted from the slow cooker in front of them. Participants were allowed to refill their bowl as many times as they wished. Upon termination of eating, volunteers were asked to complete a final set of rating scales, as well as pleasantness ratings for both the preload and the pasta meal. Both test sessions followed identical protocols, except for the type of preload given and the video watched during the twenty-minute interval, which were both counterbalanced across participants.

Upon successful completion of the experiment, participants were given a brief questionnaire relating to the perceived objectives of the study, after which they were fully debriefed and received five pounds for their time.

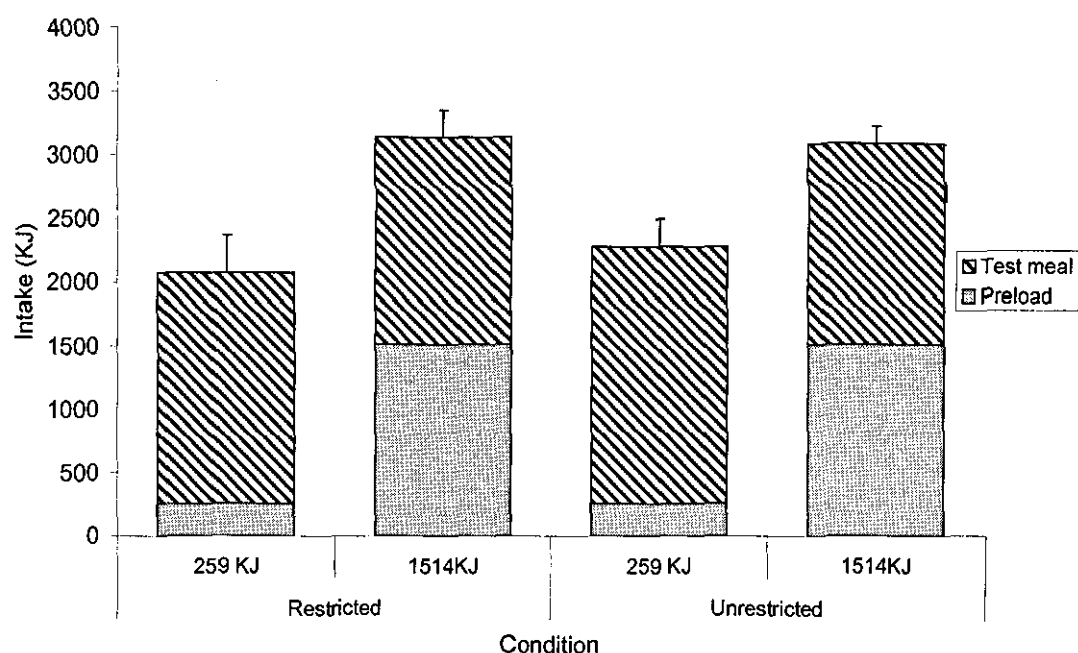
#### **4.2.2.7 Data Analysis**

Mixed ANOVAs were used to examine hunger, fullness, desire to eat and prospective consumption at each time-point, as well as energy intake, in order to contrast the four test conditions. Paired t-test were used with a bonferroni correction to assess whether differences in subjective ratings existed at individual timepoints during the experiment.

## 4.2.3 Results

### 4.2.3.1 Intake

A main effect of preload energy was seen over the four test conditions  $F_{1,30} = 5.511$   $p = 0.026$  (Fig. 4.6), with a mean reduction in intake of 309kJ following the high-energy preload. Restricting explicit information about the preload did not exert a significant influence on energy intake during the meal  $F_{1,30} = 0.51$ . No interactive effect was observed between information and preload energy conditions ( $F_{30,1} = 2.088$   $p = 0.180$ ).



**Figure 4.6** Total energy intake by experimental condition. Error bars represent standard error about the mean.

**Table 4.3** Mean intake levels for each test condition, brackets denote standard deviations.

	Restricted n = 16		Unrestricted n = 16	
	259 KJ	1514KJ	259 KJ	1514KJ
Preload	259 (0)	1514 (0)	259 (0)	1514 (0)
Test meal	1815 (1180)	1619 (868)	2016 (872)	1571 (540)
Total lunch	2074 (1180)	3133 (868)	2275 (872)	3085 (540)

#### **4.2.3.2 Dietary compensation**

Participants averaged a compensation index score of 0.25, which indicates that on average when participants consumed the high-energy preload, their test meal intake was reduced by 25% of the extra energy contained in the preload.

#### **4.2.3.3 Sensory ratings of preloads and pasta**

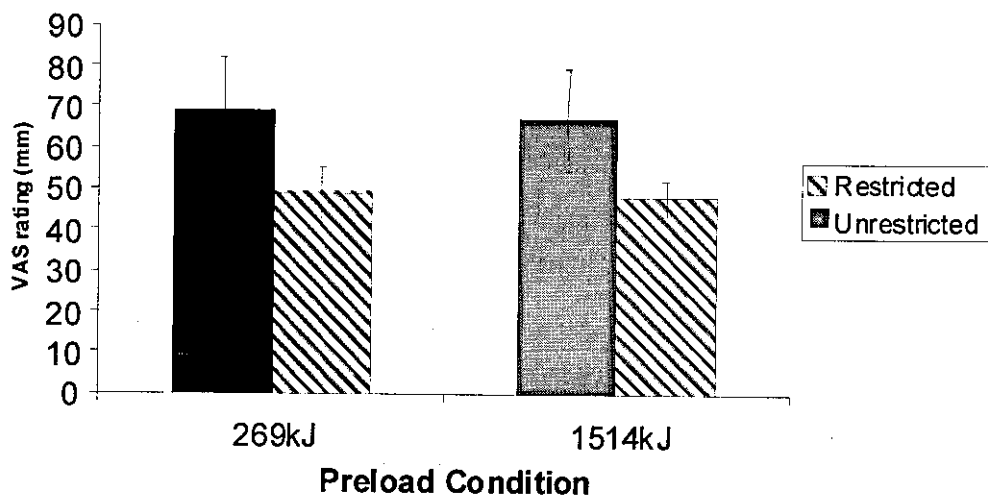
No significant effects of preload energy were observed for preload palatability ratings  $F_{1,30} = 0.181$   $p = 0.674$ , although a trend was evident for participants to rate the pasta meal lower following the high-energy preload  $F_{1,30} = 3.522$   $p = 0.070$ . A main effect of information restriction was observed for preload palatability ratings  $F_{1,30} = 13.609$   $p = 0.001$  (see figure 4.7). No such effect was evident for pasta palatability ratings  $F_{1,30} = 1.513$   $p = 0.228$ . When compared with the equivalent results from experiment 1 using an independent samples t-test, The pasta used in this study was observed to be significantly less palatable than pizza used in experiment 1 ( $t = 4.101$ ,  $p < 0.001$ )

#### **4.2.3.4 Subjective ratings**

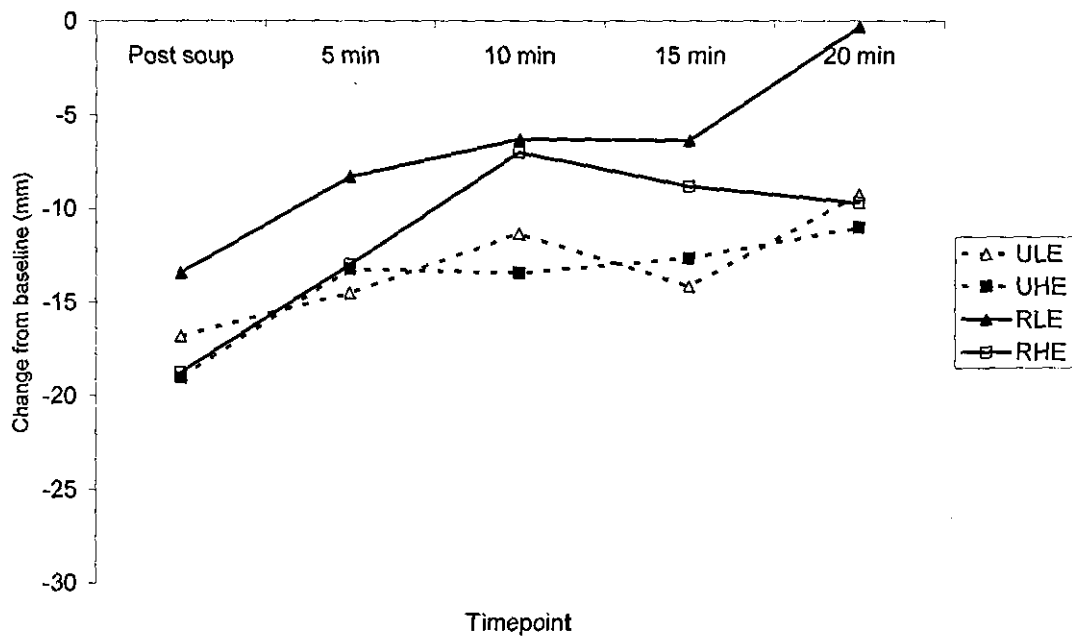
Baseline measures in all conditions indicated no initial differences in any of the ratings taken between the four test conditions. Difference scores were calculated for each subsequent time point relative to the baseline scores (Figures 4.8 – 4.11.)

An examination of the six time points after preload consumption revealed a main effect of time for hunger  $F_{5,26} = 11.684$   $p < 0.001$ , fullness  $F_{5,26} = 14.061$   $p < 0.001$ , Desire to eat  $F_{5,26} = 29.335$   $p < 0.001$  and prospective consumption ratings  $F_{5,26} = 11.831$   $p < 0.001$ . Across the two preload conditions, no effects of preload energy were observed for any of the measures. While no significant effects of information restriction were observed for hunger, fullness or desire to eat ratings, a main effect of information  $F_{1,30} = 4.689$   $p = 0.038$  was noted in prospective sandwich consumption estimates, with smaller changes from baseline observed in the restricted information condition. This indicated smaller decreases in hunger following the preload in this condition, relative to the unrestricted condition. The greatest difference was observed between the restricted and unrestricted ratings 20 minutes after the preload was

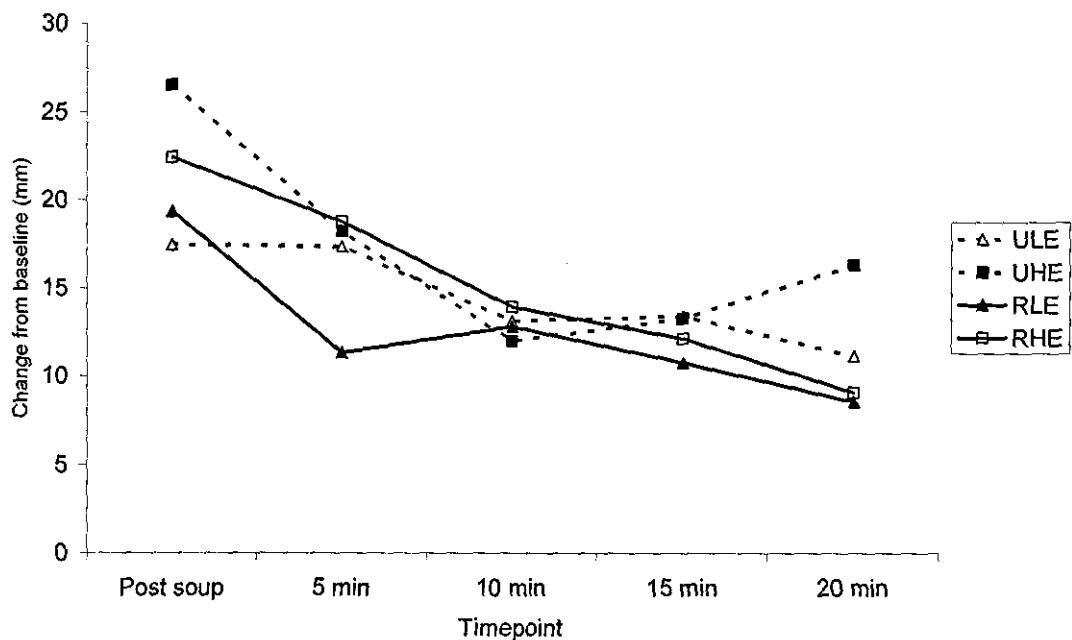
consumed. Here, the restricted participants reported a mean reduction in prospective consumption of 0.52 sandwiches (SD 1.72), compared with a mean reduction of 1.59 sandwiches (SD 1.48) for the unrestricted participants.



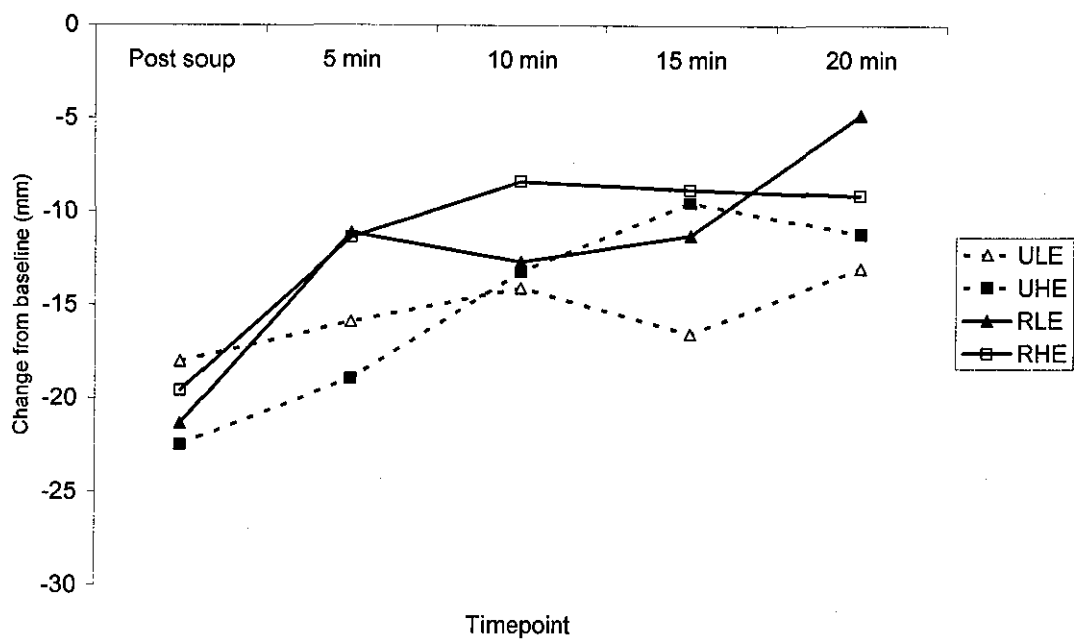
**Figure 4.7.** Preload palatability ratings in the four test conditions. Error bars represent standard error about the mean



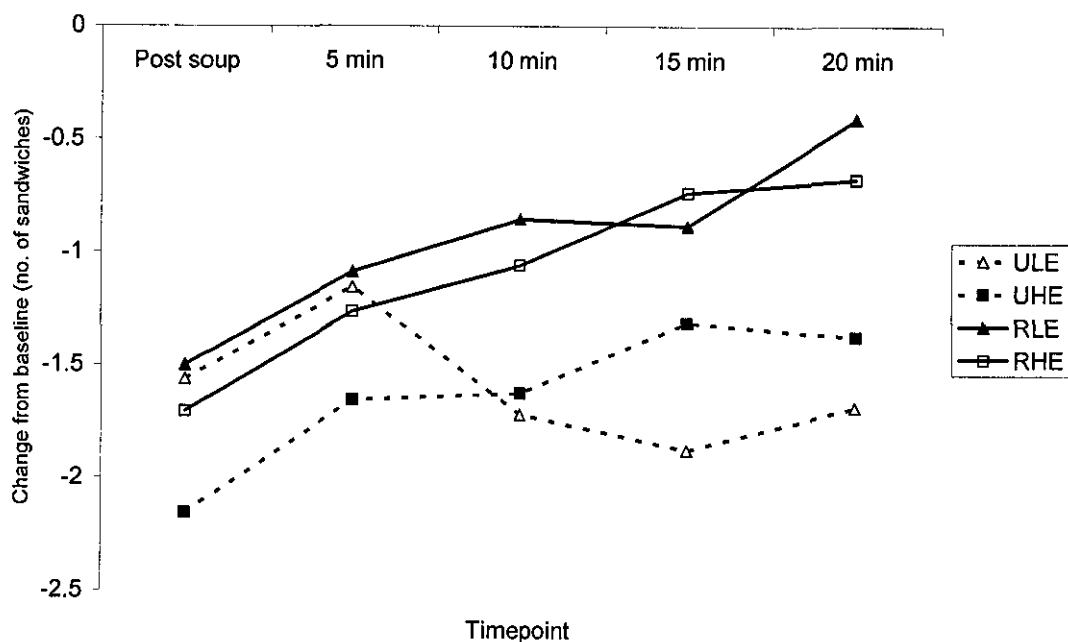
**Figure 4.8** Mean change in subjective hunger scores at timepoints throughout the experiment. ULE = unrestricted info, low energy preload. UHE = unrestricted info, high energy preload. RLE = restricted info, low energy preload. RHE = restricted info, high energy preload.



**Figure 4.9** Mean change in subjective fullness scores at timepoints throughout the experiment. ULE = unrestricted info, low energy preload. UHE = unrestricted info, high energy preload. RLE = restricted info, low energy preload. RHE = restricted info, high energy preload.



**Figure 4.10** Mean change in subjective desire to eat scores at timepoints throughout the experiment. ULE = unrestricted info, low energy preload. UHE = unrestricted info, high energy preload. RLE = restricted info, low energy preload. RHE = restricted info, high energy preload.



**Figure 4.11** Mean change in prospective consumption scores at timepoints throughout the experiment. ULE = unrestricted info, low energy preload. UHE = unrestricted info, high energy preload. RLE = restricted info, low energy preload. RHE = restricted info, high energy preload.



#### 4.2.4 Discussion

This experiment had two main objectives. Firstly, this experiment aimed to expand upon the results obtained in experiment one. By altering several factors within the experimental design, it was ensured that the incomplete compensation noted in the previous study was not due to limitations in methodology. The adaptations made to the protocol were on the whole successful. Using a pasta test meal allowed a much larger amount to be served at once, which both prevented participants from emptying their plate, and also from accurately judging the quantity eaten based upon the quantity left. As hoped, the pasta was also viewed as less palatable on average than the pizza in the last experiment with a mean VAS palatability rating of 48 mm, compared with 68 mm for the pizza. Despite these adaptations, compensation was actually slightly lower in this study, which suggests that the protocol may not have been the limiting factor for participants' ability to compensate. In addition to the intake measure alterations, changes were also made to the subjective ratings. Similarly to the last experiment no systematic differences were observed between the different test conditions at any point throughout the study, although anecdotally the new measures seemed to be better understood by the participants. The prospective consumption measure in particular produced more realistic estimates of anticipated meal size compared with the estimates using quiche or pizza from the first experiment. Using the revised prospective consumption measure also removes the potential problem of using the same food for both a prospective consumption measure and intake measure, as it is possible that asking participants how much pizza they would like to eat, and then using pizza as a test meal may be more likely to guide test meal intake than if two different foods are used.

The main focus of this experiment was to begin to explore the issue of whether information about a preload may influence a participant's behaviour in a laboratory-based experiment. A main effect of the information provision was observed in the prospective consumption, with participants in the restricted information condition

displaying a smaller deviation from baseline ratings. This provides a direct indication that participants in the restricted information group displayed different appetitive responses to the unrestricted group, and supports the notion that receiving information about the food being consumed is important in the generation of satiation. However, this is the only result within this study that highlights this observation, so conclusions must be drawn from this with caution.

It was predicted that when using matched preloads, poor compensation may result from a reliance on the expectancies of the preload, rather than the actual energy content of the preload. However, the observed results were not able to support this argument. Firstly, the observed results may suggest that in adult participants sensory information about the preload is not a detrimental influence in compensatory ability. This would be supported by some previous studies (Aron, Mela & Evans, 1994; Caputo & Mattes, 1993) that have displayed improved compensation in participants who were aware of the energy content of preloads. However, as it has already been established that participants are unable to reliably discriminate between the two preload varieties used in the present experiment, it is difficult to see how the sensory information about these preloads could enable participants to compensate more accurately.

Methodological factors may provide an alternative explanation for the results observed here. Asking participants to consume the preload through a straw using a nose clip is not ecologically valid, and some participants did comment that they found it unpleasant to do so. It is possible that the invasive nature of the information manipulation masked effect of information. This suggestion is supported by the VAS pleasantness ratings of the preloads, as significantly lower palatability scores were noted in the restricted information group which may have confounded results. Unfortunately, specific questions related to the experience of consuming the preload were not asked, it cannot be fully determined how well this task was tolerated by participants. None of the participants asked to withdraw from the study because of this, although it was made clear that they were free to do so at any time. Due to the relatively small financial incentive for completing the study (£5) it is also unlikely that participants were continuing with a task they felt was particularly unpleasant merely for financial gain.

While the subjective appetite ratings taken during the trials are inconclusive with only prospective consumption highlighting an effect of information, this should not be treated as definite proof that this argument is incorrect. In order to investigate this issue further, an experiment involving a less invasive procedure may be useful for comparative purposes.

**Chapter 5   Participants' expectancies  
about a preload are associated with  
their ability to compensate for covertly  
added energy loads**

## **5.1 Experiment 3: Assessing participants' expectancies of a preload**

### **5.1.1 Introduction**

The previous experiment began to examine the extent to which participants were using relying on previous experience with similar foods to guide their intake following a preload. In particular, the experiment examined how participants responded when sensory information about the preload was restricted, as if participants are uncertain about the nature of the preload, they cannot associate it with previous experience. While some differences between these two groups were highlighted, the invasive nature of the experimental manipulations may have influenced the validity of the observed results. Consuming the preload through a straw using a noseclip resulted in significantly lower palatability ratings for the preload, with some participants reporting it to be somewhat unpleasant. This difference across the test conditions undermined the objectives of the study somewhat, as it is impossible to determine whether the palatability change was a confounding factor in the study. In order to examine this issue from a novel perspective, the literature surrounding this issue was re-examined.

#### **5.1.1.1 Methodological differences between studies**

Many experiments have examined whether participants are sensitive to information provided by a food regarding its energy content or satiating ability. Some experiments have been focussed upon the effects of nutritional labelling of test foods (e.g. Shide & Rolls, 1995; Yeomans et al., 2001), whereas others have been designed to assess how the sensory profile of a food can provide participants with information about its characteristics (e.g. Wooley, 1972). There is still some disagreement in the literature; Earlier studies such as the work conducted by Wooley, Wooley and Dunham (1972), and more recently by Shide and Rolls (1995) have suggested that participants are sensitive to information manipulations. In these studies participants were observed to

respond to external information about the foods in the form of sensory differences or different nutritional labels, rather than responding to the visceral sensations brought about by the actual nutrient contents of the foods used. Conversely, Yeomans et al., (2001) found 16 male participants to be insensitive to the labelling of soup preloads, as eating behaviour at a test meal 30 minutes after consuming the preload was only influenced by the actual energy content of the preload, despite labelling differences across different conditions. Kral et al. (2002) observed a similar result when manipulating energy density contents and labelling of preloads, with 22 female participants' subsequent food intake dictated by the actual, rather than labelled energy densities of preloads.

A common observation throughout the literature involving preloading studies is that due to large variations in the methodologies used, comparisons between studies can at times be difficult. Studies examining information and eating behaviours are no exception to this, and one distinction that can be made between the studies mentioned is a difference in the way that the labels are used. Some studies (Solheim 1992, Miller et al., 1998,) compared information with no-information conditions in order to determine the effects of labels as they may be used for real products. Others, such as Ogden and Wardle (1990), and Shide and Rolls (1995) use labels to mis-inform some participants, in order to create beliefs about the food that differ from reality. Whether labels trying to create false beliefs about foods do so to the same extent and in the same manner as labels informing participants about the actual properties of a food is unclear.

#### **5.1.1.2 Problems associated with experimental designs using labelling techniques**

Although in laboratory-based studies nutritional labels are often used to manipulate beliefs about the experimental foods, their suitability for this purpose has not been verified. The provision of labels may generate demand characteristics in a number of ways. Awareness questionnaires are used to examine the likelihood of this. However, in previous studies using nutritional labels, these demand characteristics may have

been unduly discounted due to an incorrect interpretation of such measures. When participants are asked which preloads were high in fat, the response may be somewhat unclear. It is difficult to know whether participants are actually answering the question, or just reporting which preload they remember being labelled as such. It does not necessarily reflect how participants perceived the preload. Even if participants believe the labels (which is an assumption in itself), how this interacts with participants' initial perceptions of the preload is unclear – Is a low-fat potato chip actually regarded as low in fat, or just lower in fat than high-fat chips (but overall, still high in fat)? The provision of an overtly labelled preload, in addition to the artificial setting of a laboratory-based study, may also induce a participant to focus on the preload and its contents more than would normally be expected. This attention towards the preload may take the form of cognitively evaluating the preload, or just by focusing on the visceral signals it generates in an unnatural manner.

Techniques utilising nutritional labels were proposed by Wardle (1987) and Ogden & Wardle (1990) as better alternatives to the methods employed by Wooley et al., (1972). Methodological issues previously discussed regarding Wooley et al.'s study are plausible arguments. As participants were asked about a preload after its consumption, no doubt the answers given were based largely on the visceral sensations accompanying its consumption. These in turn will also be influenced by the participants' 'baseline' feelings. As the ratings reported were absolute rather than difference scores from baseline ratings, the initial hunger levels of the participants cannot be ascertained. Possibly a better alternative would be to take appetite and expectation ratings about a preload before and after exposure to it (i.e. a small sample), so that the belief change brought about by the sensory profile of the preload can be extracted. However, in practice, this may prove difficult to incorporate into a methodology, as it will be difficult to prevent the 'after' ratings being influenced by the memory of making the 'before' ratings. Problems such as these may highlight some of the reasons that more recent studies (Shide and Rolls 1995; Yeomans et al., 2001) have utilised nutritional labels.

### **5.1.1.3 An alternative method of assessing participants' beliefs**

In summary, while the early study by Wooley, Wooley and Dunham (1972) undoubtedly has some imperfections in its methodology, more recent studies using nutritional labels to try to manipulate beliefs have brought with them their own limitations which may be even harder to overcome. The next study in this thesis employed a novel methodology that aimed to circumvent these problems.

The measure was intended to be used prior to a preloading study. By incorporating the principles highlighted in Wooley et al., (1973) of examining participants' pre-existing beliefs about a preload, the uncertainties surrounding the effects of nutritional labels were avoided, as labels were not relied upon to change participant beliefs.

The measure employed in this experiment aimed to gain an insight into participants' prospective hunger by asking them estimate how hungry they expected to be after consuming a soup preload. Rather than abstract ratings, it was proposed that participants may be better able to express their expectations if they were asked to provide more naturalistic estimates. To achieve this, participants indicated their estimates by selecting a portion of cornflakes they expected to satisfy their predicted level of hunger after consuming the preload. In order to obtain this estimate, a continuum of portion sizes of food were presented to each participant, ranging from much smaller than a normal portion to much larger than a normal portion. Participants then selected the one they expected to want. Cornflakes in particular were used as they could easily be served in any portion size, and they were not served in discreet units. Cornflakes were also chosen as most participants would be familiar with them to some extent, and they were unlikely to evoke strong emotive responses.

The experimental hypothesis for this study followed the same rationale as the previous experiment, albeit using a different measure with which to test it. To recap, using the theory of learnt satiation, humans will rely at least partially upon learnt associations between a food and its satiating properties. In experimental situations where participants are provided with identical tasting preloads that vary dramatically in energy content, a learnt satiation effect would see participants eating similar amounts following both preloads, as the learnt association would be the same on both occasions. Thus compensation would be hindered by learnt satiation. In the previous



experiment, it was argued that by removing the sensory information about a preload during its consumption, a participant may be forced to fall back to their visceral sensations generated by the preload, thus improving compensatory ability. This could be expressed as a relationship between a participant's certainty about the properties of a food, and their sensitivity to its actual energy content. The hypothesis of this experiment was as follows:

The degree of certainty a participant has regarding the hunger reducing ability of a soup preload will display a significant negative correlation to their ability to regulate their energy intake following preloads with differing energy contents.

## **5.1.2 Methods**

### **5.1.2.1 Design**

The preloading design of this experiment was conducted identically to the 'information unrestricted' condition of the previous experiment, with the addition of a measure to assess participants' beliefs.

### **5.1.2.2 Participants**

Twenty-four, male university students were recruited for the study via university notice boards. Participants were screened for dietary restraint (DEBQ restraint <2.0), and acceptance of the foods used in the study. Participants were required to adhere to the same requirements as for the previous study. Additionally, participants' liking of the test foods was assessed, and only participants who expressed liking for all of the test foods were included in the study. Rated liking such as this indicated at least some familiarity with the foods used, as no participant responded having not tried the foods previously.

### **5.1.2.3 Preload belief measure**

In order to assess participants' expectancies of the soup preload, a novel measure was administered prior to consumption of the preload during the first test day. Participants tasted a small sample of the soup preload, and were then shown to a cubicle containing 8 bowls of cornflakes. Cornflakes were chosen as they are a common food in British diets, and are uniform in their appearance, which makes varying portion sizes simpler. The bowls contained varying amounts of the cereal, and were placed in ascending order, left to right. The bowls contained 10, 45, 80, 115, 150, 185, 220, and 255 grams of cornflakes, respectively. The portion sizes had been selected to vary from much smaller than a normal portion to much larger than a normal portion. To put these amounts in context, 240 grams represented around half of the contents of a

small box of cornflakes, whereas 10 grams represented only a few flakes. Participants were asked to imagine that after consuming the soup preload, they would be given a bowl of cornflakes to eat. They then predicted which bowl of cereal they expected to want to eat after consuming the whole 500-ml soup preload, which was described to them as 'just under one pint'. This estimate therefore provided an indirect measure of how satiating participants expected the preload to be. To assess participants' uncertainty about the preload, they were then asked to select portion sizes that would represent the smallest and largest portions they predicted that they might want after drinking the preload. The difference between these two portion sizes (in kJ) was considered as the participant's uncertainty about the preload, as this represented the range of portions that they believed they might want.

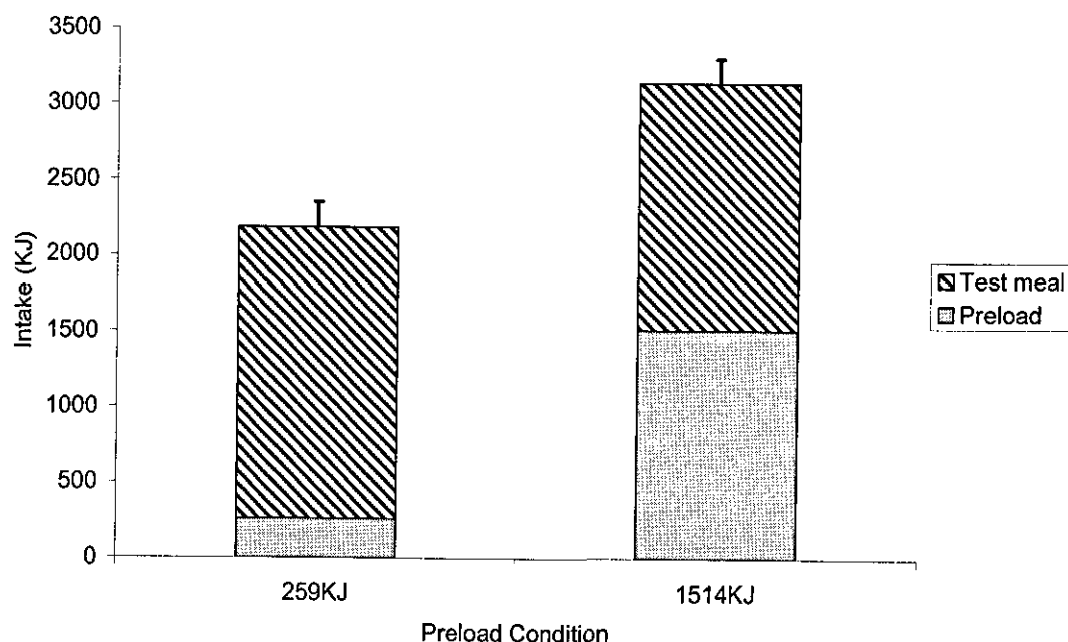
#### **5.1.2.4 Data analysis**

Subjective and prospective measures of appetite were compared using repeated-measures anovas, with Preload condition and timepoint as within-participant factors. Post hoc analyses of subjective ratings at each individual timepoint, as well as intake during the two test meals were compared using a paired-samples t-test, using a bonferroni correction where appropriate. Linear regression was employed to compare participants' preload perception data with their eating behaviours at the test meal.

## 5.1.3 Results

### 5.1.3.1 Intake

A reduction in pasta intake of 297 kJ was observed after the high-energy preload relative to the low-energy variant ( $F_{1,23} = 15.083$ ,  $p = 0.001$ ). Energy intakes at the pasta meal are illustrated in figure 5.1. Total lunch intakes were observed to be significantly higher in the high-energy preload condition ( $t = 12.534$ ,  $df = 23$ ,  $p < 0.001$ )



**Figure 5.1** Total energy intake by experimental condition. Error bars represent standard error about the mean.

**Table 5.1** Mean intake levels for each test condition, brackets denote standard deviations.

	n = 24	
	259KJ	1514KJ
<b>Preload</b>	<b>259 (0)</b>	<b>1514 (0)</b>
<b>Test meal</b>	<b>1925 (833)</b>	<b>1628 (794)</b>
<b>Total lunch</b>	<b>2184 (833)</b>	<b>3142 (794)</b>

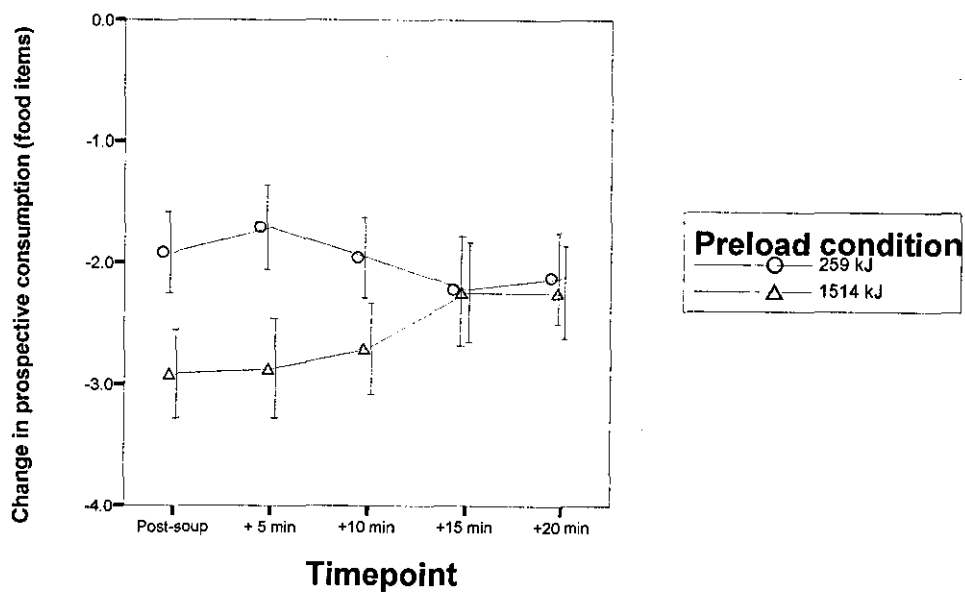
### **5.1.3.2 Dietary compensation**

Participants averaged a compensation index score of 0.24, which indicates that on average when participants consumed the high-energy preload, their test meal intake was reduced by 24% of the extra energy contained in the preload.

### **5.1.3.3 Subjective ratings**

Difference scores of the four subjective measures revealed a main effect of time on hunger [ $F(5,19) = 39.095$ ,  $p < 0.0001$ ], fullness [ $F(5,19) = 29.392$ ,  $p < 0.0001$ ], desire to eat [ $F(5,19) = 28.982$ ,  $p < 0.0001$ ] and prospective consumption [ $F(5,19) = 26.339$ ,  $p < 0.0001$ ]. No effect of energy was noted for any of the fullness [ $F(1,23) = 2.128$ ,  $p = 0.158$ ], desire to eat [ $F(1,23) = 0.166$ ,  $p = 0.687$ ] or prospective consumption ratings [ $F(1,23) = 1.635$ ,  $p = 0.214$ ]. Whilst hunger ratings also failed to show an effect of preload condition, the results suggest a trend towards a greater suppression of hunger following the 1514 kJ preload [ $F(1,23) = 3.680$ ,  $p = 0.068$ ].

No time x preloads energy were observed for any of the measures, although the data indicates a trend towards this interaction for the prospective consumption measure [ $F(5,19) = 2.322$ ,  $p = 0.079$ ]. The three subjective measures are illustrated in figure 3.3, and the prospective consumption measure is illustrated in figure 5.2.



**Figure 5.2.** Prospective consumption following 259 kJ and 1514 kJ preloads. Error bars represent standard error about the mean

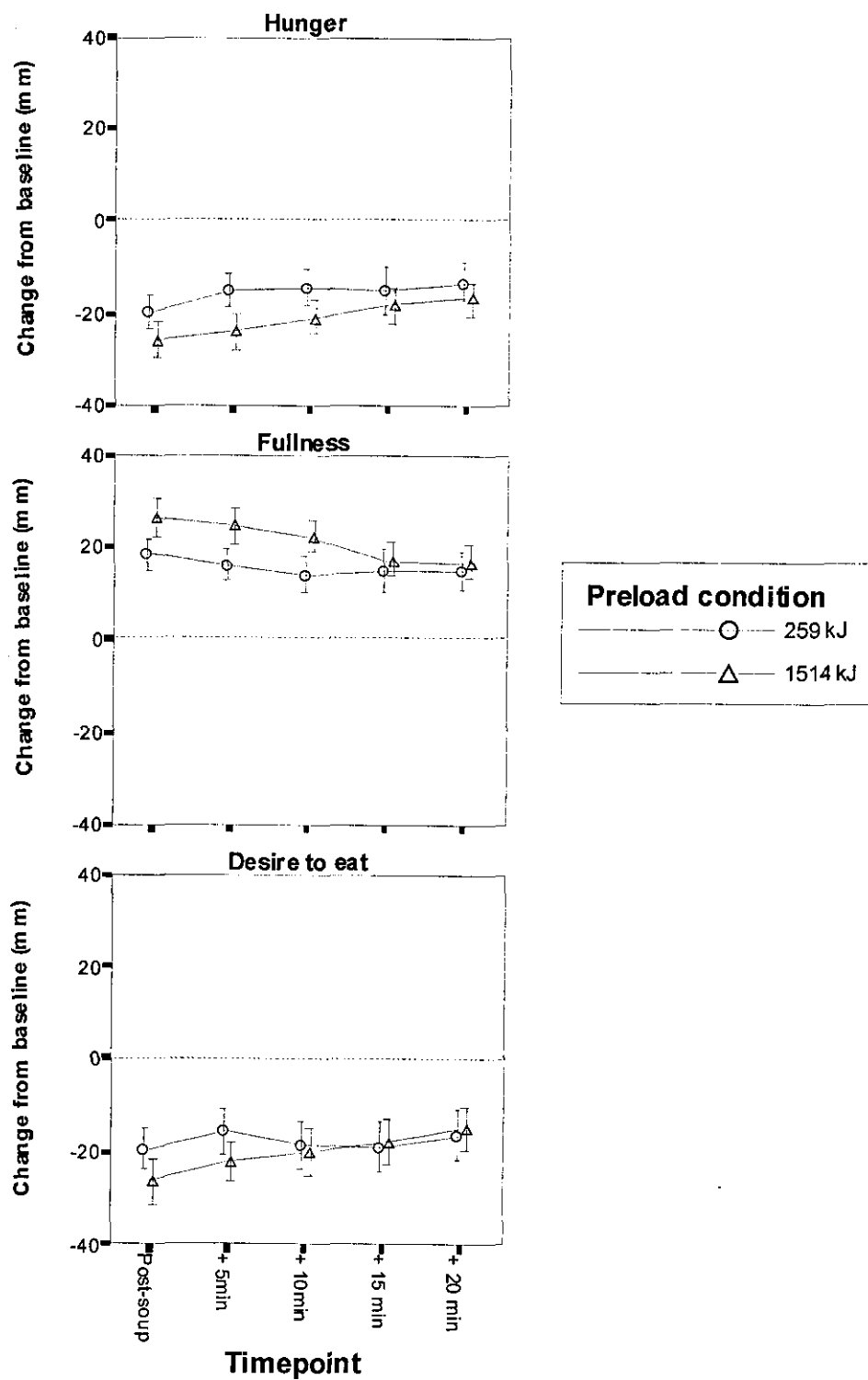


Figure 5.3. Subjective ratings of hunger, fullness and desire to eat at timepoints throughout the experiment. Error bars represent standard error about the mean.

#### 5.1.3.4 Hedonic ratings

No significant differences were observed between the preloads [ $t = -1.056$ ,  $p = 0.302$ ] or test meals [ $t = -0.034$ ,  $p = 0.973$ ] consumed in the different test conditions.

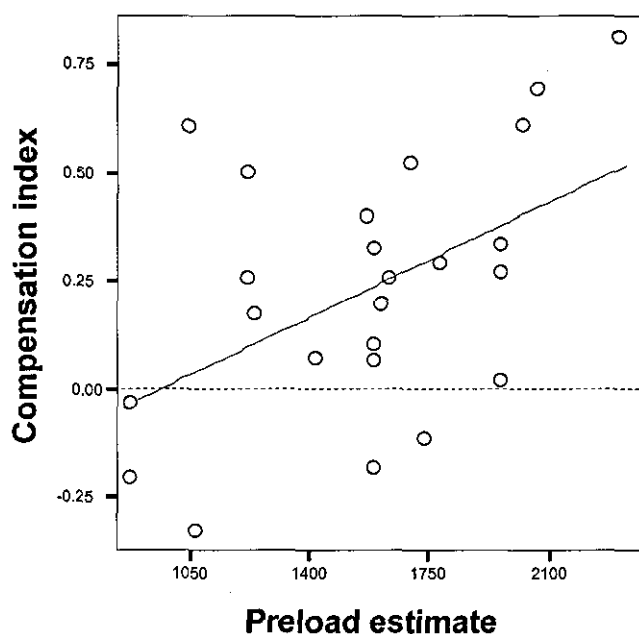
**Table 5.2.** Hedonic evaluations of soup preloads and pasta test meals during the two test conditions. values represent group means (sd)

	259 kJ	1514 kJ
Soup	65.6 (12.6)	68.1 (10.2)
Pasta	39.2 (18.7)	39.3 (29.4)

#### 5.1.3.5 Preload perception

No relationship was observed between preload uncertainty and intake at the test meal, with poor correlations observed for intake at day one or two, or compensation across both days. Participants' estimate of the satiating ability of the preload (based on prospective hunger after first tasting the preload) was poorly correlated with intake during the first or second trial. A significant correlation was noted between the estimate and the degree of compensation observed across the two test sessions [ $-0.490$ ,  $p = 0.015$ ]. This association is illustrated in figure 5.4.

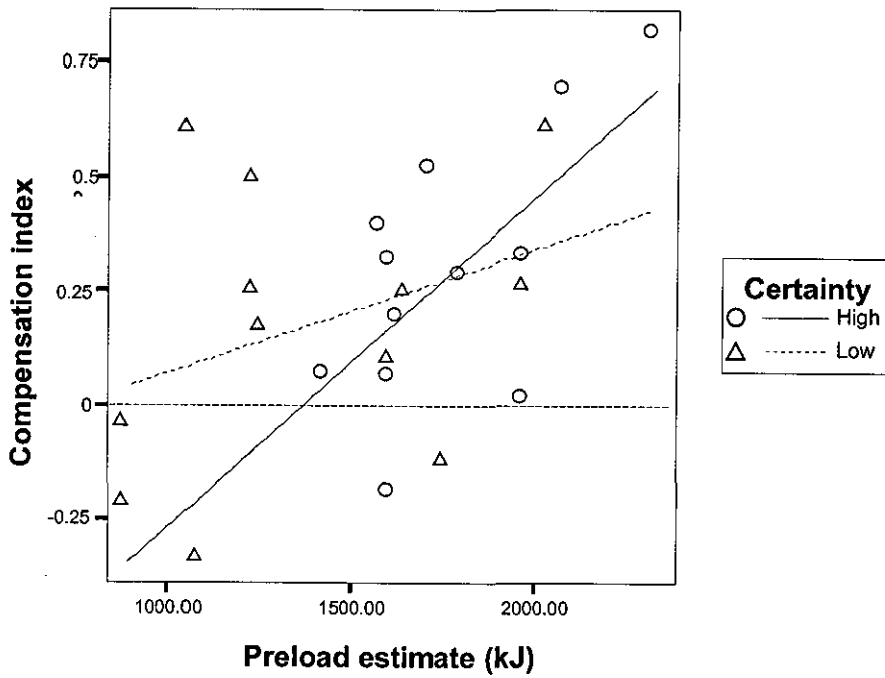




**Figure 5.4.** Association between the compensation across the two test days and the perceived satiating value of the preload.

Upon further investigation, preload estimate did not display any association with baseline VAS hunger ratings [ $r = -0.84$ ,  $p = 0.697$ ], preload palatability [ $r = -0.264$ ,  $p = 0.213$ ], or the order of preload presentation [ $r = 0.18$ ,  $p = 0.932$ ].

To examine whether an interaction existed between the effects of the preload estimate and preload uncertainty, the data was subdivided using a median split of uncertainty scores. This is illustrated in figure 5.5. Although linear regression failed to show a significant interaction between the two variables, the high-certainty group suggested a trend towards a positive correlation with compensation, while the low-certainty group appeared to be more randomly distributed.



**Figure 5.5.** Association between the degree of compensation observed across the two test meals, the perceived satiating value of the preload, and rated certainty.

### 5.1.3.6 Responses to debriefing

Generally, participants were oblivious to the true purpose of the experiment, with only 2/24 participants identifying that manipulating the soup was the focus of the study. 33% of the participants noted a difference between the two soups when questioned, and of this group, 38% correctly identified the high-energy version.

### 5.1.4 Discussion

A significant reduction in intake was observed after the high-calorie preload relative to the low-energy variant. The reduction in intake of 297kJ (24%) is comparable with the level of compensation seen in previous studies. The data from the subjective ratings is also similar to previous studies, as no significant differences are evident between the two preload conditions. The data appears to show the expected relationship however, with the high-energy preload tending to increase fullness and reduce hunger more than the low-energy preload. This improvement over previous experiments may be due to gradual refinement of the methodology, such as an improved delivery of the instructions to participants and a more thorough briefing about the use of the subjective ratings.

This experiment displayed a significant positive relationship between a participant's estimate of the satiating value of a preload and their ability to compensate for extra energy covertly added to it. No relationship between participants' uncertainty of this measure and compensation was observed. However, although insignificant due to the small sample size, a potential interaction was observed between the estimate given and their rated uncertainty. The interpretation of these findings will now be considered.

While significant association between the perceived satiating efficiency and the degree of compensation does not prove a causal relationship, this finding could indicate that the perception of calories may mediate the sensitivity to a covert manipulation of preload energy 30 minutes after its consumption. This finding would support previous literature such as Wooley, Wooley and Dunham (1972), who found the perception of calories to be more predictive of intake than the preload. Wardle (1987) suggested that the findings of Wooley, Wooley and Dunham (1972) study may have been artificially created by the timing of the questions asked, and while this criticism may also be levelled at the present study, the method of labelling may be just as (if not more so) prone to limitations. In the present study, by asking participants about their beliefs about the preload prior to any other part of the study the risk of the ratings being influenced by the rest of the study is lessened. While, it could be argued that the risk of the rest of the experiment being influenced by the ratings is increased, the provision of labels may also generate demand characteristics in a number of ways.

Despite awareness questionnaires which suggest the contrary, demand characteristics present in nutritional labelling-type studies may have been unduly discounted due to an incorrect interpretation of the questionnaire results. When asked which preloads were high in fat, participants may report the preloads they remember being labelled as such, as this is what they believe the experimenter wants. It does not necessarily reflect how participants perceived the preload. Even if participants believe the labels (which is an assumption in itself), how this interacts with participants' initial perceptions of the preload is unclear. As the current experiment only assesses participant's pre-existing beliefs about the preload, this source of bias may be avoided.

The potential interaction between estimate and uncertainty ratings warrants further investigation, to determine whether a larger sample size would reveal a significant relationship. The observed results of the present study somewhat contradictory to initial predictions, which hypothesised that uncertainty would facilitate compensation. This result would suggest that being certain about the preload mediates the relationship between compensation and preload estimate to become evident, with uncertainty creating a similar level of compensation regardless of the preload estimate. While it stands to reason that if a participant is unsure of their estimate that it would have little effect upon their behaviour, why being certain about the estimate would make participants sensitive to it is more unclear.

One possible interpretation of this may be due the fact that humans are more sensitive to feelings of hunger than fullness. If the participant believes the preload to be relatively low in energy, they may perceive the preload more in line with the low-energy variant. From this they will also draw conclusions about how much pasta would be needed to fill them up following the soup. When the two preloads are consumed, the low-energy preload will create the expected visceral signals, while the high-energy preload will leave them feeling more satiated than expected. The lack in compensation seen in this group may be due to participants' poor ability to recognise when they have ingested more energy than they expect in the high-energy preload. This would lead to a similar intake in both preload conditions. Conversely, when participants believe a preload to be relatively energy-rich, they may perceive the preload to be more akin to the high-energy variant. When the two preloads are

consumed, the high-energy preload will create the expected visceral signals, while the low-energy preload will leave them feeling more hungry than expected. A greater ability to recognise unexpected hunger would lead to a greater compensatory response in this group, as intake at the test meal would be stimulated following the unexpected low-energy preload.

An alternative theory explaining the patterns seen would suggest that the enhanced compensation seen in the high-estimate, high-certainty group may be due to artificially-generated demand characteristics. If this is the case, participants who expect the soup to create a large sensation of fullness with a high degree of certainty may be primed to compensate better than others. As this group is certain the soup will create a large change in their hunger state, they may be more sensitive to variations in these effects brought about by the different preloads. This group may subsequently compensate more accurately for the preload energy difference across the two days. Conversely, participants who are certain that the soup will have little effect on their internal hunger state may be primed to ignore changes in their visceral feedback, as they are not expecting much hunger change to take place in either condition. Ignoring visceral signals in this way may subsequently result in poorer compensation across the two conditions.

If this second alternative can be proven to explain the results observed in this study, whether this is a fault of this particular design, or a problem for preloading designs in general is also a matter for future study.

Whether the measure used here to assess beliefs has interfered with participants' eating behaviours is somewhat uncertain, and is a limitation of the current design. The debriefing questionnaire did not ask specific questions about this possibility, and so it cannot be ruled out. It is feasible that the preload beliefs measure acted to focus participants' attention towards the properties of the preload in an artificial manner, which may generate the effect mentioned above. The debriefing questionnaire did however suggest that preload sensory differences were not the cause of the observed effects, as only one in three participants reported a difference in the two conditions. Within this group, when asked to guess which preload contained the higher energy content, three participants guessed correctly which did not deviate significantly from chance levels.

Another limitation may also be present in the preload belief measure. As the participant is only asked to predict how many cornflakes they wish to consume after consuming the preload, it is impossible to accurately know how much of a reduction in hunger this represents. It is possible that the preload estimate made by participants may simply reflect baseline hunger scores, and are not a reflection on participants' views of the preload. However, baseline hunger ratings were taken, and these were not found to be significantly correlated with energy compensation across the two test days. Participants were also screened for their liking of cornflakes prior to testing, so none of the participants had any aversions to the cereal that may bias the results. It is apparent though that some uncertainty remains over this measure, and further study was required to ensure that the results observed were not generated by the novel measure.

### **5.1.5 Conclusions**

The results of this experiment highlighted an association between a participant's prediction of the satiating ability of the preload, and their sensitivity to its actual energy content. Due to the nature of the method of measuring participant beliefs about the preload, there is a possibility that initial hunger levels of the participants may have generated this relationship, although baseline subjective hunger ratings do not support this theory. The experiment also offers some suggestion that the participants' certainty of their predictions may mediate this relationship, albeit in a manner which is contrary to initial predictions. One possible explanation for these findings is that the effect is driven by participants' attention towards the preload, or alternatively that the findings is due to fact that individuals are often more sensitive to hunger cues than satiety cues. Further testing will help to reinforce and better interpret the findings of this experiment, and by using a different measure with which to measure participants' beliefs about the preloads, it can be verified that the effect is not merely an artefact of the novel methodology employed here.

## **5.2 Experiment 4: Associations between expectancies and compensation cannot be attributed to initial hunger**

In order to further substantiate the findings of the previous experiment, a second study was conducted to examine the apparent relationship between expectancies of a preload and sensitivity to its energy content. It could be argued that one of the shortcomings of the previous experiment lay in the fact that the estimates that participants made were not independent from their hunger state. As participants were estimating how much they felt they would like to eat after consuming the preload, their initial hunger will obviously affect this result. It is therefore possible that participants' baseline hunger could be generating the observed effect, rather than their beliefs about the preload. Although the lack of association between baseline hunger scores and energy compensation did not support this criticism, in order to properly address this issue another measure of preload beliefs was devised. While this measure again relied on participants making judgements about the satiating efficacy of different portion sizes of food, the key difference was that instead of making judgements based on their own prospective hunger, this measure involved participants judging one food against another. In doing this, it would hopefully be possible to determine an index of the satiating ability of one food in terms of another, thus allowing participants to make a judgement independently of their hunger state. Using this design of experiment, the possibility that the preload belief measure is influencing participants during the test meal should be lessened. It is also possible that, due to the measure in experiment 3 overtly asking participants about the preload prior to consuming it, their behaviour during the test meal may have been influenced by the judgement they made. The new measure addressed this by embedding the relevant questions in a bank of similar, but irrelevant questions. Thus, the following hypothesis was tested in experiment 4:

In a dietary preloading experiment, there will be significant positive correlations between participants' expectancies of the preload, their certainty of these

expectancies, and their sensitivity to manipulations in the energy content of the preload.

### **5.2.1 Methods**

This experiment used an identical preloading design as the previous experiment, with the addition of a different measure to assess participants' beliefs.

#### **5.2.1.1 Participants**

Thirty-eight, male university students were recruited for the study via university notice boards. Participants were screened for dietary restraint (DEBQ restraint <2.0), and acceptance of the foods used in the study. Participants were required to adhere to the same requirements as for the previous study, with regard to eating before the test, daily routines etc. Additionally, participants' liking of the test foods was assessed, and only participants who expressed liking for all of the test foods were included in the study. Rated liking such as this indicated at least some familiarity with the foods used, as no participant responded having not tried the foods previously.

#### **5.2.1.2 Preload belief measure**

To address the issues raised following the previous experiment, the measure used to assess participants' beliefs was adapted. For this experiment the measure consisted of a series of comparisons between different foods. The comparisons were made between the soup used as a preload vehicle, cornflakes, and plain tortilla chips.

Participants were presented with two bowls of food: a bowl containing a fixed amount (820 KJ) of food to consider (termed the 'sample food'), and a larger supply of a second food, with which participants made their estimate (termed the 'second food'). The second food was presented in a cereal box for the cornflakes, a large bowl for the tortillas, and a thermos flask for the soup.



For each comparison, participants were asked to imagine how much the sample food would reduce their hunger were they to consume it at that moment. They were then asked to predict how much of the second food would reduce their hunger by the same extent. To assess participants' certainty surrounding this estimate, they were then asked to imagine the largest and smallest portions sizes of the second food that they could conceivably consider as equivalent to the sample food, in terms of its satiating properties. The range between the smallest and largest estimate was considered as the participant's uncertainty about the preload, as this represented a range of portions sizes within which they would consider as roughly equal to the sample food. The order in which the participant made the upper and lower confidence estimates was counterbalanced across participants, although the preload estimate was always made first for each comparison. The weight of each portion size (g) was then converted into an energy value (kJ) for the purposes of analysis.

Each food type was used in both roles, and sufficient comparisons were made so each food type was compared against each other in both permutations, excluding comparisons between the same types of food. The order of the comparisons was randomised across participants. An illustration of the comparisons made is shown in table 5.3. The comparisons shaded in grey were included to hide the purpose of the measure, to try to prevent the participant from drawing conclusions about this test which could potentially influence their behaviour at the test meal. As all of the meaningful comparisons involved soup as either the sample or second food, these 'dummy' comparisons were not used in the analysis of the data.

As the instructions for this task were very specific and easily misunderstood, participants were given a typed copy of the instructions to read with a diagram illustrating exactly what the questions were referring to. After reading these instructions, participants were encouraged to ask questions about the task if they were still unsure. This ensured that all participants fully understood the task.

**Table 5.3** Table illustrating the different comparisons made by participants during the initial stage of the experiment. Each row refers to a different set of comparisons where an estimate was made by the participant of the amount of the 'second food' required to create the same satiating effects as 820 KJ of the 'sample food'

No.	'Sample food'	'Second food'
1	Soup	Cornflakes
2	Cornflakes	Soup
3	Soup	Tortilla
4	Tortilla	Soup
5	Tortilla	Cornflakes
6	Cornflakes	Tortilla

### 5.2.1.3 Deriving preload estimates from the comparisons

From the raw data obtained from the comparisons, two estimates of the soups expected satiating value could be derived. One estimate was calculated by averaging the comparisons where soup was poured to make the estimate (comparisons 2 & 4 in table 5.3), and the other was calculated by averaging the comparisons where either tortillas or cornflakes were used to make estimates against samples of soup (comparisons 1 & 3 in table 5.3). For both types of comparison, the statistic obtained from the data was the same; the quantity of soup perceived to be equivalent to 820 KJ of either of the other two foods. For the 2 comparisons using 820 KJ of tortillas or cornflakes as the sample food and soup as the second food, no further analysis needed to be conducted. These two values were averaged to form the 'soup estimate'. For the two comparisons in which soup was used as the 820 KJ sample (and either cornflakes or tortillas were used as the second food), The result needed to be manipulated in order to obtain the data in the same form as the soup estimate. Here, each result had to be extrapolated up or down appropriately to obtain the quantity of soup that would theoretically have been required for participants to pour 820 KJ of either tortillas or

cornflakes. These two values were then averaged to create the 'other foods estimate.' An overall uncertainty rating was calculated by averaging the four uncertainties obtained from each of the four comparison types.

#### **5.2.1.4 Data analysis**

Subjective and prospective measures of appetite were compared using repeated-measures anovas, with preload condition and timepoint as within-participant factors. Post hoc analyses of subjective ratings at each individual timepoint, as well as intake during the two test meals were compared using a paired-samples t-test, using a bonferroni correction where appropriate. Linear regression was employed to compare participants' preload perception data with their eating behaviours at the test meal.

## 5.2.2 Results

### 5.2.2.1 Intake

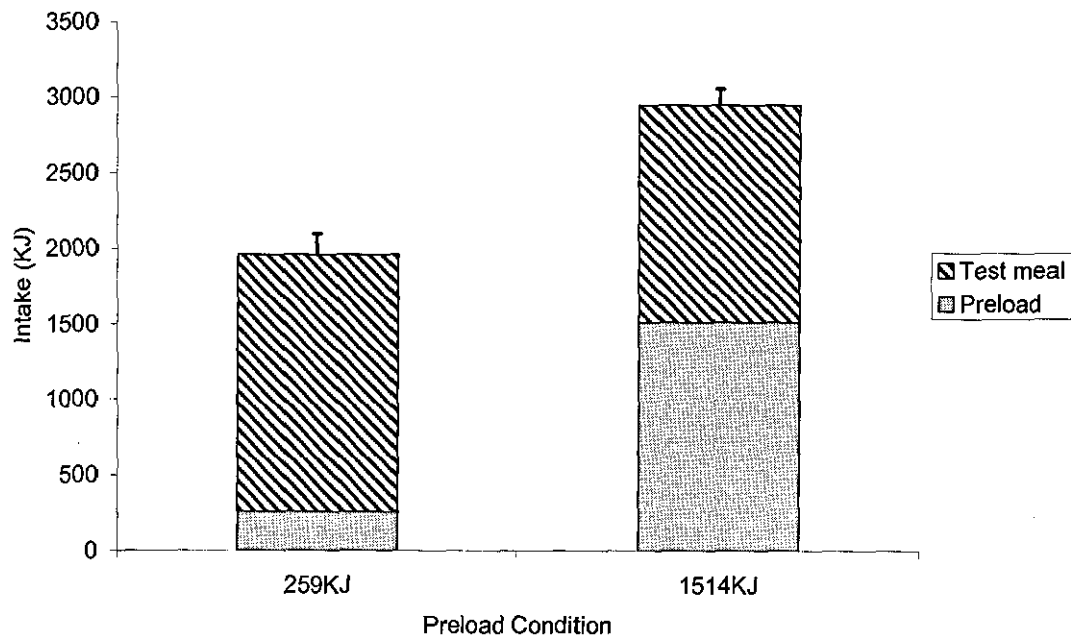


Figure 5.6 Total energy intake by experimental condition. Error bars represent standard error about the mean.

Table 5.4 Mean intake levels for each test condition, brackets denote standard deviations.

	n = 38	
	259KJ	1514KJ
Preload	259 (0)	1514 (0)
Test meal	1700 (838)	1431 (653)
Total lunch	1959 (838)	2945 (653)

A reduction in pasta intake of 342 kJ was observed after the high-energy preload relative to the low-energy variant ( $F=19.853$ ,  $1,37$   $p > 0.001$ ). This reduction equated to 27% of the additional energy ingested in the high-energy condition. Energy intakes at the pasta meal are illustrated in figure 5.6. Total lunch intake was observed to be significantly higher following the high-energy preload ( $t=11.089$ ,  $df = 23$ ,  $p < 0.001$ ).

### **5.2.2.2 Dietary compensation**

Participants averaged a compensation index score of 0.27, which indicates that on average when participants consumed the high-energy preload, their test meal intake was reduced by 27% of the extra energy contained in the preload.

### **5.2.2.3 Subjective ratings**

Difference scores of the four subjective measures revealed a main effect of time on hunger [ $F(4,34) = 3.525$ ,  $p = 0.009$ ] and fullness [ $F(4,34) = 11.531$ ,  $p < 0.001$ ], while no effects of time were noted for either desire to eat [ $F(4,34) = 1.802$ ,  $p = 0.132$ ] or prospective consumption [ $F(4,34) = 0.813$ ,  $p = 0.519$ ]. No effect of energy was noted was found for any of the hunger [ $F(1,37) = 0.442$ ,  $p = 0.510$ ], fullness [ $F(1,37) = 1.233$ ,  $p = 0.274$ ] or desire to eat ratings [ $F(1,37) = 0.282$ ,  $p = 0.599$ ]. Although insignificant, prospective consumption ratings suggest a trend towards a greater suppression of prospective consumption following the 1514 kJ preload [ $F(1,37) = 3.415$ ,  $p = 0.073$ ].

An interaction between preload energy and time was evident in vas hunger ratings [ $F(4,34) = 2.615$ ,  $p = 0.038$ ], and the data also suggested a possible trend towards this interaction for both fullness [ $F(4,34) = 2.011$ ,  $p = 0.096$ ] and desire to eat ratings [ $F(4,34) = 2.097$ ,  $p = 0.084$ ]. The three subjective measures are illustrated in figure 3.7, and the prospective hunger measure is illustrated in figure 5.8. When examined individually, none of the timepoints revealed a significant effect of preload energy for any of the four measures.

### **5.2.2.4 Hedonic ratings**

In line with the previous experiments, no significant differences were noted in either preload ( $p = 0.453$ ) or pasta ( $p = 0.860$ ) palatability ratings.

**Table 5.5.** Mean palatability ratings of the soup preload, and the pasta test meal.

	259 kJ	1514 kJ
Soup	73.5	66.9
Pasta	55.4	57.8

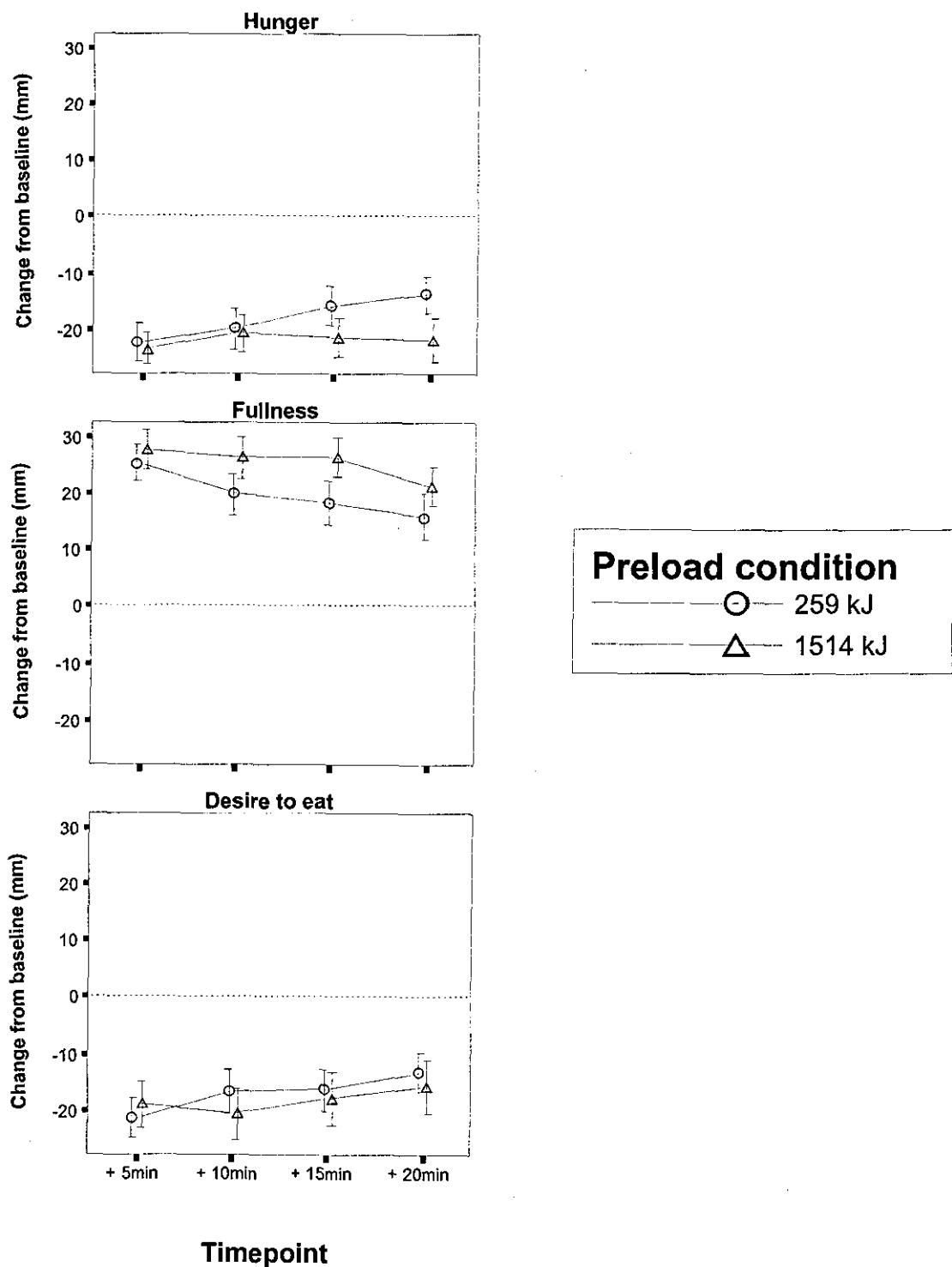
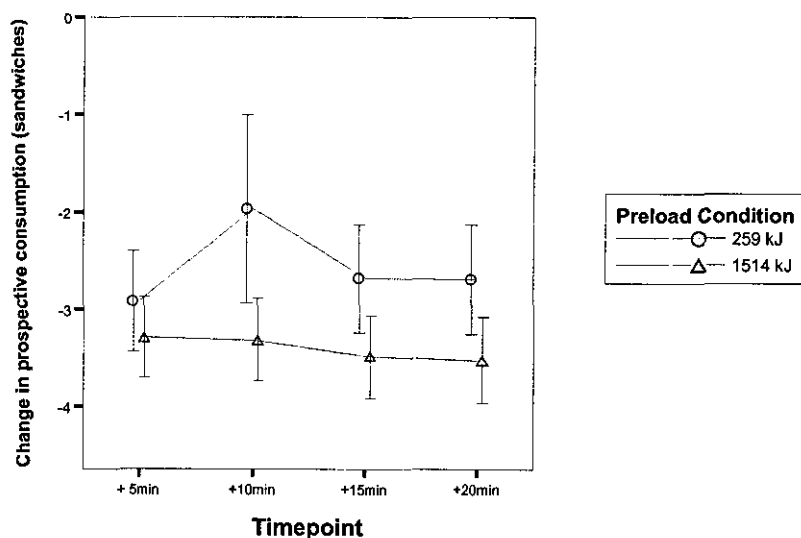


Figure 5.7. Subjective ratings of hunger, fullness and desire to eat at timepoints throughout the experiment



**Figure 5.8.** Prospective hunger following 259 kJ and 1514 kJ preloads

#### 5.2.2.5 Preload Belief measure

##### Preload estimate 1

The estimate derived from the measures where participants used soup to make their prediction failed to show a relationship with compensation across the two test days [ $B = 0.36$ ,  $t = 0.188$ ,  $p = 0.852$ ]. Similarly, no evidence for an interaction between total uncertainty and this estimate was noted [ $B = 0.36$ ,  $t = 0.193$ ,  $p = 0.848$ ]. This result is displayed in figure 5.9, with (for illustrative purposes only) the data divided into high and low certainty groups by means of a median split.



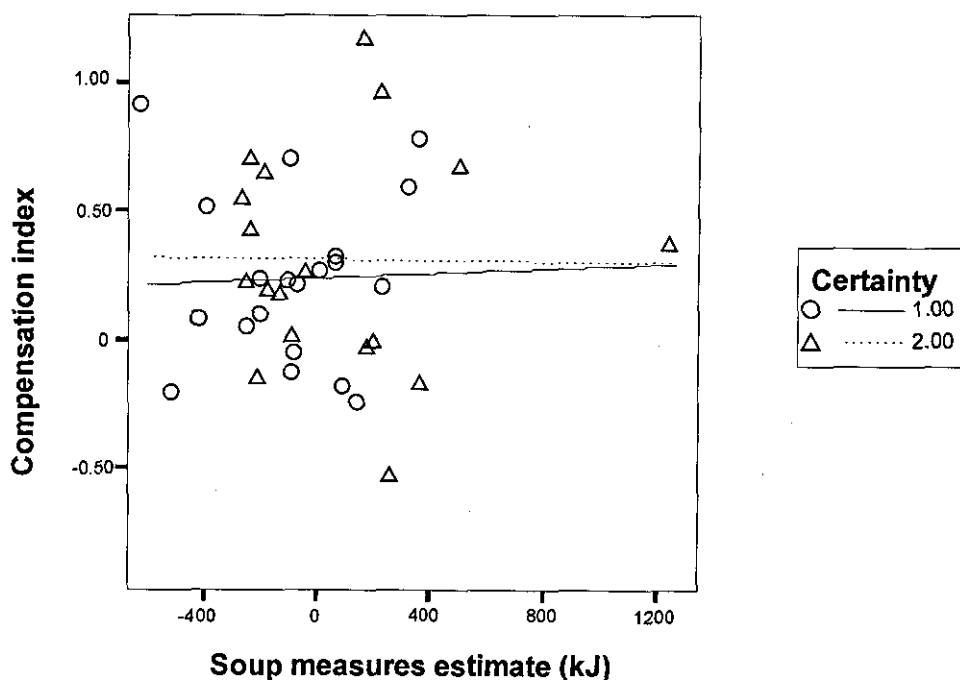


Figure 5.9 Association between preload estimate 1, uncertainty, and energy compensation.

## Preload estimate 2

For the estimate derived from the predictions using cornflakes or tortillas, a significant interaction was noted between the preload estimate, total uncertainty, and compensation [ $B = 0.371$ ,  $t = 2.266$ ,  $p = 0.030$ ]. The model also revealed a near significant correlation between this preload estimate and compensation [ $B = -0.298$ ,  $t = -1.779$ ,  $p = 0.084$ ]. Figure 5.10 illustrates this finding, again with the data divided by means of a median split of uncertainty.

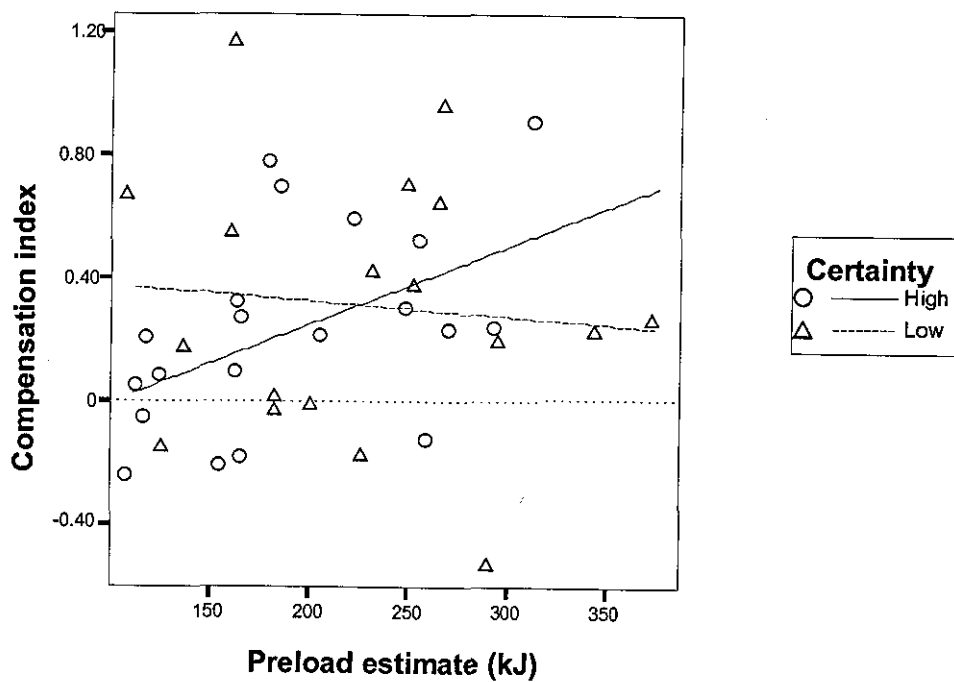


Figure 5.10 Association between preload estimate 2, uncertainty, and energy compensation.

### 5.2.3 Discussion

This experiment aimed to replicate the findings of the previous study, whilst using an adapted methodology. As a novel measure had been employed to assess participants' beliefs for the previous experiment, by emulating these results using an alternative method, it could be ensured that the observed result were not merely an artefact of the measure developed for the previous experiment.

The present experiment again noted an association between a participant's expectation of the preload's satiating value (the 'preload estimate') and their ability to accurately compensate for extra energy covertly added to the preload on one test day. In contrast to the previous experiment, the level of uncertainty associated with this estimate mediated the relationship between the preload estimate and the degree of compensation. Participants with a greater degree of certainty about their prediction demonstrated a positive correlation between their estimate and their sensitivity to the energy manipulation, while less certain participants generally showed less correlation between the two variables. This replicates the pattern noted in experiment 4, where the high-certainty group displayed a steeper gradient between estimate and preload, with a greater correlation.

This interaction between preload estimate and uncertainty was not initially predicted, and is somewhat contradictory to the initial reasoning presented earlier in this thesis. As the literature examining learned satiety shows individuals to rely on learnt cues to guide their intake, it was hypothesised that a greater uncertainty about a food would lead to greater compensation. This would be due to less reliance on prior memories of the effects of similar foods. Instead, it was argued that greater uncertainty would result in a greater tendency to resort to internal visceral cues, which would allow the participant to detect the energy covertly added to the preload. In reality, very little association was observed between a participant's uncertainty and compensation in terms of a main effect, and an interactive effect which conflicts with this reasoning. The interaction noted in experiment five indicates that relatively little compensation is observed in participants displaying a greater uncertainty, and enhanced compensation only observed in participants who expected the preload to be particularly satiating, with a relatively high degree of certainty.

Although it cannot be determined why this relationship exists, there are plausible explanations that warrant further investigation. Firstly, the result seen here may indicate that a differential exists between participants in terms of their ability to make the predictions required for the preload estimate and uncertainty measures. It is possible that some of the participants may show greater accuracy and precision when making these estimates than others, which could explain why the effect can only be observed in a portion of the sample. Participants who demonstrate greater inaccuracy when making their estimates may not display such associations as the greater variance in their responses may mask any true patterns in the data. It could be argued that this group may also exhibit lower levels of precision, which could manifest itself in an apparent greater uncertainty due to the greater range between estimates. Together, this would result in this group displaying greater uncertainty, and little or no association with eating behaviours. If this is an accurate interpretation of the observed results, this may have implications for the choice of measures used, and this will be discussed in more detail later.

An alternative interpretation of this data may relate more to the creation of demand characteristics arising from administering the measures used. The enhanced degree of compensation observed in participants who expected a highly satiating preload with a high degree of accuracy may be due to a cueing effect. It stands to reason that this group of participants will have a definite idea of the preload's post-ingestive effects (judging by their small uncertainty ratings), and is expecting a relatively large satiating effect of the preload (judging by their relatively large preload estimate). It may be argued therefore, that this group will be the most likely to notice the covert changes in energy content of the preload, as it will produce unexpected visceral signals on one of the test days. Less certain participants may not exhibit the same levels of sensitivity, as they do not have definite preconceptions about how they expect to feel. Also, participants who do show a high degree of certainty, but expect the preload to have little satiating value, may also fail to notice this change. As this group of participants is expecting relatively little change in hunger or fullness, they may not be primed to attend to changes in their visceral cues to the same extent as participants who expected a relatively large post-ingestive effect of the preload. The results of this experiment support these speculations, as high certainty/high estimate

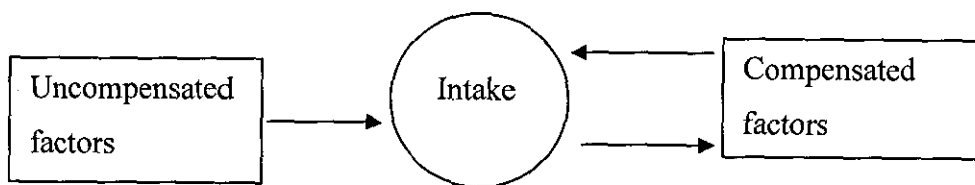
participants show enhanced compensation relative to both high certainty/low estimate participants, and the low certainty group as a whole. Whether the high certainty/low estimate group actually compensate even less than the low certainty group is uncertain, due to the large between participant variations, and so conclusions of this type must be drawn with caution.

#### **5.2.3.1 Possible models that can explain the results from experiments 4&5**

The present research may be linked to the concept of attentional focus playing a role in participants eating behaviours. Herman et al. (1999), Bellisle and Dalix (2001), Boon et al. (2002) and Higgs (2002) have all observed that manipulating participants' attention during a test session can influence their appetite. It is also possible that attentional focus towards the properties of the food is mediated by participants' estimates of its satiating value. A perception that the food has a high satiating value may prompt participants to attend to their visceral cues more than a perception that a food has little or no satiating value. Thus participants would be better positioned to compensate following a food that is perceived to be satiating.

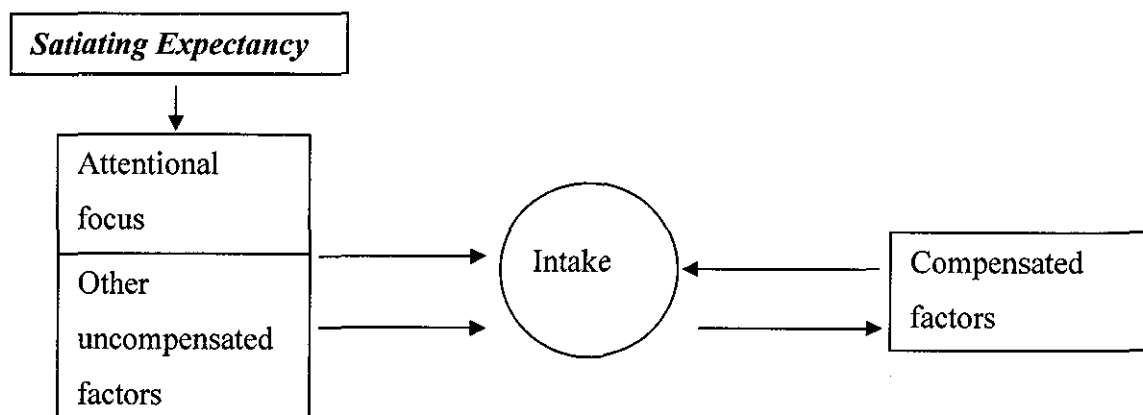
Heatherton et al. (1989) noted that, in a study that used placebo pills to cognitively manipulate feelings of hunger and satiety, unrestrained participants (as used in my experiments) displayed a heightened sensitivity to their internal cues following the placebo. This mirrors the present research in that when participants expected a sizeable change in hunger from the food, a greater sensitivity to internal compensatory cues was noted. A potential effect of the cognitive evaluation of food may also have been present in a study by Rolls et al., (1999). Here a compensatory effect of water provided with a meal was only observed when the water was actually incorporated into the meal (by creating a soup). While it is acknowledged that other physiologically-based factors may have caused this effect, it is also possible that providing the water as a drink caused the participants to mentally discard it as having any satiating properties, thus not attending to the satiety signals that it potentially created. Conversely, when incorporated into the meal, the water will have appeared to

have increased the size of the food presented to them, altering their expectancies of satiety. de Castro (2002) proposed that human intake is controlled by compensatory mechanisms arising from food intake, as well as other factors such as social facilitation and dietary restraint that are not affected by the intake they influence. These factors are therefore considered as uncompensated factors. He proposed the following model to explain how factors such as these influence intake.



**Figure 5.11** de Castro's (2002) General intake regulation model

It is proposed that, considering the above model, the expected effects of the preload will influence intake indirectly via an effect on the uncompensated factor of the individual's focus of attention



**Figure 5.12** de Castro's (2002) General intake regulation model, adapted to include the uncompensated factor of attentional focus, which in turn is affected by the Satiating expectancy of the food in question.

An alternative explanation for the results seen in experiments 4 & 5 concerns the difference between the feedback mechanisms of hunger and satiety. It has been suggested that the compensatory mechanisms involved in regulating energy intake are not symmetrical. de Castro (2002), Stubbs and Whybrow (2004) and Berthoud (2004) have all argued increasing obesity rates indicate that individuals have strong protective mechanisms against starvation and under-nutrition, but relatively poorer mechanisms guarding against over-nutrition and the resulting weight gain. In the context of the present experiment, according to this argument, participants may be expected to compensate effectively when energy is covertly removed from a food, as they are correcting for an unexpected energy deficit. Conversely, when energy is covertly added to a food, a relatively poor ability to detect and correct for the unexpected energy excess would be expected. How this can relate to experimental preloading studies may be best illustrated with an example:

Consider two participants taking part in the present experiment, one who thinks that the soup has a high satiating value, and another who thinks that it will have little satiating value. Each participant over the two conditions, will have one trial where

their expectations were correct, and one trial where their expectations were incorrect. The participant expecting a large satiating effect will be correct after the high-energy soup, while the participant expecting little satiating effect from the soup will be correct following the low-energy variety. The difference between the two participants will be that one will have an unexpected deficit in energy on one of the test days, while the other will have an unexpected surplus of energy. The poorer compensation seen by the participant with the unexpected energy surplus fits with the concept that humans are more sensitive to negative, as opposed to positive, changes in energy intake.

#### **5.2.4 Experiments 3 & 4: Summary**

Both of these experiments have highlighted that a participant's perception of a preload is associated with their sensitivity to covert manipulations in the preload's energy content. Although the observational nature of these studies dictates that a causal link between the two cannot be established, if this can be proven, it may have some interesting implications for other dietary preloading studies. Further studies examining proposed mechanisms behind this relationship may help to properly identify this phenomenon. The subsequent experiments in this thesis will seek to investigate this finding further.



**Chapter 6    Employing psychophysical  
analysis to assess participants'  
expectancies about a preload.**

## **6.1 Experiment 5: A novel application for psychophysical analysis**

### **6.1.1 Introduction**

Experiments three and four introduced an interesting finding that a participant's perception of a soup preload is related to their short-term sensitivity to covert manipulations of the preload energy content. However, following these experiments, several concerns were raised. While the two experiments used different methodologies to arrive at this finding, the measures used were both novel in design. Replication using an experimental design already grounded in previous literature would help further reinforce the findings of the previous experiments. Additionally, the extent to which eating behaviours during the preloading study were being influenced by the measures was unclear. Exposure to the visual and olfactory stimuli present when using actual portions of food may have influenced subsequent eating behaviours via stimulating cephalic phase responses. Repeatedly asking participants to consider a portion of food placed in front of them may have influenced how they behaved when actually consuming it. A more abstract way of obtaining this data may help reduce these possible effects. A methodological short-coming was also apparent with these measures, as they were relatively labour-intensive for relatively little data. Ideally, a more elegant solution to the problem was sought.

In response to these concerns, other existing experimental designs were considered. Several criteria needed to be met by any prospective measure. Firstly, it needed to be practicable for use alongside a dietary preloading study. In response to potential issues raised about previous studies examining information and food intake, it also needed to be able to assess participants' expectations about foods without creating large demand effects – i.e. the measure should not interfere with behaviours during the preloading study, nor should it leave ambiguity about what participants responses actually meant. Additionally, to avoid the types of criticisms levelled at Wooley, Wooley and Dunham (1972), the measure itself should not be prone to interference from the other stages of the experiment. Ideally, to avoid these problems, a measure

that could be taken without participants' knowledge of its true purpose would offer the best solution.

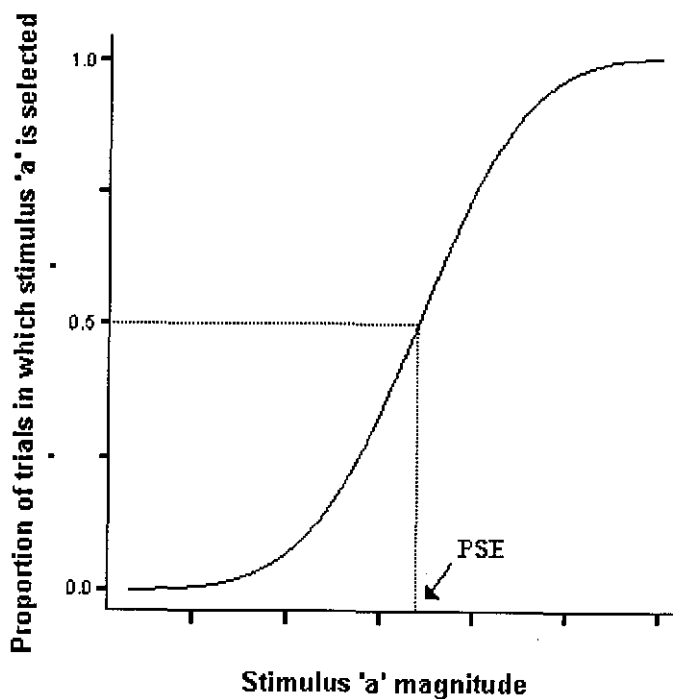
Following broader reading, one area that stood out as potentially offering a suitable methodology was the field of psychophysical analysis. Although no studies were found that examine the particular issues investigated here, methodologies have been developed that compare fixed 'standard' stimuli against varying 'comparison' stimuli. This type of experiment often aimed to determine which stimuli were perceived as equal, and also to determine how much the stimuli had to vary before the participant perceived the difference. If these types of experimental design could be adapted to use visual stimuli in the form of portions of different foods, then these measures would hopefully be able to provide the same answers sought from the perception measures used in experiments three and four. Using psychophysics, a computer based task could be designed that would consist of a series of comparisons between images of two portions of different foods. For each comparison, the participant would select which of the two portions they would expect to reduce their hunger the most. The quantity of food depicted in the images would vary with each comparison, so participants would have to repeatedly re-evaluate how filling they expect the first food would be in relation to the second. Statistics could then be drawn from the responses illustrating how one food is considered overall in relation to the other, and the participants certainty surrounding this estimate.

#### **6.1.1.1 The method of constant stimuli**

The constant stimuli method is an example of a psychophysical task that dates back at least to Fechner's work in the 19th century (cited in Jones, 1974). Theoretically, it is an adaptation of a 'yes'/'no' type detection task, with 'yes' representing one classification, and 'no' representing another (Macmillan and Creelman 1991). This chapter will focus on this type of experiments, and for simplicity where hypothetical examples are given the two alternatives will be referred to as 'yes' and 'no'. This task involves the presentation of a standard stimulus, followed immediately by the presentation of a comparison stimulus, after which the participant must make a decision about the comparison stimulus, in relation to the standard. In particular, this

type of experiment is aimed towards producing a psychometric function for a particular stimulus pair. A psychometric function describes how, for a single criteria, a participant is likely to respond to a stimuli as it changes in intensity. For example if a participant was asked "Is this portion of food larger than you would wish to eat right now?" and was shown a series of meals varying in size, the psychometric function would display the relationship between the portion size shown to the participant, and the probability that they would respond 'yes'. Figure 6.1 illustrates a typical psychometric function, with the function having an ogive form. As would be expected, the function indicates that for very small portion sizes, the probability of a 'yes' response nears 0. As the portion sizes increase, so does this probability, until at excessively large portion sizes, it approaches 1. In the case of the method of constant stimuli, this curve can be derived by repeatedly presenting the range of stimuli to participants in a random order to determine the relative proportions of 'yes' and 'no' responses for each level. Typically, participants can respond with certainty to the stimuli at either end of the function, but are more uncertain for moderately sized portions, leading to some 'yes' and some 'no' responses. This ratio of yes:no can then be converted to the probability of a 'yes' response, as seen on figure 6.1.

Two statistics that are of interest to the current research can be derived from such an experiment, The Point of Subjective Equality (PSE) and Just Noticeable Differences (JNDs)



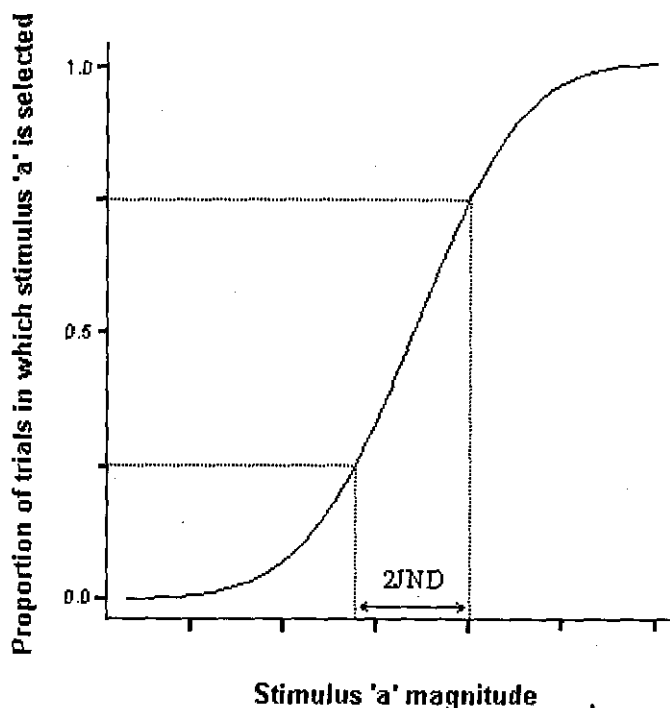
**Figure 6.1** A hypothetical psychometric function describing the relationship between the magnitude of stimulus 'a', and the probability that it is selected in a 'yes/no'- type psychophysical task. The stimulus level at the PSE is also illustrated.

#### 6.1.1.2 PSEs and JNDs

The PSE of a dataset refers to the hypothetical stimulus size where either a 'yes' or a 'no' response is equally likely. This point may coincide with an actual comparison stimulus, but is more likely to lay somewhere between two adjacent stimuli. In this more common scenario, the PSE will be extrapolated using the function that best fits the observed data. This statistic therefore illustrates the point at which a participant will be as likely to respond with a 'yes' as they are to respond 'no', and so can be considered a measure of equality between the two stimuli. For this reason it is hoped that this statistic can be used in place of the preload estimate (PE) from experiment four.

The JND of a dataset depends on the distribution of the data, as it is calculated from the inter-quartile range of the data – that is, the range between the points at which a 'yes' response is predicted 25% and 75% of the time. As with the PSE, this may

coincide with actual stimulus magnitudes, but it is usually extrapolated from the function of the dataset. The inter-quartile range is then halved to produce the JND for the dataset. This measure essentially measures how sensitive a participant is to change in stimulus magnitude, as it reports the range of portion sizes needed to bring about a pre-determined change in probability. For this reason it is hoped that this measure can be used in place of the uncertainty (PU) estimates of experiment four, as PU indicated how much a portion of food needed to change before it would no longer reduce a participant's hunger by the same extent.



**Figure 6.2.** A graph illustrating how JNDs are calculated from a psychometric function

### 6.1.1.3 Summary

In order to reinforce the findings of the previous experiments in this thesis, an alternative method was sought to assess participant's expectancies of a soup preload.

Psychophysics was highlighted as potentially offering a suitable technique. If a psychophysical task could be effectively employed for this use, it may provide a more efficient method for use in future studies, as well as providing a methodology that is more firmly grounded in previous literature, compared to the novel tasks employed previously. Before using such a task in a dietary preloading study, some smaller scale exploratory work would be able to determine whether food portion stimuli could be incorporated into a constant stimuli psychophysical procedure. Such an experiment would also provide an opportunity to assess the correspondence between this and the expectancy measures used previously in this thesis. The hypothesis tested in this experiment was as follows:

The Preload Estimate and Preload Uncertainty measures employed in experiment 4 will display a significantly positive correlation with the PSE and JND statistics obtained in a method of constant stimuli psychophysical task.

## **6.1.2 Methods**

### **6.1.2.1 Participants**

Twelve participants were recruited via university notice board advertisements. Previous participants were excluded, as this implied they had prior experience of the soup preload. Each participant completed the experiment in one test session, lasting approximately 30 minutes. Testing took place in cubicles within the Ingestive Behaviour lab, between the times of 09.30 and 17.00. Participants were fully debriefed at the end of the experiment, and were compensated for their time.

### **6.1.2.2 Design**

A one-sample design was employed, with the observed PSE and JND estimates generated by the psychophysical measure, and then compared against preload estimate and uncertainty measures as the preceding experiment.

### 6.1.2.3 Psychophysical measure.

The psychophysical measure consisted of a computer-based task, in which participants were asked to compare two images of food portions displayed simultaneously. Participants clicked on the image they believed would reduce their hunger the most, after which the next pair of images would appear on the screen. The images fulfilled the roles of two different kinds of stimuli - Standard stimuli, and comparison stimuli. The standard stimulus remained the same throughout a block of trials, acting as a reference for the participant. The comparison stimuli varied in intensity throughout the session, with the participant judging each different comparison stimuli in relation to the fixed standard stimuli

The measure utilised digital images of five different foods: soup, baby new potatoes, pasta, and rice salad). Each of the foods were presented in identical bowls. The standard stimulus varied across the different stages of the experiment, and consisted of 64g of soup, pasta, rice salad or new potatoes. The comparison stimuli consisted of six different portion sizes of cornflakes. Images of 16g, 32g, 48g, 64g, 80g and 96g portion sizes were taken. To allow the stimuli to be 'roved' (as will be explained below), images were also taken of each stimulus - 25%, - 50%, + 25% and + 50%. . Each image contained two representations of the portion size to help participants judge the depth of the bowls. One depicted the portion as viewed from approximately 30° from horizontal, and the other represented the portion as viewed from approximately 60° from horizontal.

The measure comprised of four sets of trials, using a different food (except cornflakes) as the standard stimulus in each set. Cornflakes were used as the comparison stimulus in all of the four sets.

Each set comprised of a series of comparisons between the standard stimulus, and each of the comparison stimuli for that particular food. For each comparison, the participant considered which they anticipated to have a greater ability to reduce their hunger. Using this criterion, participants then had to select either the standard or the comparison stimulus. In total, 15 estimates were made between each of the six comparison stimuli and the standard stimulus, giving a total of 90 estimates per set.



The experimental design utilised a roving procedure, to minimise memory effects due to repeated presentations of the same stimulus pairs. By enlarging or reducing the stimulus pair proportionally, the same relative difference will exist between the two stimuli (and therefore the same estimation will be made), whilst appearing to be a novel comparison to the participant. Roving positions of +25%, +50%, -25% and -50% were used. This allowed five different comparisons to be created for each stimulus pair, thus enabling 15 presentations of each stimulus pair whilst actually repeating each image pair only three times.

#### **6.1.2.4 Preload estimate and uncertainty**

In order to assess whether this psychophysical method produces results comparable to the measure previously used, a shortened version of the preload perception measure was also included in the experiment. This consisted of a quarter of the measure used in experiment four. Here, cornflakes were used to estimate how filling participants expected a fixed amount of soup to be. The preload estimate and uncertainty were derived from this measure in the same manner as before. The tortillas vs. cornflakes estimations were excluded, as these were merely decoy measurements included to prevent the measure interfering with the compensation study that followed it. The estimations using soup against a fixed amount of cornflakes were also excluded, as they generally displayed a weaker relationship with compensation. It was argued that for this exploratory work, it would be more time-efficient to concentrate on the variable that demonstrated the strongest correlations in the previous study.

#### **6.1.2.5 Procedure**

Participants completed all the trials in a single session, although the 4 different sets of comparisons were conducted separately. The ordering of the sets, and the ordering of the comparisons within each set was randomised across participants.

The psychophysical measure was presented on a pc computer, using visual basic software. The images were presented on a 17" SVGA monitor, which resulted in the images appearing approximately 160mm x 115mm. For each comparison, the

standard stimulus was presented alongside the relevant comparison stimulus, with a button displayed below each image, both labelled '*More hungry*'. Participants were instructed to decide which of the two portions would have least hunger reducing properties (and thus leave them feeling more hungry), and click on the relevant button, using a mouse-driven cursor. After selecting one of the images, the screen changed immediately to the next comparison, and the process was repeated in this manner until all the comparisons in that set were complete. The procedure was repeated for all four sets of stimuli.

Immediately following the psychophysical measure, participants completed the familiarity and anticipated pleasantness ratings, and finally, the preload perception measure.

#### **6.1.2.6 Data analysis**

Preload estimate and uncertainty estimates were derived from the data using the same methods as the previous measure. The data from the psychophysical measure was aggregated to form a psychometric function, from which both PSEs and JNDs could be derived. Firstly, participants' responses to each stimulus were separated, giving 15 responses to each comparison stimuli. The data from each stimulus was then converted to the proportion of those 15 responses to which the participant expected that the standard stimulus would reduce their hunger more than the comparison stimulus. As is illustrated in figure 6.1, a psychometric curve can be produced when the response proportions from the different stimuli are plotted together. This termed the psychometric function of the dataset. Generally, the proportion of 'yes' responses (i.e. the comparison stimuli is expected to reduce hunger more than the standard stimuli) will increase as the intensity (i.e. the size of the portion) of the comparison stimuli increases. In this context, the psychometric function describes the relationship between stimulus intensity, and the proportion of yes responses. However, as previously discussed, examining the data in this way does not take into account an individual's response bias, and so it is impossible to obtain PSEs and JNDs that can be objectively compared between respondents. To allow such comparisons, the data is converted to z scores by means of a pc-based spreadsheet package (Microsoft Excel).

Converting normally distributed data in this way will transform the ogive curve of the 'yes' proportions to a linear function when expressed as z-scores. The equation of this function was then calculated using a linear regression function of a pc-based statistics package (SPSS v 11.0 for windows).

The PSE of the dataset was derived from this equation by calculating the stimulus magnitude when the z-transformation of the data equalled 0, as  $z[0.5] = 0$ , so this represents the point where 'yes' and 'no' responses were both equally likely. As the JND of a dataset can be described as the stimulus magnitude between  $z[0.5]$  and  $z[0.25]$  or  $z[0.75]$ , it can also be considered to be half the inter-quartile range of the data. To calculate the inter-quartile range, the stimulus range between  $z[0.25]$  (which equates to -0.675), and  $z[0.75]$  (which equates to 0.675) is calculated. This value is then halved to derive a JND.

Correlations between the different measure types were then examined using Pearson's product moment correlation coefficient.

### 6.1.3 Results

Participants' PSE, JND, PE and PU for each set of trials are displayed in table 6.1. Of the four standard stimuli used in the psychophysical measure, soup was observed to create the lowest PSE estimate, despite the efforts to match the satiating properties of the soup to the other foods. A low PSE score infers that a smaller portion of cornflakes would be considered as equivalent to the stimuli, and therefore the stimulus is seen as less satiating. Rice salad was observed to be the most satiating of the four stimuli, with a PSE of 34.54g. The soup standard was also noted to elicit the smallest JND score (10.23g). This indicates that, for the stimuli presented, soup created the least uncertainty for the participants. Pasta was observed to create the greatest uncertainty in participants, with a JND estimate of 22.97g.

**Table 6.1.** Average preload estimate (PE), preload uncertainty (PU), point of subjective equality (PSE), and just noticeable difference (JND) estimates using different standard stimuli. Values represent estimates made in grams of cornflakes, and denote group means and standard deviations.

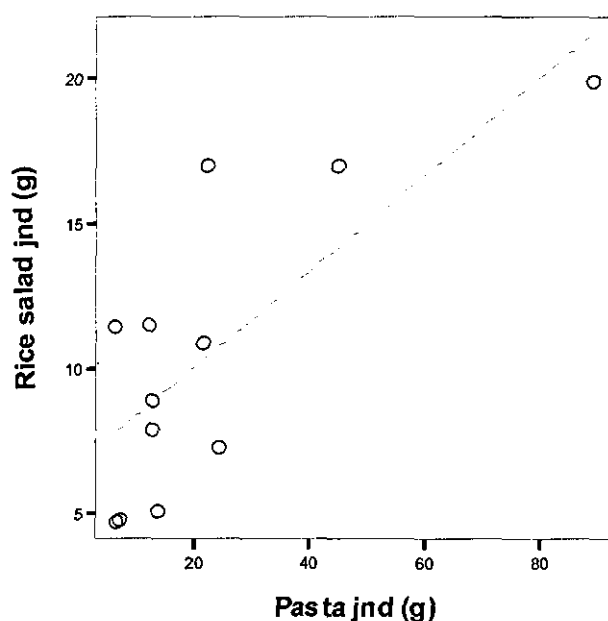
Experiment 4		Psychophysical measures				
measures						
	Soup		Soup	Potatoes	Rice salad	Pasta
PE (g)	73.92 (37.02)	PSE (g)	23.47 (10.83)	34.54 (12.56)	35.53 (8.77)	25.02 (8.30)
PU (g)	32.75 (13.88)	JND (g)	10.23 (5.08)	15.95 (15.91)	10.52 (5.17)	22.97 (23.28)

#### 6.1.3.1 Correlations

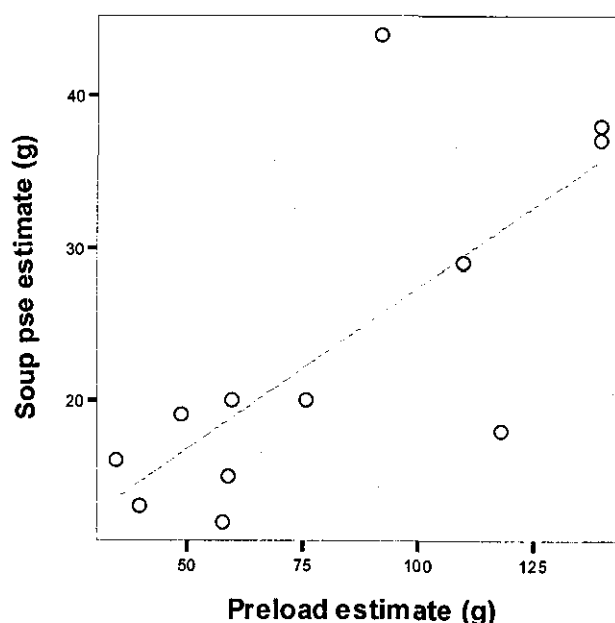
PSE measurements for the four standard stimuli generally showed little evidence of correlation, with an apparent negative correlation between potato/cornflakes and

pasta/cornflakes PSE's the exception to this ( $r = -0.581$ ,  $df = 10$ ,  $p = 0.047$ ). JND estimates were related to a slightly greater extent, with a significant association observed between rice/cornflakes and pasta/cornflakes estimates ( $r = 0.756$ ,  $df = 10$ ,  $p = 0.004$ ), which is illustrated in figure 6.3. The data also provides some indication (although non-significant) of similar relationships between potato/cornflakes and rice/cornflakes ( $r = 0.551$ ,  $df = 10$ ,  $p = 0.064$ ), and pasta/cornflakes and soup/cornflakes JND estimates ( $r = 0.497$ ,  $df = 10$ ,  $p = 0.100$ ).

When compared against PE and PU measures used in the previous experiment, a significant correlation was observed between the soup/cornflakes PSE estimate and the PE ( $r = 0.734$ ,  $df = 10$ ,  $p = 0.007$ ). This association is illustrated in figure 4.4. No significant associations were apparent between the soup/cornflakes JND estimates and the PU measure taken.



**Figure 6.3.** Association between JND estimate derived from rice/cornflakes and the pasta/cornflakes psychophysical measures.



**Figure 6.4.** Association between PSE estimate derived soup/cornflakes psychophysical measure, and the PE measure used previously.

### 6.1.3.2 PSE and JND contrasts

Repeated-measures analysis of variance revealed a significant difference ( $F_{3,33} = 3.743$   $p = 0.020$ ) between soup/cornflakes PSE estimates the other three food combinations. When examined individually, post hoc tests highlighted a difference between the soup/cornflakes and rice/cornflakes measure ( $t = 2.872$ ,  $df = 11$ , two-tailed,  $p = 0.045$ ), but failed to show any significant differences between the soup/cornflakes measure and the potato/cornflakes or pasta/cornflakes measures. Soup/cornflakes JND estimates also failed to display significant differences with any of the other food combinations when a Greenhouse-Geisser adjustment was made to correct for an aspheric dataset ( $F_{1.905, 20.950} = 2.773$   $p = 0.088$ ).

### 6.1.4 Discussion

This experiment aimed to compare two different types of measure both designed to assess prospective hunger. By asking participants to complete both measures, the degree of congruity between the measures could be ascertained. It was argued that if the different measures are both assessing the same motivations, a relatively high level of correspondence should be observed. The results provide some support for this argument. An association was observed between the PE measure used previously and the PSE estimate derived from trials incorporating soup as a standard stimulus. This infers that this new measure is suitable for ascertaining the satiating value of one food (i.e. soup) relative to another (i.e. cornflakes). However, the soup/cornflakes JND estimates were not found to be associated with PU, which may have several implications. Firstly, the lack of correlation may suggest that JNDs cannot be accurately measured using this protocol.

#### 6.1.4.1 Can this methodology be used to assess JNDs?

While previous studies have used the constant stimuli method to determine JNDs in this way, the use of such measures to assess dietary uncertainty is novel to this study. The range of individual differences in satiating expectancies may have limited this methodology, as they introduced floor or ceiling effects to the data of some participants. When planning this study, a range of comparison stimuli was created, with the aim of encompassing all participants' response distributions. This issue can be illustrated if figure 6.5 is considered. Here, three psychometric functions are displayed. Figure 6.5 a depicts the desired situation, where  $p(\text{yes})$  approaches zero at the smallest stimulus size, it also approaches 1 at the largest stimulus size, thus incorporating all of the response distributions in between these two extremes. Unfortunately, due to a larger than anticipated range of responses across participants, the selected testing levels do not encompass all the responses provided by the participants. Some participants may produce psychometric functions which instead resemble figures 6.5B or 6.5C. In figure 6.5B, the largest stimuli does not elicit a  $p(\text{yes})$  close to one, so therefore the whole response distribution for this participant is not represented, and assumptions made from this dataset will not be truly

representative of the participant's actual response characteristics. There are also several stimuli where  $p(\text{yes}) = 0$ , which is undesirable, as perfect scores (i.e. 1 or 0) cannot be converted to z-scores. These values have to be adjusted by means of a somewhat arbitrary value (Macmillan and Creelman 1992). Also, error associated with converting the  $p(\text{yes})$  to z scores increases sharply at very high probabilities. Figure 6.5C shows the converse of figure 6.5B, and in this example,  $p(\text{yes})$  does not near zero at the smallest stimulus size, and so again the full psychometric function is not represented. There are also several comparison stimuli intensities where  $p(\text{yes}) = 1$ , which poses the same problem already mentioned for figure 6.5B.

There are solutions to this problem using the method of constant stimuli. The distance between each testing level can be increased to widen the range of testing levels, or alternatively more testing levels can be incorporated into the test. Unfortunately, neither offer a suitable solution in the present context. By increasing the distance between each testing level, detail will be lost from the participants' responses, making the results less accurate. Increasing the number of testing levels would encompass all of the responses without becoming sacrificing accuracy, but it would also increase the length of the test significantly. As this task was to be incorporated into a preloading study paradigm, this would not be practical.



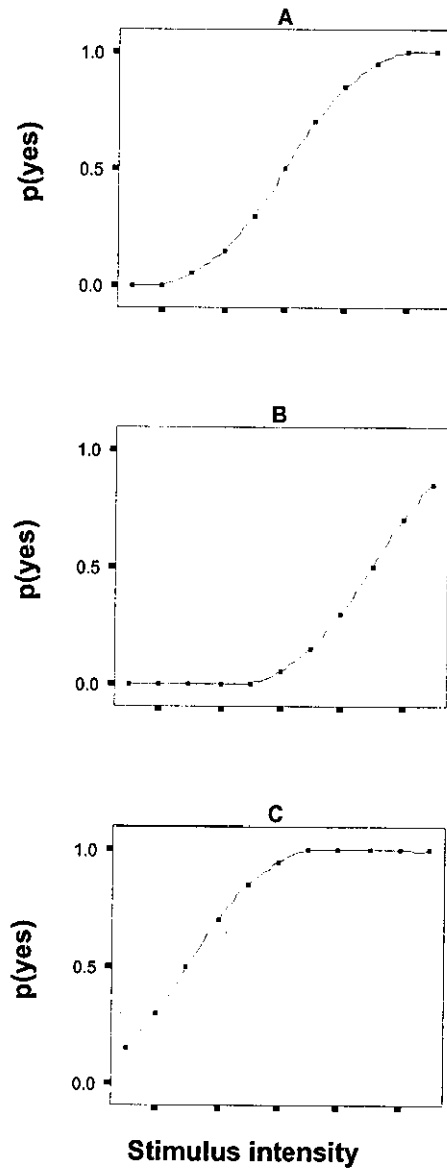


Figure 6.5 Three hypothetical psychometric functions illustrating how floor and ceiling effects can result from poor choice of testing levels.

#### 6.1.4.2 Does the PU estimate accurately reflect dietary uncertainty?

The lack of evidence to support this particular use of the constant stimuli method, together with the concerns highlighted casts some doubt over whether the methods employed in this study are suitable for extracting JNDs.

Alternatively, the problem may reside with the PU measure designed for the previous study. Following the inconclusive results obtained from the PU measure in the previous study, it was suggested that this measure may not be performing as expected, and the PU measure was in fact an approximate measure of ability to complete the task. A larger variance associated with poorer, less consistent performance, may have resulted in apparently larger PU values. Thus, the PU measure may have actually been measuring participants' memory of their previous responses, rather than their uncertainty about the properties of the food.

#### **6.1.4.3 Is uncertainty food-specific or general ?**

This study also aimed to explore ways of dissociating the uncertainty generated by the standard stimuli and the comparison stimuli in participants' estimates. Any estimate of one food relative to another will inevitably create some level of uncertainty. Quantifying the actual amounts of uncertainty arising from each food is a difficult task. Booth (1981), stated that hunger and satiety motivations were specific to both the food and the situation, and similarly, it could be argued that the uncertainty generated in this type of task may not be completely stable across different combinations of foods. An individual may be more certain about the properties of rice when asked to express them in terms of pasta, for example, but not if asked to compare them against a different kind of food, such as chocolate. Taking such arguments into account, it may not be possible to define a single universal value for a food's uncertainty. One alternative may be to obtain uncertainty ratings for one food against a 'basket' of other foods, in order to arrive at an average uncertainty value. Using this technique may also highlight any foods that create a dramatically different uncertainty.

Prior to this study, it was established that soup was perceived as considerably less satiating than the other, solid foods, when presented in equal weights or energy contents to them. To resolve this problem, initial pilot work was conducted using the same methodology, to determine a quantity of soup that was approximately equal to the other foodstuffs. While this had the disadvantage of removing a direct link between the soup and the other foods – as it neither had exactly the same weight or

energy content of the other foods – It had the benefit of at least ensuring that each food had a PSE of the same order of magnitude. However, despite this adjustment, analysis revealed that differences existed between the PSEs of different food combinations. When it is considered that JNDs will be dependent on the stimulus intensity, the significance of these different PSEs becomes clearer. On face value these results suggest that different foods all elicit similar JNDs, and therefore could be considered to create the same of uncertainty in participants. However, the significantly different PSEs across the four stimuli indicate that the different JNDs cannot be compared in this way, as they are being derived from different intensity stimuli. Taking this into account, there is little evidence from this study to suggest that uncertainty varied across the four foods used as standard stimuli.

## **6.2 Experiment 6 : Adaptive psychophysical procedures can provide a more suitable psychophysical task**

### **6.2.1 Introduction**

The previous study used the method of constant stimuli to try to determine PSE and JND statistics from a series of comparisons between several foods. Unfortunately, as has been discussed, several limitations of this methodology have become apparent, from which the conclusion was drawn that this method is inappropriate for this type of experiment. Rather than using the method of constant stimuli, an alternative method may incorporate an adaptive element to the methodology. Adaptive procedures use algorithms to adjust the testing level during the experiment, to focus subsequent trials on the testing levels of interest, based upon the previous responses given. This poses a more efficient alternative to the method of constant stimuli, as it does not 'waste' trials on testing levels from which little information can be obtained. This is beneficial because it drastically reduces the number of trials needed to obtain reliable PSE and JND estimates. Another benefit of adaptive techniques is that experimenters do not need to have definite estimates of JND and PSE statistics prior to testing. This is especially relevant to an experiment assessing portion sizes, as due to the subjective nature of the estimate being made, there may be considerable between-participant variation.

Several different adaptive methods exist, but there are several common features of the various techniques. Firstly, criteria need to be determined that decide when the testing level of the experiment should be changed. Second, how the testing level is changed also needs to be determined. Finally, how the raw data is interpreted also needs to be determined. The alternatives used by previous studies are introduced below:

#### **6.2.1.1 When to change the testing level.**

Probably the simplest way to decide when to change the testing level in an adaptive procedure is to adjust the testing level after each stimulus presentation. An early

example of such a procedure was employed by Bough (1958), who examined the relative brightness of blue and yellow lights using pigeons. The birds were taught to peck the brighter of two illuminated discs. The two discs were then illuminated using different coloured light, to see how the different wavelengths of light affected the subjective perception of brightness. Initially, the two discs were illuminated at the same intensity, but each time the yellow disc was pecked, the blue light was increased in intensity, and every time the blue light was pecked, the intensity of the blue light was decreased by an equal amount. Eventually, this technique allowed Bough to ascertain the intensity at which the blue light was perceived to be equal in brightness to the yellow light, as at this testing level both colours were pecked equally as often. Unfortunately, this technique would not be suitable for a visually-based task using human participants (as in the previous studying this thesis), due to the fact that participants would be likely to realise that they were being shown the same stimuli repeatedly. This in turn would be likely to create a memory effect. Once the participant has made a judgement about a particular stimulus pair, presenting the same pair to participant again would always elicit the same response as they can remember the judgement they made initially, rather than assessing the stimuli independently each time.

Wald (1947) proposed a more sophisticated method of determining when a change of testing level is required. This method is based upon the principle that if a participant is tested exactly on their threshold level for any particular stimuli, then experimenters could (in theory) expect the participant to respond with exactly 50% yes responses, and 50% no responses. In reality of course, over small number of trials this is unlikely to be the case. Using this logic, it is not desirable to change levels whenever performance deviates from the ideal. A more appropriate technique is to change testing level when the participant's performance deviates from the threshold level by a predetermined margin. Wald (1947) suggested that in order to keep testing at a particular level, the actual response rate should equal the expected response rate (if the participant were at threshold) plus or minus a constant, termed the deviation limit. This is illustrated in the equation below.

$$N_b(C) = E[N(C)] \pm W$$

Where  $N_b(C)$  represents the bounding number of events after  $t$  trials,  $E[N(C)]$  denotes the expected number of events after  $t$  trials.  $W$  is a constant called the deviation limit. With each subsequent trial,  $N_b(C)$  is compared against the expected number of responses plus or minus a constant. If the actual number of responses falls outside of this range of values, the testing level should be changed. The direction of this change depends on whether the number of observed responses fell above or below the permitted range.

#### **6.2.1.2 How to change the testing level**

As well as deciding when to change the testing level, a decision also needs to be made regarding the nature of the change. There are several rules that have been used within previous experiments to decide this.

The simplest methods involve changing the stimuli by a fixed step size each time. One study already mentioned by Bough (1958) employs this method, as does Cornsweet (1962). However, the inherent problem with this type of methodology (called a staircase procedure) is that some prior knowledge of an appropriate step size is needed for the experiment to work. A step size that is too large could change the task from trivially easy to impossibly difficult in one step, whereas a step size that is too small may not create a noticeable difference in performance. As one of the main benefits of an adaptive procedure is that the experimenter does not need to know where the threshold is prior to testing, having to run pilot studies to determine step size limits its usefulness somewhat.

Another early method was suggested by Dixon and Mood (1948), who proposed gradually decreasing the step size during the test run, with each step divided by the number of steps in the run at that point. Unfortunately, although this method will allow the testing to be gradually refined as it approaches the threshold, if a participant makes a mistake, or even several mistakes in a row (and thus makes the testing level step away from the threshold), it becomes increasingly difficult for the testing level to recover back to around the participant's threshold. As argued by Creelman and

Macmillan (1991), there needs to be some mechanism for correcting incorrect steps that increases step size.

### 6.2.1.3 PEST

In 1967, Taylor and Creelman devised an adaptive procedure for the analysis of psychometric thresholds called Parameter Estimation by Sequential Testing (PEST). The basic premise of PEST was that, in a 2AFC task, a participant's responses should be equally distributed across the two alternatives at a threshold level of testing (as both alternatives should be equally salient). Thus, by means of an iterative process, the threshold level of testing can be ascertained. After each trial, PEST compares the responses of the participant, and if they are responding sufficiently away from chance levels, then the testing level is adjusted up or down accordingly. The pest procedure uses a number of different rules to achieve this.

The initial testing levels need to be determined prior to testing. Taylor and Creelman (1967) state that initial testing level is defined by using the estimation  $PSE + (JND \times 4)$ , and the initial step size is determined by the estimation  $4 \times JND$ . Assuming that a participant has responded in a manner that requires the testing level to be changed, how the testing should be changed to also needs to be determined. To determine the new level of testing, PEST uses the following rules.

- On each step reversal (i.e. a step in the opposite direction to the previous step), the step size is halved. There is however, a minimum step size below which step sizes are not reduced.
- A change of step in the same direction as the previous step is the same size as the previous step, with the following exceptions:
  - i. The third consecutive step in the same direction results in a doubling of the step size, and each further consecutive step in that direction is also doubled until the next reversal.

- ii. If a reversal follows a doubling of step size, then an extra same-size step is taken before doubling
- iii. There is a maximum step size above which steps are not increased.

PEST typically employs a fixed number of trials, rather than relying on an aspect of the participant's performance to determine when to end testing.

#### **6.2.1.4 Maximum likelihood procedure**

An alternative method of determining the next level of testing is by using maximum likelihood methods. When a change in testing level is needed, these methods find the most probable psychometric function that fits the observed data up to that point. The testing level is then changed to the midpoint of this function.

$$L(x) = [p(x)]^R [1 - p(x)]^{N-R}$$

Where  $p(x)$  represents a specific form of the function, that specifies what proportion of 'yes' responses should be seen at each testing level.  $R$  represents the number of 'yes' responses (or equivalent) and  $N-R$  represents the number of 'no' responses. The likelihood that the observed sequence of responses is produced by the function  $p(x)$  is denoted by  $L(x)$

#### **6.2.1.5 For example:**

If a logistic function  $p(x)$  predicts that for a particular testing level,  $p(\text{yes})$  is 0.75, and in a sequence of responses a participant responds 'yes' four times and 'no' 2 times, the likelihood that this pattern of responses is formed by the function  $p(x)$  is as follows:



$$L(x) = (0.75)^4 (0.25)^2$$

$$L(x) = 0.0198$$

Choosing a form for the function  $p(x)$  specifies a family of curves that may fit the observed responses, each varying in their PSE and JND values. By calculating the likelihood for curves with varying values of PSE, it is possible to determine which variant of  $p(x)$  (and therefore which values of PSE) is most likely to have created the observed responses. The testing level is then changed to this estimate, and the testing continues.

#### **6.2.1.6 Maximum likelihood techniques: advantages and disadvantages**

Robbins and Monro (1951) illustrated that using the maximum likelihood procedure after every trial in this way is the most efficient way to find a threshold. Two published packages that use the maximum likelihood approach to find thresholds are 'Best PEST' (Pentland, 1982) and QUEST (Watson & Pelli 1983). Two key disadvantages of these two methods make them unsuitable for the present research. Firstly, the 'real time' calculation of maximum likelihood analysis following each response will still require a relatively high-specification pc to be able to analyse the data without any delay at all, especially as the current experimental design would also involve updating the digital photographs after each response. Even a delay of a couple of seconds after each response may make the procedure unwieldy for participants, which may in turn hinder the results if participants become excessively bored during the study. Whereas this processing requirement is no longer the prohibitive factor it may have been in the past, it would potentially increase the cost of the experiment if newer computing equipment needed to be purchased.

The second limitation of both QUEST and Best PEST is that the slope of the psychometric function (and accordingly the JND) needs to be fixed by the experimenter prior to testing. This presents a problem, as due to the novel nature of the present research it cannot be determined with any certainty what slope the psychometric function will have, especially when considering that different

participants will be likely to have different psychometric functions. Finally, needing to fix the slope of the functions will also render these methods unsuitable, as measuring participants' JNDs is one of the aims of the current research, which obviously cannot be achieved using methods where they need to be predetermined.

Fortunately, there is a method that can address all of the problems that have been highlighted with QUEST and Best PEST, but still retain the use of the maximum likelihood procedure that has been proven to be the optimal method for determining thresholds (Robins and Munro, 1951). Hall (1981) proposed a hybrid procedure that included elements from both PEST and maximum likelihood analysis. This method could therefore take advantage of PEST's ability to focus testing levels around the threshold, but also taking into consideration the whole of the data set produced when determining PSEs and JNDs. One of the limitations of adaptive procedures such as PEST is that only the last data point in the test session is used, with all of the responses prior to that being discarded. Applying maximum likelihood analysis to all of the data set following the completion of a fixed-length PEST run allows all of the data to contribute to the resulting psychometric function. Another important benefit of this technique is its ability to estimate both PSE and JND values for any given psychometric function, which the PEST procedure alone cannot. This procedure also offers the key benefit of not needing to conduct maximum likelihood analysis following every response, which reduces both the processing requirements and the complexity of the programming needed considerably.

#### **6.2.1.7 Hall's Hybrid procedure**

The hybrid procedure proposed by Hall (1981) initially uses the stepping rules of PEST during a run. This incorporates the simplified version of Wald's sequential likelihood test ratio to determine when to change the stimulus level, and the PEST criteria for deciding what the testing level should be changed to. After the PEST run is completed, a maximum likelihood procedure is conducted on the response data to obtain PSE and JND estimates.

The maximum likelihood technique used in Hall's hybrid procedure (1981) is essentially the same as the previously described. This procedure used the logistic function, although this could be substituted for the Weibull or Gaussian functions depending on the type of responses seen. For consistency, the logistic function will be used here. The logistic function can be approximated by the following equation,

$$P(x) = \left( 1 + \frac{N-1}{1 + \exp(-(x - \alpha) / \beta)} \right)$$

**Equation 6.1** Approximation of the logistic function, as used in Hall's Hybrid procedure (1981).  $x$  represents stimulus intensity,  $\alpha$  represents the function midpoint (PSE) and  $\beta$  represents the function gradient (JND)

This function therefore provides a probability of a 'yes' response for any stimulus level within the participants psychometric function (i.e. the range of probabilities of a 'yes' response extend from 0 to 1), when the functions midpoint (PSE) and gradient (JND) are known. In the context of the previous experiment, this equation could therefore estimate the probability that a specific bowl of soup would be judged to be more filling than a portion of cornflakes that lies somewhere within the range of definitely less filling - definitely more filling than the soup, when the PSE and JND of the participant's psychometric function are known. To illustrate how this can be applied to a paradigm similar to the previous study in this thesis, the example mentioned previously can be reconsidered. This example illustrated how the probability can be calculated that an observed distribution of responses at a one testing level could be produced by a particular function. This example could also be extended to include responses at several different testing levels, as is illustrated below:

As has already been discussed, if a logistic function  $p(x)$  predicts that for a particular testing level,  $p(\text{yes})$  is 0.75, and in a sequence of responses a participant responds

'yes' four times and 'no' 2 times, the likelihood that this pattern of responses is formed by the function  $p(x)$  is as follows:

$$L(x) = (0.75)^4 (0.25)^2$$

However, this only describes how testing at one level can be analysed using a maximum likelihood procedure. Additional terms can also be entered for responses made at other testing levels, by finding the probability of a 'yes' response at the new levels by altering the  $x$  term of the logistic function equation accordingly. Thus, if this example is enlarged to include six responses from two further testing levels, the equation would appear as follows:

Testing level 2:  $p(\text{yes}) = 0.65$ , with a 3:3 response distribution.

Testing level 3:  $p(\text{yes}) = 0.20$ , with a 1:5 response distribution.

Would be entered into the equation as:

$$L(x) = (0.75)^4 (0.25)^2 (0.65)^3 (0.35)^3 (0.20)^1 (0.80)^5$$

By altering the values of PSE and JND, the probabilities for each of the terms will be altered. By repeating this process for all of the different possible combinations of PSE and JND, the likelihood of each of these combinations can be compared, and the most likely combination of PSE and JND can be determined. This is essentially how Hall's Hybrid procedure calculates these values, by conducting a maximum likelihood procedure on all of the data obtained during the PEST. When calculating the likelihood of the data, Hall (1981) recommends taking the natural log of the probabilities rather than the calculation shown to avoid problems with dealing with very small numbers.

#### **6.2.1.8 When to stop testing**

There are several different methods of deciding when to end a test run for an adaptive procedure. The most simple is to decide prior to testing upon a fixed length for the run, and to analyse whatever data has been produced. This is the method that Hall (1981) uses for his hybrid procedure, as equal length runs are necessary for the maximum likelihood measurement to be valid between participants. More complex rules have been implemented in other studies, with the testing continuing until the step size reaches some minimum point, or a certain number of step reversal has taken place (both suggesting that the testing level is approaching the threshold). QUEST used confidence intervals to determine when testing should be stopped, with testing ending when the data fitting a particular psychometric function within certain confidence interval limits. While this has been shown to be a particularly accurate rule to use (Emerson, 1986), the unpredictability of test length makes it unsuitable for use in techniques such as Hall's Hybrid Procedure.

#### **6.2.1.9 Summary**

Experiment 5 has highlighted that the method of constant stimuli is not a viable technique when studying the perceived satiating ability of foods. A potential alternative may be to use an adaptive technique that can obtain reliable results with much fewer trials, and without needing prior estimates of PSE and JND. Hall (1981) suggested a method that may be suitable for the present context, as it utilises maximum likelihood analysis, without creating an excessive processing demand. By employing this technique in a similar protocol to the last study, it can hopefully be determined whether these types of adaptive psychophysical procedures can be used to replicate the previous findings of this thesis. As such the hypotheses to be tested in this experiment are similar to those of experiment five: The preload estimate and preload uncertainty measures employed in experiment 4 will be positively correlated with the PSE and JND statistics obtained in a psychophysical task utilising Hall's Hybrid procedure. It is also hypothesised that there will be a positive correlation

between subsequent trials of the hybrid procedure, indicating the measure to be performing consistently.

## **6.2.2 Methods**

### **6.2.2.1 Participants**

Twelve participants (mean age 19.6 years, 7 females, 5 males) were recruited via university notice board advertisements. Previous participants were excluded, as this implied they had prior experience of the soup preload. Each participant completed the experiment in one test session, lasting approximately 30 minutes. Testing took place in cubicles within the Ingestive Behaviour lab, between the times of 09.30 and 17.00. Participants were fully debriefed at the end of the experiment, and were compensated for their time.

### **6.2.2.2 Design**

A one-sample design was employed, with the observed PSE and JND estimates obtained by a psychophysical measure, and then compared against preload estimate and uncertainty measures as the preceding experiment.

### **6.2.2.3 Psychophysical measure.**

Similarly to the previous experiment, this study used digital images of different foods as standard and comparison stimuli. The images were created in the same manner as before using a digital camera. For this experiment, only one standard stimulus was used. This consisted of a 278-ml bowl of the soup preload. The comparison stimuli consisted of 60 images of different portion sizes of cornflakes varying between 1 gram and 60 grams in 1-gram increments, and were chosen to represent portions that ranged from obviously less filling than the preload to obviously more filling than the preload. This range of stimuli were chosen to ensure that regardless of participant variability, each participant's estimate of the preload would lie somewhere within the 60g range of comparison stimuli.

The task was presented in an identical format to the previous experiment. The experiment was split into 4 'runs' that were completed consecutively. Unlike the

previous experiment, rather than showing a pre-determined selection of comparisons, this experiment utilised an adapted PEST procedure to adapt the selection of comparisons presented to participants, based on their preceding responses. Each run started at the same testing level, which presented the largest bowl of cornflakes (60g) alongside the standard stimulus of soup. Each subsequent trial then remained at this level until the responses given by the participant deviated from chance by a pre-determined margin, as determined by Wald's (1947) sequential likelihood test ratio.

When this ratio was exceeded, the testing level changed, and then the process was repeated with testing remaining at this new level until the participant's responses again exceeded the ratio. The direction and magnitude of the change was determined by the rules of the PEST procedure, as have been described earlier. Each run of the PEST procedure was fixed at 50 comparisons. However, as the test involved participants considering the same comparisons several times consecutively, to prevent them from only making the comparison once and then responding three times, each meaningful comparison was alternated with a random comparison that was not analysed. This technique ensured that the magnitude of the comparison stimuli varied after every comparison, which prevented the participant from using the memory of a previous response to inform subsequent responses. Consequently, each run consisted of 100 comparisons, although only half of these were actually used in the experimental analysis. The algorithm used to determine when and how the testing level should be changed was based upon the following algorithm:

**Initial variable values:**

Stimulus = 60, Step = 10, N(trials) = 0, N(total trials) = 0, N(left button) = 0,  
+ve steps = 0, -ve steps = 0

**Algorithm:**

- **Present stimulus**
- Update N(total trials) +1



- If:
  - left button pressed, update  $N(\text{left button}) + 1$  and update  $N(\text{trials}) + 1$
  - right button pressed, update  $N(\text{trials}) + 1$
- Then, if  $N(\text{total trials}) = 50$ , end experiment
- Then, If:
  - $N(\text{left button}) > N(\text{Trials}) \times 0.5 + 1$ , goto 2
  - $N(\text{left button}) < N(\text{Trials}) \times 0.5 - 1$ , goto 3
- End Loop

## 2

- Update  $N(\text{left button})$  '0' and update  $N(\text{trials})$  '0'
- If +ve steps  $\neq 0$ , Then;
  - Update +ve steps '0' and update -ve steps '+1'
  - Then, update step to  $[0.5 \times \text{step}]$ .
  - If  $\text{step} \leq 2$ , update step '2'
  - Then update stimulus to  $[\text{stimulus} - \text{step}]$
- If +ve steps = 0, then;
  - update -ve steps '+1'
  - If -ve steps  $\geq 3$ , then;
    - Update step to  $[\text{step} \times 2]$
    - Update stimulus to  $[\text{stimulus} - \text{step}]$

- If -ve steps  $\leq 2$ , then;
  - update stimulus to [stimulus - step]
- If Stimulus  $< 2$ , then update stimulus '2'.
- End loop

### 3

- Update N(left button) '0' and update N(trials) '0'
- If -ve steps  $\neq 0$ , Then;
  - Update -ve steps '0' and update +ve steps '+1'
  - Then, update step to  $[0.5 \times \text{step}]$ .
  - If step  $\leq 2$ , update step '2'
  - Then update stimulus to [stimulus + step]
- If -ve steps = 0, then;
  - update +ve steps '+1'
  - If +ve steps  $\geq 3$ , then;
    - Update step to [step $\times 2$ ]
    - Update stimulus to [stimulus + step]
  - If +ve steps  $\leq 2$ , then;
    - update stimulus to [stimulus + step]
- If Stimulus  $> 60$ , then update stimulus '60'

End loop

Each run of the psychophysical task produced a computer file that listed the testing level of each of the 50 comparisons (i.e. the size of the cornflakes portion compared against the 278-ml soup portion), and the response given by the participant to this particular comparison (i.e. whether the participant felt that the soup or cornflakes would reduce their hunger the most). Following the completion of the four runs, a maximum likelihood procedure was conducted on this data by entering it into a custom-made spreadsheet. This procedure returned the most probable values for the spread and midpoint of the psychometric function for each run, based on the observed data. The spreadsheet used a compound formula (As illustrated in formula 6.1) to compare the likelihood that the observed data was created by psychometric functions with PSE and JND values varying from 1 – 100. This resulted in 10,000 likelihood calculations being computed automatically by the spreadsheet for each PEST run. Following this calculation, the spreadsheet returned the most likely psychometric function, and therefore the most likely values for PSE and JND.

```
{=SUM(IF($C$1:$C$50=1, LOG(1/(1+(EXP(-($B$1:$B$50-$H15)/J$14)))),LOG(1-  
(1/(1+(EXP(-($B$1:$B$50-$H15)/J$14))))))}
```

**Formula 6.1** An example of the Microsoft Excel formula used to determine which value of PSE and JND would create the most likely psychometric function, based upon the observed data.

#### 6.2.2.4 Preload estimate and uncertainty

In order to assess whether this psychophysical method produces results comparable to the measure previously used, the shortened version of the preload perception measure was also included in the experiment.

#### **6.2.2.5 Procedure**

At the start of the experiment, the psychophysical measure was explained to each participant. They were instructed to consider which portion (soup or cornflakes) depicted on the screen would leave them feeling most hungry, were they to eat it at the beginning of a meal. Participants then indicated their choice by clicking the button beneath the relevant picture. Clicking either of the buttons advanced the procedure to the next comparison, until all 100 comparisons had been completed. The psychophysical measure was presented on a pc computer, using Visual Basic software. The images were presented on a 17" SVGA monitor, which resulted in the images appearing approximately 160mm x 115mm. The appearance of the psychophysical task was identical to that of the previous experiment.

Each participant completed the psychophysical task four times. After two consecutive runs, the participant made PE and PU estimates in the same manner as the previous experiment, using cornflakes to estimate how filling they expected a 278-ml sample of soup would be. These measures were completed three times, from which the mean values were taken. Finally, two more runs of the psychophysical measure were completed. The experiment was typically completed in under 30 minutes, with of each of the five component parts taking approximately five minutes to complete.

#### **6.2.2.6 Data analysis**

Pearson's correlation coefficient was used to determine extent to which the values produced by the 4 runs of the psychophysical task were associated with each another.

Correlations were also examined between the values of spread and midpoint and the estimates made by the participants using the preload perception measure as per the previous experiments.

### 6.2.3 Results

The data from the four runs of the hybrid procedure and the two runs of the novel measure is displayed in table 6.2. The four mean estimates of PSE made by the hybrid procedure were observed to decrease in value with each successive run. The greatest decrease was seen between the first and second runs, with progressively smaller differences observed between the second and third, and third and fourth runs. The deviances of the PSE estimates were also smaller at the end of the four trials, although the greatest deviance was noted during the second run. Mean JND estimates were also noted to decrease markedly throughout the four runs, and considerably greater variance was noted following the first two trial runs, compared with the third and fourth. Mean PE and PU estimates derived from the novel measures taken from experiments 4 and 5 were remarkably constant across the two runs of that measure, with PE and PU estimates varying by less than 1g on each occasion.

**Table 6.2** Mean PE and PU estimates, and PSE and JND estimates from Hall's hybrid procedure.

Experiment 4 measures			Hall's Hybrid Procedure				
	Trial 1	Trial 2		Trial 1	Trial 2	Trial 3	Trial 4
PE (g)	42.9 (12.2)	43.6 (12.7)	PSE (g)	30.0 (13.6)	28.5 (15.6)	26.5 (12.4)	26.0 (12.7)
PU (g)	15.3 (8.5)	15.5 (9.1)	JND (g)	16.8 (23.5)	11.5 (20.3)	6.6 (3.7)	5.0 (2.2)

#### 6.2.3.1 Correlations

The associations between the PSE and JND statistics generated by the hybrid procedure, and the PE and PU estimates are displayed in table 6.3. A strong

correlation was observed between PSE estimates and the mean of the PE estimates from the previous measure. The greatest degree of correlation was exhibited following the first run of the hybrid procedure, with each subsequent run displaying progressively weaker correlation to the PE estimate. However, even the fourth run of the hybrid procedure still displayed a significant correlation with the PE estimate. Figure 4.6 illustrates the correlations between PSE and PE values across the four experimental runs.

No significant associations were noted between JND and PU estimates across any of the four trials. The data does display a consistent negative correlation between PU and JND, which gradually improves with each subsequent trial. However, examination of scatter plots for this data set fail to reveal any obvious patterns in the data. Figure 4.7 illustrates the relationship between PU and JND estimates across the four trials. As two outlying points in trial one make interpretations of these figures difficult, figure 4.8 illustrates that even with these two points removed the data, it still fails to highlight any definite trends between JND and PU.

**Table 6.3** Associations each participant's PSE and JND estimates, and the equivalent estimates using the novel method of experiment 4

	Hybrid procedure runs			
	Trial 1	Trial 2	Trial 3	Trial 4
PE correlation	$r = 0.745$	$r = 0.684$	$r = 0.569$	$r = 0.504$
with PSE	$p < 0.001$	$p < 0.001$	$p = 0.006$	$p = 0.017$
PU correlation	$r = -0.051$	$r = -0.163$	$r = -0.344$	$r = -0.365$
with JND	$p = 0.830$	$p = 0.468$	$p = 0.117$	$p = 0.095$

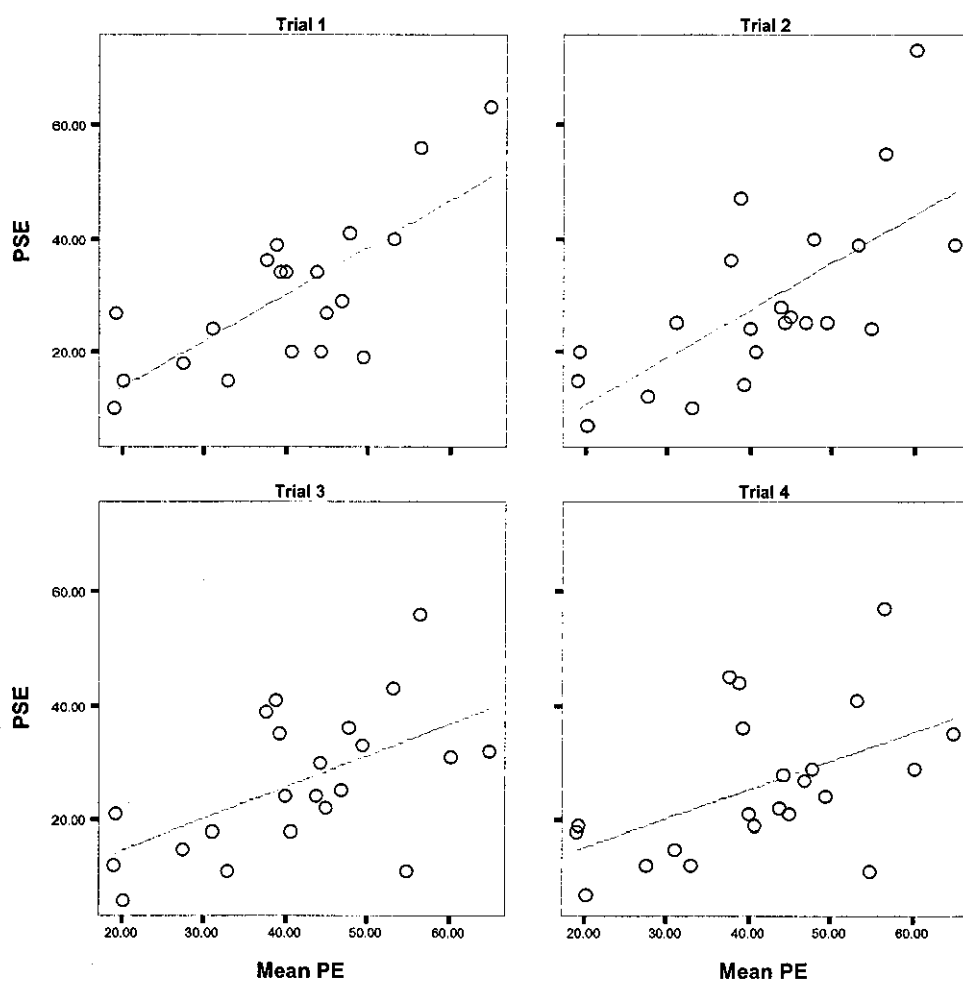
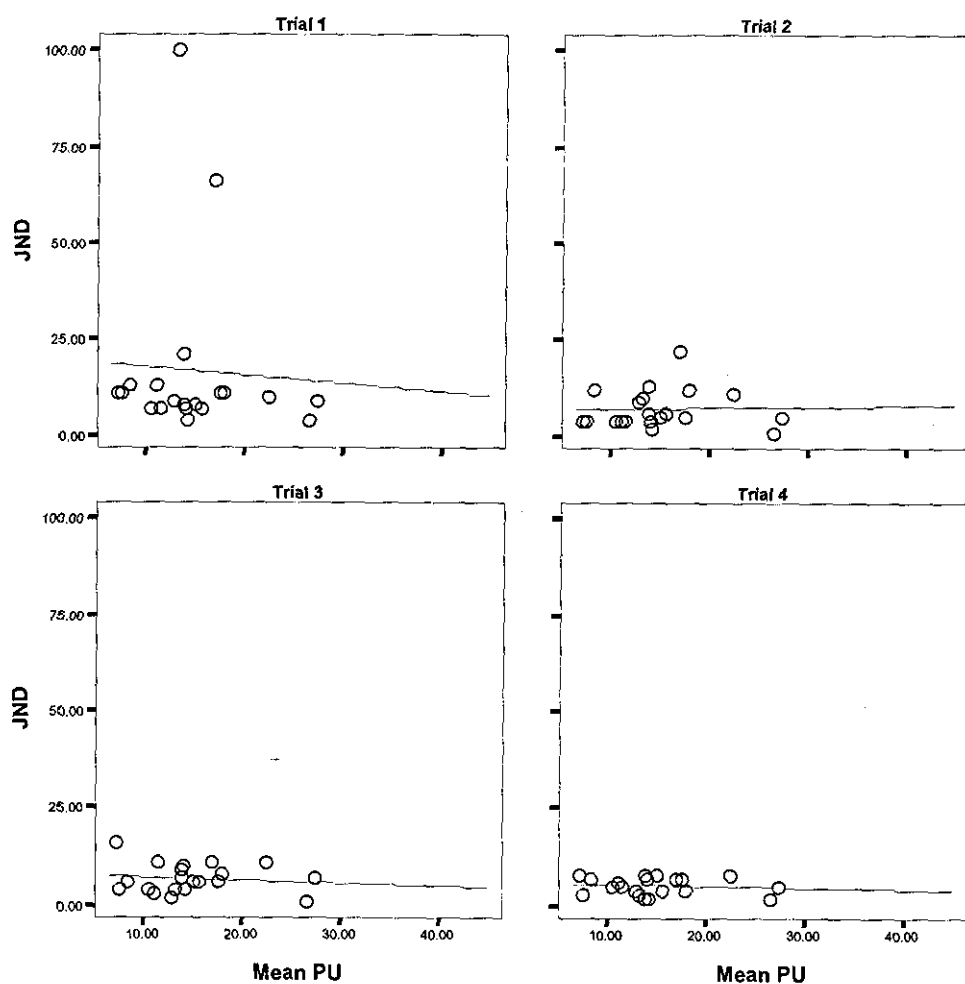
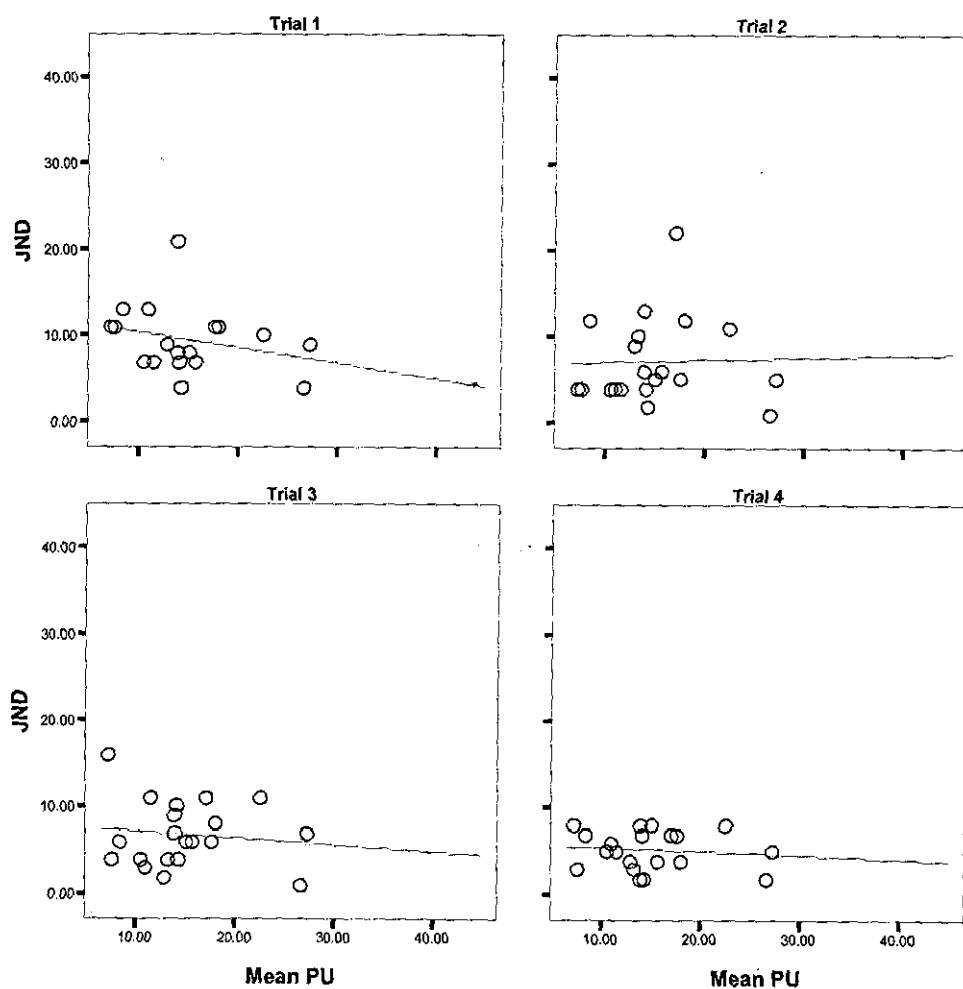


Figure 6.6 Scatter plot illustrating the correspondence between the PSE derived from Hall's Hybrid procedure, and the PE estimate derived using the previous methodology.



**Figure 6.7** Scatter plot illustrating the correspondence between the JND derived from Hall's Hybrid procedure, and the PU estimate derived using the previous methodology.





**Figure 6.8** Scatter plot illustrating the correspondence between the *JND* derived from Hall's Hybrid procedure and the *PU* estimate derived using the previous methodology, after two outlying values from Trial one were removed.

## 6.2.4 Discussion

Experiments five and six both highlighted a correlation between PE and PSE estimates using two different methods based upon different psychophysical procedures. Conversely, JNDs were not found to be significantly associated with PU estimates in either experiment. Although Hall's hybrid procedure actually displayed a marginally lower correlation with PE estimates, there are several reasons to believe that this is a more appropriate procedure to use in the present context that will be discussed later.

Another aim of experiment 6 was to determine how consistently the Hybrid measure would perform, by comparing four runs of the task against the preload perception measure that was conducted between the second and third run of the Hybrid procedure. It was hoped that conducting the hybrid procedure several times would also highlight how many runs needed to be in order to obtain reliable results. For each participant, the preload perception measure was also conducted twice and averaged in order to obtain reliable PE and PU estimates against which to compare the PSE and JND estimates. While all four PSE estimates correlated significantly with PE, the greatest association was observed following the first run of the hybrid procedure, with each subsequent run displaying less correlation and consequently a smaller significance level. This result was somewhat contrary to the variance observed for each of the PSE values, with between-participant variation decreasing with each subsequent run of the hybrid procedure. Although it cannot be fully determined why a greater variance of PSE values is linked to a better correlation with PE estimates, it is plausible that this may represent a gradual deterioration in performance by the participants with each run of the procedure. At the start of the experiment, participants are asked to compare the expected satiating effects of the portion sizes presented to them, rather than simply visually matching the portion sizes of the two foods. It is argued that this gradual decrease in variance between participants represents a gradual transition from responding to the foods expected effects during the first run, to matching the sizes of the two foods as fatigue or boredom begins to set in. As responses based upon matching portion sizes would be likely to exhibit less variance than responses based upon a subjective evaluation of the food, this may explain the present contrast between PSE variance and correlation with PE estimates.

Unlike PSE and PE estimates, JND estimates did not display any significant associations with PU estimates in either experiment. Some indication of a negative correlation between the two estimates was noted in the latter of these experiments, with each of the four Hybrid procedure runs producing JND results that were negatively correlated with PU estimates, albeit poorly. However, upon further examination of scatter plots of this relationship, the majority of the data points do not appear to reflect this association, with one or two outlying values seeming to create the observed correlation. These results throw further doubt on to the PU estimate produced by the preload perception measure in experiments three and four as two separate psychophysical procedures were unable to produce any reliable correlation between it and JND estimates, which theoretically should produce the same results.

The fact that these psychophysical measures are both based upon established methodologies provides a reasonable argument to choose these over the preload perception measures devised for use in experiments three and four. However, bearing in mind that both psychophysical measures produced PSE estimates that correlated strongly with PE estimates, in order to justify the claim that the Hybrid procedure offers the most suitable method, several factors need to be considered:

#### **6.2.4.1 Outliers**

Both studies highlighted a good correlation between PE and PSE estimates. The method of constant stimuli even produced PSE estimates that displayed a marginally better correlation with PE than the equivalent hybrid procedure estimates, with fewer participants. So why should the Hybrid procedure be considered as any better, when neither procedure produced JND estimates that correlated with PU estimates? Possibly the simplest argument regarding the observed results is illustrated by the scatter plots in figures 6.4 and 6.6. Here, it can be observed that for experiment five, the actual association between the PE and PSE measures was created largely by 3 data points. It could also be argued that these data points were anomalous to the rest of the data set, and so may be creating a misleading effect. Conversely, the 20 data points of the experiment six display a much more convincing relationship with PE values. Of course with such a small number of participants in experiment five ( $N = 12$ ), it is

difficult to determine exactly how these data points should be considered, but as has been explained previously, other problems became apparent that made further testing pointless.

#### **6.2.4.2 Floor and ceiling effects**

One of the main problems with the method of constant stimuli was that floor and ceiling effects were created in the data, which would influence the validity of the results obtained. These effects were seen because of the difficulties in creating a large enough range of portion sizes with small enough increments between each portion size, while still keeping the number of comparisons performed by participants to a feasible level. The PEST element of the hybrid procedure eliminated this problem as it allowed a much larger pool of available portion sizes without creating unnecessary increases in experiment length. As PEST selected the correct levels of testing based on participant responses, it ensured that number of comparisons were kept to a minimum. The method of constant stimuli required every stimulus to be presented to the participant an equal number of times, whereas PEST allowed less relevant stimuli to be presented less frequently, or even not at all.

#### **6.2.4.3 Coping with between – participant variability**

Another reason that the method of constant stimuli is not suitable is the requirement of this method to have prior estimates of the PSE being measured. As this technique required a range of testing levels that encapsulated the entire psychometric function, some idea of where the PSE lay was necessary in order to present the appropriate stimuli to the participant. This becomes a problem because unlike traditional applications of psychophysical tasks that examine sensory thresholds, a task in which participants are asked to judge the hunger reducing properties of a food will see a relatively large variation in responses between participants. To accommodate for this, either a separate stimuli set needs to be created for each participant, or one stimuli set needs to be wide enough to cover the whole psychometric function of all the participants (i.e. not merely their PSE). It is obvious that either of these two

alternatives represent a substantial increase in the amount of testing required, to the point where it becomes unfeasible to conduct this measure immediately prior to a compensation study as the novel measures were.

While it is possible for floor and ceiling effects to be present in the Hybrid procedure if insufficient stimuli have been created for the PEST procedure to select from, correcting this problem is much easier. Simply by adding more pictures to the pool of available stimuli, for subsequent participants, the procedure will automatically be able to utilise them if necessary. Unlike the method of constant stimuli, adding more stimuli to the hybrid procedure's pool will not increase the length of a test run.

#### **6.2.4.4 Maximum Likelihood analysis.**

Another benefit of the Hybrid procedure is its use of maximum likelihood analysis. This has been illustrated to offer the most efficient method of obtaining thresholds (Robbins and Munro, 1951). Hall's hybrid procedure in particular benefits from its ability to estimate both PSE and JND statistics from a dataset, something that other prominent packages such as Best PEST and QUEST cannot. A problem encountered by solely maximum likelihood-based procedures is that several consecutive incorrect answers can ruin a whole test run, as the likelihood calculations use the whole dataset to determine the next testing levels. Incorrect answers near the beginning of a test run will therefore skew the most-likely psychometric function, which in turn leads to a series of mundane comparisons for the participant, after which boredom can potentially become a problem. Hall's Hybrid procedure avoids this problem, as the ability of PEST to increase as well as decrease step size allows incorrect responses to be recovered from more quickly. As described previously, the Hybrid procedure's use of PEST has an additional benefit that the processing requirements following each response is dramatically reduced. The maximum likelihood analysis can be conducted after the experiment on whatever data has been produced by the PEST element of the study.

#### 6.2.4.5 Summary

Both of these experiments have produced PSE estimates that correlate with the PE estimates derived from the novel measures used in experiment four. The use of established psychophysical procedures, and the correlation between these and the results of experiments 3 and 4 helps to further reinforce these findings. Conversely, neither experiment was able to produce JND estimates that correlated convincingly with the previous PU estimates. This supports the argument suggested previously that the PU estimate may not have been effectively measuring a participant's uncertainty about food. Of the two measures, Hall's Hybrid procedure represents the most suitable technique for the present type of experiment. Unlike the method of constant stimuli, it does not require prior estimates of PSE values in order to produce valid results, as the testing level adapts to each participant accordingly. For a task such as judging portion sizes the between-participant variability can be relatively large, which makes this adaptability even more important. The method of constant stimuli's inability to deal with these variations without increasing the test length markedly can be observed by floor and ceiling effects on much of the data for experiment five.

The hybrid procedure used in experiment six has been shown to produce reasonably stable results over four test runs, with PSE estimates from each run correlating significantly with the PE estimates. Although the group variance associated with each PSE estimate decreased with each successive run, it was argued that this may actually represent deterioration in performance, as participants switch from considering their subjective expectations of the food to merely matching food volumes. This argument is supported by the gradual worsening of the association between PSE and PE as the variance decreases.

In short, while experiment five highlighted encountered several problems when adapting the method of constant stimuli, Hall's hybrid procedure in experiment six has proven much more successful. The results from these exploratory studies indicates that this may offer a useful alternative to the novel measures presented in experiments three and four, providing an efficient method of determining how filling a participant expects a food to be prior to its consumption.

**Chapter 7   Providing nutritional  
information about a preload can  
influence participants' eating  
behaviours in a dietary preloading  
experiment**

## **7.1 Experiment 7: Can attention influence dietary behaviour in unrestrained participants?**

### **7.1.1 Introduction**

The next experiment further investigated the relationship between the preload satiating expectancy and participants ability to compensate when the energy levels of the preload were covertly manipulated. Why this relationship exists is unclear, and there are several alternative hypotheses that may explain the observed results.

One variable not accounted for in experiments one to four was past experience of eating lunch at the time the test was provided, or even if they normally consumed lunch at all. The methodology for this present research are based partly on previous studies by Yeomans et al., (2001) and Gray et al., (2002 & 2003) who also did not include this variable. It is possible that this factor may have influenced participants' eating behaviours by influencing their attentional focus towards the preload's effects. Consuming a 500-ml preload may have different implications for a participant who regularly consumes large meals at lunchtime, compared with a participant who does not. The act of consuming the preload may influence some participants to focus their attention towards the visceral sensations created by it more than others. This theory was supported by Birch et al., (1986), who demonstrated that children could compensate well for a preload, but only when told to think about their feelings of hunger afterwards. Higgs (2002) observed that bringing the memory of eating to the forefront of a participant's mind can influence eating behaviours, and it could be argued that different normal lunchtime routines may make consuming this preload more memorable for some than for others. However, it cannot be predicted with any certainty which direction such an effect would act, as there are plausible arguments for both. Consuming an unusually large lunchtime meal may cause participant to think about their visceral feelings more than usual, thus potentially influencing their eating behaviours. Conversely, it may be participants who do normally eat large lunchtime meals that may be more likely to think about their visceral feelings. It could be argued that these individuals will have a more definite concept of how they should



feel following a first course of soup, and so will be more sensitive to changes in their visceral feedback brought about by the energy manipulation.

Another potential factor which may be relevant to an attentional focus/compensation theory, relates to the debate surrounding the differences in satiating efficiency of liquid and solid food (Bellisle & Rolland-Cachera, 2001). A lack of energetic compensation following energy containing liquids has been suggested as a possible contributor to the emergence of obesity in the developed world, and a review by Mattes (2006) has highlighted additional experimental evidence to support this claim (Dimeglio & mattes 2000, Raben et al., 2003), in addition to the epidemiological data which highlights a positive correlation between soft drink use and obesity on a larger scale (Ludwig et al., 2001; Popkin & Joy Nielson, 2003). The literature surrounding this issue uses largely biological theories and reasoning to explain these findings, and to incorporate into a psychologically-based theory into this debate would be somewhat novel. To recap, the present hypothesis proposes that a participant's expectation of the preload will influence dietary compensation by mediating the focus of attention towards their visceral sensations of hunger and fullness. How satiating the preload is expected to be may in turn be related to its physical form. This theory may be used to explain the poor compensatory effect of liquids as generally, despite often containing larger quantities of sugars, people do not expect sweetened drinks to have a large satiating effect. In the previous studies of this thesis, expecting the preload to have little satiating effect has led to poor compensatory ability at the subsequent test meal. It should, however, be noted that the finding that liquids evoke relatively smaller regulatory effects is not a unanimous one. Almiron-Roig, Flores & Drewnowski (2004) suggested that methodological differences may account for some of the previous findings. Specifically, the time interval between preload and test meal was identified as a contributing factor to the observed effects. Despite this, the weight of evidence suggesting that differences do exist between solids and liquids, along with its concordance with the predictions of theory presented in this thesis, indicates that the relationship between focus of attention, expectations and compensation warrants further investigation.

### **7.1.1.1 Summary**

Attentional focus has been proposed as an possible causal variable in the observed relationship between participants predictions about a preload and their sensitivity to covert manipulations of its energy content. It has been suggested in this thesis that consuming a food that is expected to be highly-satiating acts to focus attention towards visceral sensations to a greater degree as a greater change in appetite will be expected.

The objective of the following two studies was to test this theory and determine whether an effect of focus of attention can be observed. The first experiment in this chapter aimed to establish whether manipulating participants' focus of attention could produce observable differences in participants eating behaviours a preloading paradigm.

It was hypothesised that participants will eat significantly less, and experience significantly less sensations of hunger when they are prompted to think about their internal hunger state, relative to control conditions.

## **7.1.2 Methods**

### **7.1.2.1 Design**

A repeated measures design was employed, with participants visiting the laboratory on two occasions. Attentional cues were varied across the two conditions, and presentation of the cues was counterbalanced. The preload consumed by participants was kept constant across the different test conditions.

### **7.1.2.2 Participants**

14 male undergraduate students participated in the study, and were recruited via university noticeboard. Selection criteria were as described previously. Additionally, participants' liking of the test foods was assessed, and only participants who expressed liking for all of the test foods were included in the

study. Rated liking such as this indicated at least some familiarity with the foods used, as no participant responded having not tried the foods previously.

### **7.1.2.3 Materials**

#### **7.1.2.3.1 Texts**

The study required that participants read from a passage of text during each of two test sessions. The two texts were excerpts from a first year undergraduate textbook (Sherwood, 1997). The first text (referred to as ER text) described energy balance and the mechanisms involved in satiety, whereas the second text (referred to as VS text) described the human eye and its function. It was ensured that the second text contained no reference to food, eating or the digestive system, and enough of each chapter was copied to ensure that participants could read for 30 minutes without finishing the text.

#### **7.1.2.3.2 Foods**

The same foods were used as in previous studies, namely tomato soup and tomato and herb pasta. 500-ml of the tomato soup was served as a preload, although in this study, the energy content of the preload was kept constant across the two test days at 1514 kJ. This energy content equated to the high-energy variant of the preloads used in the previous experiments. The tomato and herb pasta was also prepared and served in an identical manner as before.

### **7.1.2.4 Ratings and measurements**

Hunger and fullness VAS were used to assess participants' appetitive motivations. These scales were identical to those used in the previous experiments of this thesis. A final questionnaire was also administered to participants at the end of the second test day. This questionnaire was designed to assess whether the experimental manipulation was effective in directing participants' attention during the experiment. The participants were asked the following questions:

*What do you think was the purpose of this experiment?*

*Which (if any) of the soups do you think reduced your hunger the most?*

*During both visits, you were given a passage of text to read. Do you remember thinking about your feelings of hunger or fullness whilst reading the text?*

*Do you think that the passage of text influenced how much you thought about your hunger or fullness?*

#### **7.1.2.5 Procedure**

Participants visited the lab on two separate days, separated by at least 48 hours. After a brief questionnaire to ensure each participant's adherence to requirements of the experiment, they were then taken to individual cubicles within the laboratory. The entire experiment was conducted in this cubicle. The cubicles contained a chair and a desk, and were lit solely by artificial lighting – the cubicles had no windows. Thus the environment could be kept as constant for each participant. Participants were asked to leave their bags/mobile phones/mp3 etc. players in the laboratory away from the cubicles, in order to remove any potentially distracting stimuli. In each of the cubicles were placed a pen, a stop clock, and an answer booklet containing the ratings to be completed at stages throughout the experiment. Participants were then given brief instructions about how to complete VAS ratings and the other questions, and were given the opportunity to ask questions if anything remained unclear.

Participants were then asked to complete the first set of VAS questionnaires. After completing all the questions in the first set, participants were then provided a thermos of soup preload and a mug. Participants were instructed to taste a small amount of the soup, and then complete the second set of VAS ratings in their answer booklet. This second set of ratings contained questions relating to the perceived palatability of the preload. After completing this second set of ratings, participants were then asked to drink the remainder of the soup contained in the thermos within ten minutes. A stop clock was provided for the participant's reference. At the end of this ten - minute period, participants were provided with one of the two passages of text to read. Each

participant read one passage in the first test session, and the second passage in the other, although the ordering of the passages was counterbalanced across participants. Twenty minutes was allotted to read through the text, although more was provided than was expected to be read in this time. At the end of this interval, a meal of pasta in tomato and herb sauce was served to the participant in the cubicle. Participants were asked to complete a VAS regarding to the palatability of the pasta after the first taste, but then were then left alone after being invited to '...eat as much or as little as you like, and feel free to ask for more'. In the same manner as for experiments 2, 3 and 4, the pasta was presented in a self-heating serving container, and more was provided than was expected to be eaten. If participants ate almost all of the pasta served initially, they were always offered more, regardless of whether they had asked. When participants finished eating, they completed a final set of VAS questions on the last page of their answer booklet. At the end of the second test session, participants also completed the final questionnaire, relating to their attentional focus during the two experiments, and the perceived objectives of the study.

#### **7.1.2.6 Data Analysis**

Repeated measures anova were used to compare the test meal intake across the two test conditions. Subjective appetite ratings were also compared using repeated measures anova, with time and condition as within-subject factors. Post hoc analyses of individual time points were conducted using repeated measures t-tests with a bonferroni correction.

### **7.1.3 Results**

#### **7.1.3.1 Intake**

Participants ate a mean of 483g (1608 kJ) of pasta in the ER text condition, compared with 506g (1684 kJ) in the VS text condition. A repeated measures anova did not reveal any significant differences between intakes in the two conditions ( $F=0.2$ ,  $1,13$   $p = 0.662$ ).

### 7.1.3.2 Hunger/Fullness VAS Ratings

When entered into a repeated measures anova, no significant differences were noted between test conditions for either absolute or difference scores of hunger ( $F_{1,13} = 2.484, p = 0.139$  and  $F_{1,13} = 0.186, p = 0.673$ ) or fullness ( $F_{1,13} = 1.845, p = 0.197$  and  $F_{1,13} = 1.857, p = 0.196$ ). Although insignificant, there was some indication of an interaction between fullness difference scores and time ( $F_{1,13} = 4.075, p = 0.065$ ).

A near significant main effect of text type was observed in desire to eat scores ( $F_{1,13} = 0.133, p = 0.072$ ), and a significant interaction was also noted between text type and timepoint ( $F_{1,13} = 6.384, p = 0.025$ ). While participants' absolute prospective consumption of sandwiches was shown to be significantly different following the two text passages ( $F_{1,13} = 5.314, p = 0.038$ ), examination of the difference scores for this measure failed to support this result ( $F_{1,13} = 0.06, p = 0.938$ ).

Post-hoc paired t-tests also failed to reveal any significant differences between the two conditions at any specific timepoint when corrected for multiple comparisons using a bonferroni adjustment.

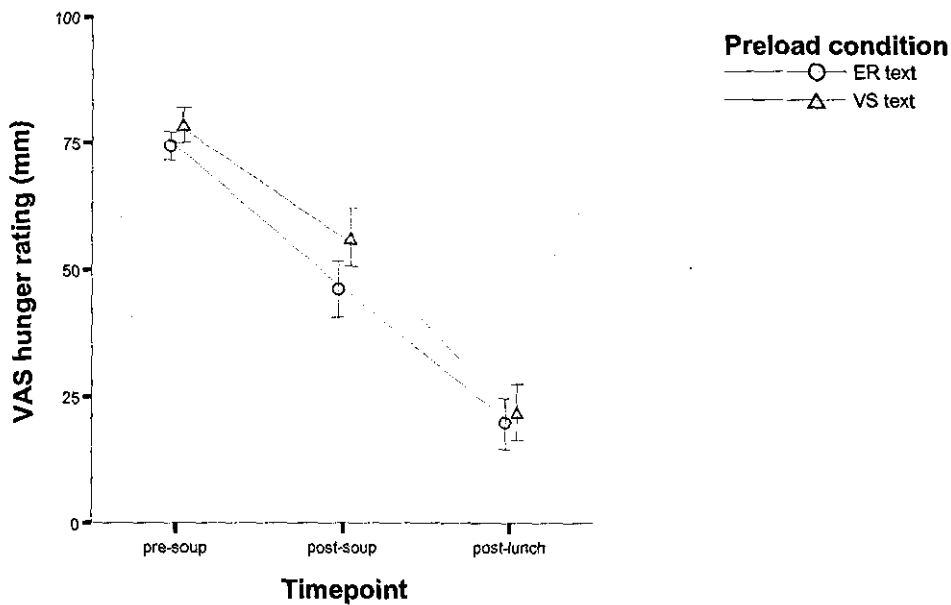


Figure 7.2. Mean subjective hunger ratings throughout each test session. Error bars represent standard error about the mean.

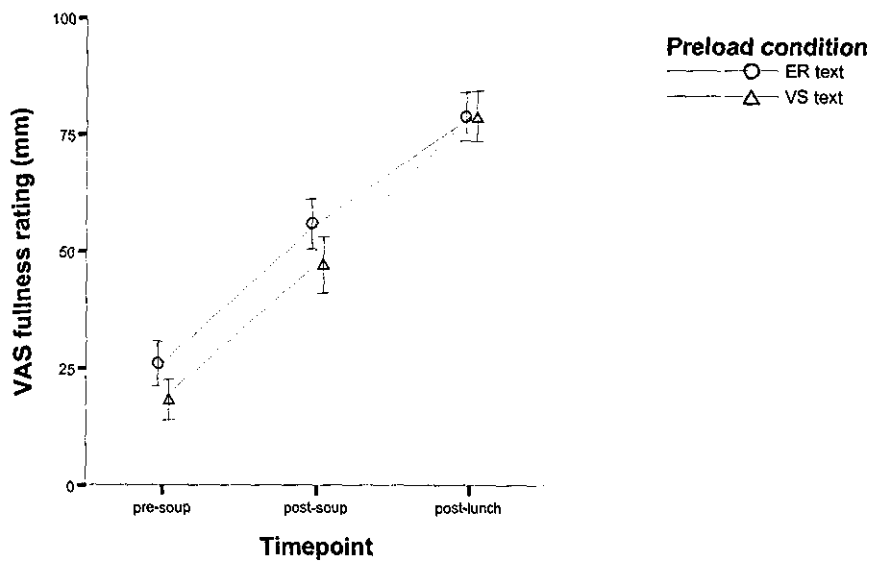


Figure 7.3. Mean subjective hunger ratings throughout each test session. Error bars represent standard error about the mean.

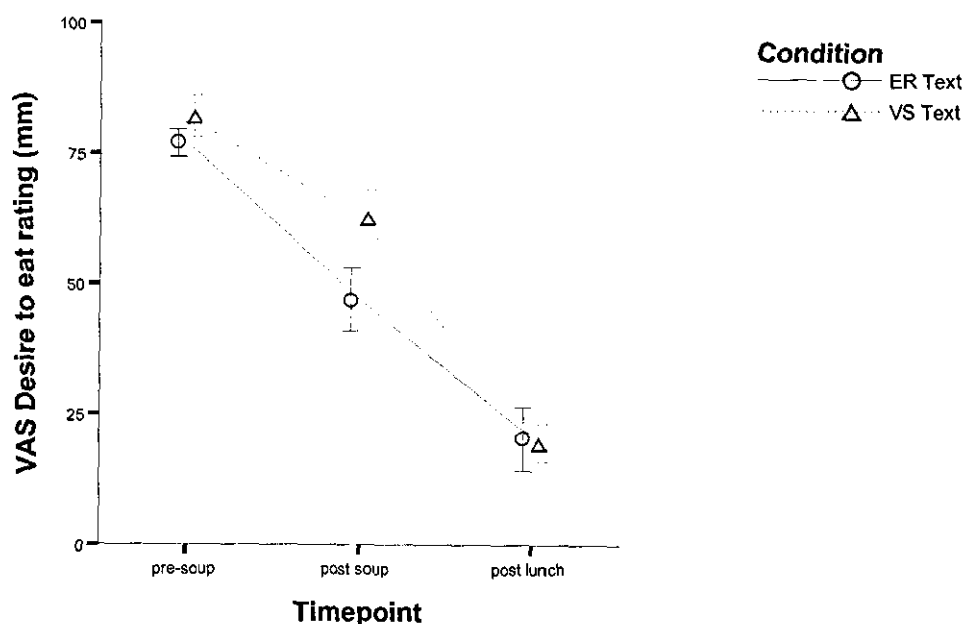


Figure 7.4. Mean subjective hunger ratings throughout each test session. Error bars represent standard error about the mean.

### 7.1.3.3 Awareness questionnaire

The soup preloads provided to the participants were identical on each day, and this is reflected by the absence of any significant differences in hedonic ratings of them

When asked during which session (if at all) participants thought about their own feelings of hunger and fullness during each test session 79% of participants reported thinking about their hunger and fullness during the eating regulation condition, with the visual system condition and not at all being reported by 24% and 7% of participants respectively. None of the participants reported thinking about their feelings during both test sessions, although this option was included on the questionnaire.

64% of participants believed that the information they read during the test session had influenced their appetite during the experiment.



**Table 7.1.** Mean hedonic ratings of soup preloads in both test conditions. ER refers to the eating regulation text condition, while VS refers to the visual system text condition. 'Sig' refers to the significance level when ratings are analysed via a repeated-measures anova with each category considered as a different within-participant factor.

Rating	VS condition	ER condition	Sig.
pleasantness	79.1 (10.2)	71.2 (11.2)	0.029
sweetness	61.7 (19.5)	64.5 (18.0)	0.292
saltiness	47.9 (19.1)	55.7 (17.3)	0.019
strength of taste	63.6 (21.7)	60.0 (18.9)	0.412
creamy	69.3 (9.9)	63.4 (16.8)	0.193

#### 7.1.4 Interim Discussion

Experiment seven failed to highlight an observable association between the attentional focus of the participants, and their sensitivity to covert manipulations of the energy content of a preload. The final questionnaire completed by participants in this experiment suggests that the different texts provided for the participants to read were at least somewhat successful in focussing their attention during the experiment. At face value this result suggests that participants' attention to the preload is not an important variable in a preload experiment. However, whether reading material is an appropriate tool with which to manipulate attention is unclear. In hindsight, several limitations exist when using this type of manipulation. Firstly, assessing exactly how much attention participants paid to the text itself was difficult to monitor. Although participants were asked not take any potentially distracting things (e.g. mobile phones, personal music players etc.) into the laboratory, this did not guarantee that participants spent the allotted time reading, and paying attention to, the text provided to them. As the participants were asked to read the texts, rather than choosing to read it themselves, questions can also be raised regarding participants' receptiveness to the information they read, and whether the text was successful in concentrating participants' attention towards their visceral sensations during the experiment.

As such, this experiment cannot support the theory that focussing attention towards a preload will influence a participants regulatory responses to it. However, due to the limitations stated above, this experiment also could not confirm the null hypothesis that attentional focus is not important in this type of experimental situation. Unsurprisingly, this method of manipulating participants' attention was deemed unsuitable for use in a larger preloading study which incorporated the psychometric assessment developed in experiments five and six.

In order to develop a paradigm more suited to the preloading experiments of this thesis, the literature examined previously regarding this topic was revisited.

The most obvious manner by which to try to manipulate beliefs appeared to be via some adaptation of the nutritional labelling technique as used in previous studies examining this issue. As discussed previously, studies such those by Yeomans et al., (2001) and Shide and Rolls (1995) attempted to manipulate participant beliefs about food by varying information provided about the food, in order to make participants think the foods varied in energy content. This type of methodology had at least some indication of previous success (unlike the novel measures devised for experiments 3 and 4), and so it was deemed that an adaptation of this type of methodology, rather than a completely novel experiment would be most appropriate.

Therefore, in order to devise an experiment based around the methods employed in nutritional labelling studies, the specific methodological reasons why this technique is proposed to be imperfect need to be identified.

The main issue in contention was the manner in which belief change was assessed. This issue would hopefully be resolved by utilising the psychometric tests developed the preceding two experiments. In order to judge the effectiveness of any belief manipulation, a 'before' and 'after' measurement of participants' beliefs needed to be taken. It is assumed that this approach has not been used previously because simply asking participants how filling they thought a preload was before and after reading nutritional information about it would not be suitable. It would be difficult to determine whether participants actually believed the content of the soup to be any different, or whether they were just responding with what they perceived to be appropriate given the information content. The abstract nature of the psychometric test allowed both these measurements to be taken, as it is less clear why participants

are comparing these two foods – they are not being directly asked how they think this food will affect their hunger, rather they are being asked how one food relates to another.

In experiments where fictional information is provided about a food, it is important that the information provided about the food is believable. This may depend on the manner in which the information is presented, or the content of the information itself. Yeomans et al., (2001) utilised fictional brand names to convince participants that identical soup preloads varied in energy content. Although from the report it is difficult to determine how effective this was, It was suggested that presenting the same soup four times to each participant, while claiming it to be four completely different products may not be ideal. Here, the use of fictional names used may have further increased the chances that participants would not believe the information provided. It is proposed that if this type of fictional information can somehow be incorporated into a more 'real' context, it may help persuade participants that the information is real. For example, if fictional brand names are used for the soup preload, can they be introduced along side other real products? If the real products are not well-known brands, the fictional branding of the preload may not appear out of place, and so may be more easily accepted by the participant.

Experiments 2 and 3 utilised novel measures to assess each participant's perception of the preload *before* the preloading studies took place. One concern following these experiments related to the possibility that performing such tasks before the preloading study may have influenced participants behaviour during it. As the preload perception measure presented actual food portions to participants, it was suggested that the cephalic phase responses evoked during this part of the experiment may interfere with participants' appetite during the preloading stage of the study. As the psychometric task involves comparing images of food portions, rather than actual food portions, the potential confounding influence of cephalic phase responses may be lessened.

The next experiment aimed to combine the psychometric analysis of participants' expectations about the preload with the preloading paradigm developed in the initial experiments of this thesis. In response to the unsatisfactory result obtained from the previous experiment, the attention manipulation used an adaptation of a nutritional labelling paradigm. This type of method has been used in the past in several studies

(e.g. Shide and Rolls 1995, Miller et al., 1998). By providing misleading information about the nature of the preload it was hoped that participants' expectations of the preload could be altered, as it is by this mechanism that the proposed model predicts attentional focus to be influenced within the participant group. As discussed, in order to overcome some of the inherent limitations associated with this type of experiment several specific factors will be incorporated into this methods used. Of these factors, the most fundamental will be the utilisation of the psychometric procedure developed in experiments five and six, which will hopefully allow the uncertainty surrounding the assessment of participant's beliefs to be avoided.

The hypothesis to be tested in this experiment was as follows:

It is hypothesised that the provision of fictional information relating to a preload will significantly increase participants' expectations of the preload's satiating effects. In line with the previous observations of this thesis, it is also hypothesised that participants' sensitivity to preloads of different energy contents will demonstrate a significant positive association to their expectations of the satiating ability of the preload. Therefore, It is hypothesised that participants' sensitivity to energy changes in a soup preload can be significantly increased by altering their expectations of its ability to reduce their hunger.

## **7.2 Experiment 8: Information provided with a preload can influence a participant's expectancies of it: Revisiting 'nutritional label' - type experimental designs**

### **7.2.1 Methods**

#### **7.2.1.1 Participants**

Thirty-two male university students participated in the study. Participants were recruited via university notice boards and email news letters. Potential volunteers

were screened for high levels of dietary restraint ( $>2.0$  on the restraint scale of the DEBQ), as well as taste aversions to the types of foods used in the study.

#### **7.2.1.2 Design**

A mixed design was employed for the study. Preload energy density was varied as a within-participant factor, while the provision of information about the preload took the form of a between-participant factor.

#### **7.2.1.3 Materials**

The same test foods were used as in the study, with a soup preload served in two energy variants, and a test meal of pasta in tomato and herb sauce, served in a self heating container.

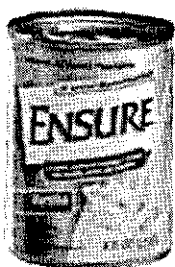
Half of the participants were provided with fictitious information about the preload that was intended to alter participants' perceptions of the satiating ability of the preload. The information claimed that the preload was a novel nutritional supplement drink currently being developed in the laboratory, and as such was intended to be particularly energy dense and satiating. Images of, and information about other products in this market were also included to both enhance the realism of the information and to help ensure that participants understood the claims being made in the information. This information was provided as full-colour, laminated A4 sheets that were provided to the participants. A reproduction of the information sheet is displayed in figure 7.5 overleaf.

Thank you for taking part in these trials

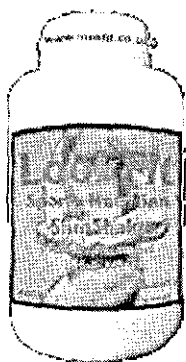
*You will shortly be asked to consume a soup which is currently under development at Loughborough University. This soup has been designed for use as a nutritionally-balanced, meal replacement product for healthy individuals, and also as a nutritional supplement to individuals suffering from involuntary weight loss.*

*As such, this soup provides a concentrated source of calories (the equivalent of an averaged-sized meal), and has been formulated to maximise its hunger-reducing properties while still having the appearance of a light, easy to drink beverage.*

This product offers a novel approach to the already competitive nutritional supplement market. Extracts from the websites of other products available in this field are illustrated below:



'Ensure® provides complete, balanced nutrition for supplemental use between or with meals. For people on modified diets, at nutrition risk or for those with involuntary weight loss. Gluten free and lactose free. Choose vanilla, chocolate, butter pecan, coffee, or eggnog. 250 calories/200g can.'



'Designed for the modern lifestyle, SlimShake with its rich and creamy formula, is high in proteins and added oat fibre, and is enriched with the essential vitamins and minerals your body needs to sustain it through the day.'

When you are asked to drink the soup, we would like you to concentrate on its taste and how it makes you feel, in terms of your feelings of hunger and fullness. Later on the trial, we will ask you about these feelings

#### **7.2.1.4 Measures**

Several measures were employed during this study. As in the previous studies of this thesis, the quantity eaten at the test meal was covertly recorded by weighing the amount of pasta before and after the meal. Subjective measures of hunger, fullness, desire to eat and prospective consumption were also taken at baseline, ten minutes after preload consumption, and at the termination of eating at the test meal stage of the experiment. Although this represented fewer time points than employed in the earlier experiments of this thesis, this number of measures was decided upon primarily to maintain consistency with experiment 7. As discussed prior to experiment seven, it was felt that altering the number of times participants were asked about their appetite during the experiment could potentially influence their focus of attention.

The same psychometric test was employed that has previously been introduced in experiment six, using the same equipment and image stimuli. From each run of the psychometric test, an estimate for both PSE and JND was calculated.

Prior to each test meal, participants were also asked the extent to which they agreed with the following comments:

- The soup has completely satisfied my hunger
- I don't think that the soup reduced my hunger at all
- I am surprised at how hungry I feel at this point in the experiment.

Answers to each statement were given via visual analogue scales, anchored at either end with completely disagree / completely agree.

#### **7.2.1.5 Procedure**

Participants visited the laboratory on two, non-adjacent week days spaced a week or less apart. The procedure on each test day was identical, except that on one day, a high-energy preload was used, and a low-energy preload on the other. The ordering of these two conditions was counterbalanced across participants. The energy contents and ingredients used for the soups were as outlined in the previous experiments of this thesis.

Upon arriving at the laboratory, participants were shown to an experimental cubicle in the laboratory, where the experiment was conducted. Following initial baseline subjective ratings, and a taste test of the preload assessing the sensory properties of the soup, an initial assessment of each participants' perception of the soup preload was then conducted. This was performed by asking participants to taste a sample of the soup, and then complete a test run on the psychometric task. The next stage of the experiment varied depending on the experimental group. The 'no information' group were asked to sit quietly for 5 minutes, before being asked to complete a further test run of the psychometric measure. During this five minutes, the 'information' group were asked to read the passage of text relating to the nature of the preload. At the end of this period, this group were also asked to complete a second run of the psychometric task, now that they had been informed of the nature of the soup they were drinking.

Following these measures, participants were then asked to drink the entire contents of the flask placed in front of them. Participants were informed that this soup was identical to the soup they had tasted previously. A ten-minute time limit was given for the consumption of the preload, and participants were asked to try to spread the consumption of the soup across this period as well as they could. Participants were told that extra time would be allowed to consume the soup if necessary, although no participants were unable to finish the soup in this time. At the end of this ten-minute period, a further set of subjective ratings were completed. Participants were then invited to read a daily newspaper during a twenty-minute interval before the meal was served. No control was made over exactly which articles were read, although the newspaper had been previously screened, removing any articles relating to food or eating. At the end of this twenty-minute period, the participants were provided with a meal of tomato and herb pasta, in the same manner as for the preceding experiments. Following this meal, participants completed one further set of subjective ratings.



#### **7.2.1.6 Awareness questionnaire.**

At the end of the second test session, participants were also asked to complete a final questionnaire which enquired about the perceived purpose of the study, and to confirm that participants were unable to reliably identify the two soups.

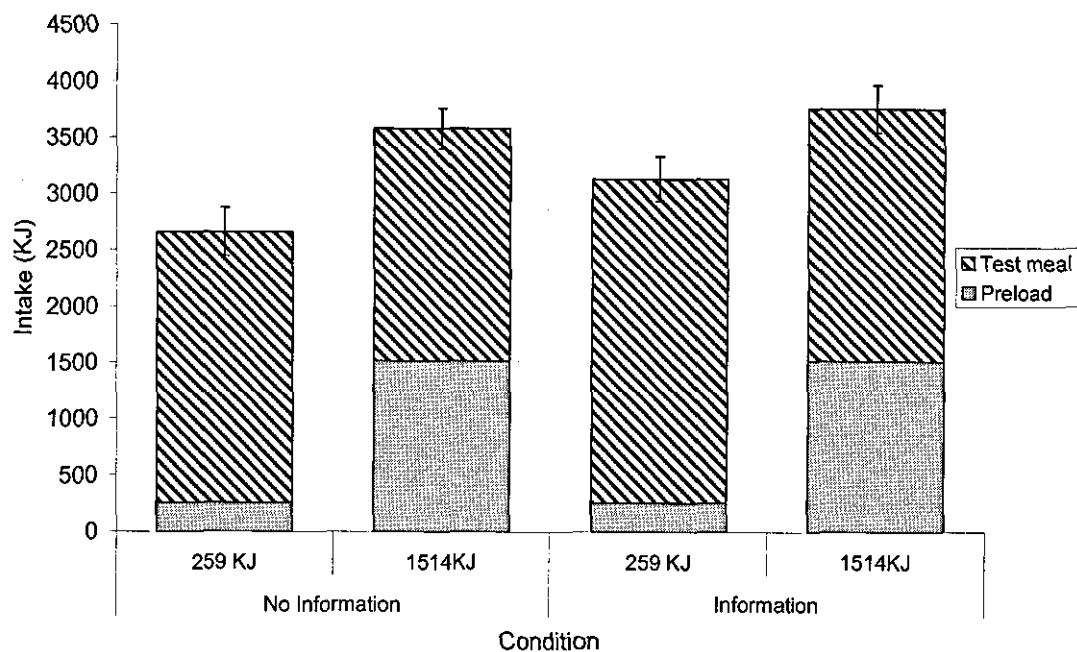
#### **7.2.1.7 Data analysis**

Intake at the pasta test meal and subjective ratings were compared using mixed model ANOVAs, with time and energy density considered within-participant factors, and information condition as a between-participant variable. PSE scores across the group were compared using repeated measures t-tests and ANOVA. Post hoc analyses of subjective ratings at individual time points were conducted using repeated measures t-tests with a bonferroni correction. Associations between PSE scores, compensation and ratings were made using Pearson's product moment correlation coefficient.

### **7.2.2 Results**

#### **7.2.2.1 Intake**

Intake at the test meal was significantly lower following the high-energy preload than the low-energy equivalent (2149KJ vs 2636KJ,  $F_{30,1}=26.189$   $p<0.001$ ). Figures 5.4 and 5.5 illustrate these observations. Total lunch intake was observed to be significantly higher following the high-energy preload ( $F_{30,1} = 65.229$   $p < 0.001$ ). There was no evidence of an interaction between the preload condition and information group upon total lunch intakes ( $F_{30,1} = 2.422$   $p = 0.130$ ).



**Figure 7.6** Total energy intake by experimental condition. Error bars represent standard error about the mean.

**Table 7.1** Mean intake levels for each test condition, brackets denote standard deviations.

	No Information = 16		Information = 16	
	259 KJ	1514KJ	259 KJ	1514KJ
<b>Preload</b>	<b>259 (0)</b>	<b>1514 (0)</b>	<b>259 (0)</b>	<b>1514 (0)</b>
<b>Test meal</b>	<b>2402 (1212)</b>	<b>2064 (1018)</b>	<b>2874 (1125)</b>	<b>2240 (1182)</b>
<b>Total lunch</b>	<b>2661 (1212)</b>	<b>3578 (1018)</b>	<b>3133 (1125)</b>	<b>3754 (1182)</b>

### 7.2.2.2 Dietary compensation

Participants averaged a compensation index score of 0.39, which indicates that on average when participants consumed the high-energy preload, their test meal intake was reduced by 39% of the extra energy contained in the preload.

7.2.2.3 Subjective and prospective measures of appetite.

Subjective ratings of hunger, fullness, desire to eat and prospective consumption are illustrated in figures 7.7 – 7.10. Repeated measures anova revealed several differences in participant responses across the different conditions. VAS ratings of hunger ( $F_{30,1} = 13.115$   $p = 0.001$ ), desire to eat ( $F_{30,1} = 8.178$   $p = 0.008$ ) and prospective consumption ( $F_{30,1} = 9.177$   $p = 0.005$ ) all displayed a significant interactive effect between preload energy density and the provision of information. A main effect of preload energy density narrowly missed significance for hunger and desire to eat measures ( $F_{30,1} = 3.405$   $p = 0.075$  and  $F_{30,1} = 3.995$   $p = 0.055$ , respectively), while rated fullness was observed to vary significantly across the two energy density conditions ( $F_{30,1} = 6.687$   $p = 0.015$ ).

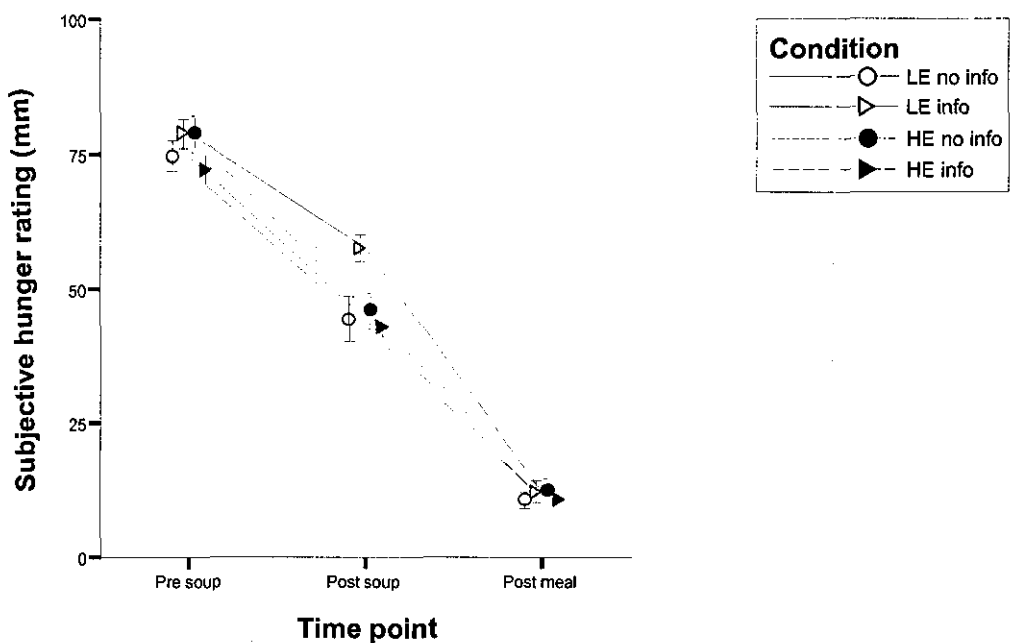


Figure 7.7 Subjective hunger throughout the four test conditions. Error bars represent standard error about the mean.

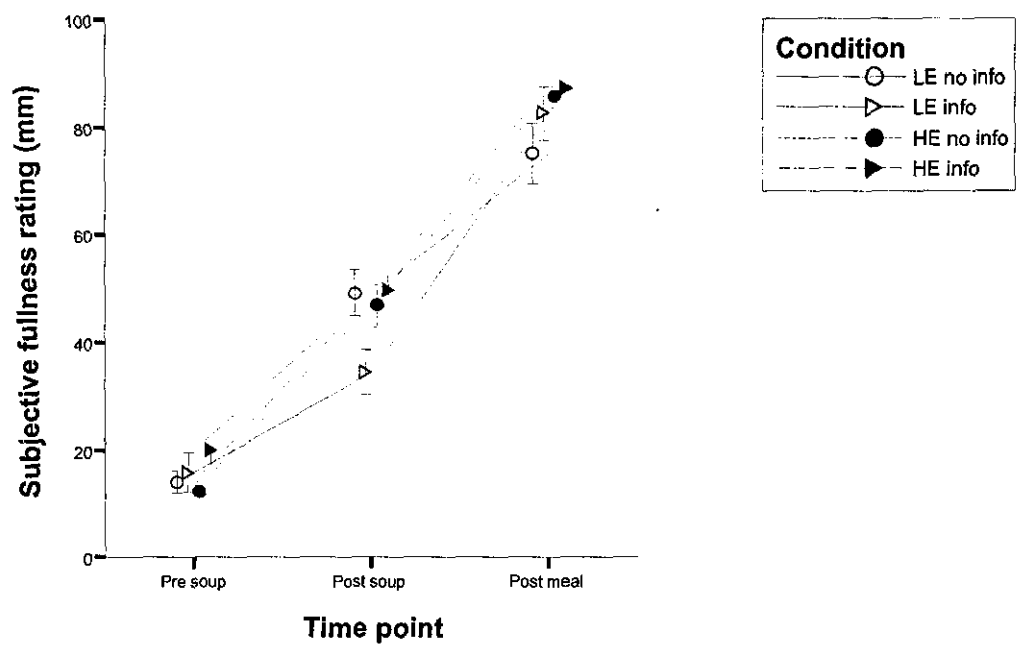


Figure 7.8 Subjective fullness throughout the four test conditions. Error bars represent standard error about the mean.

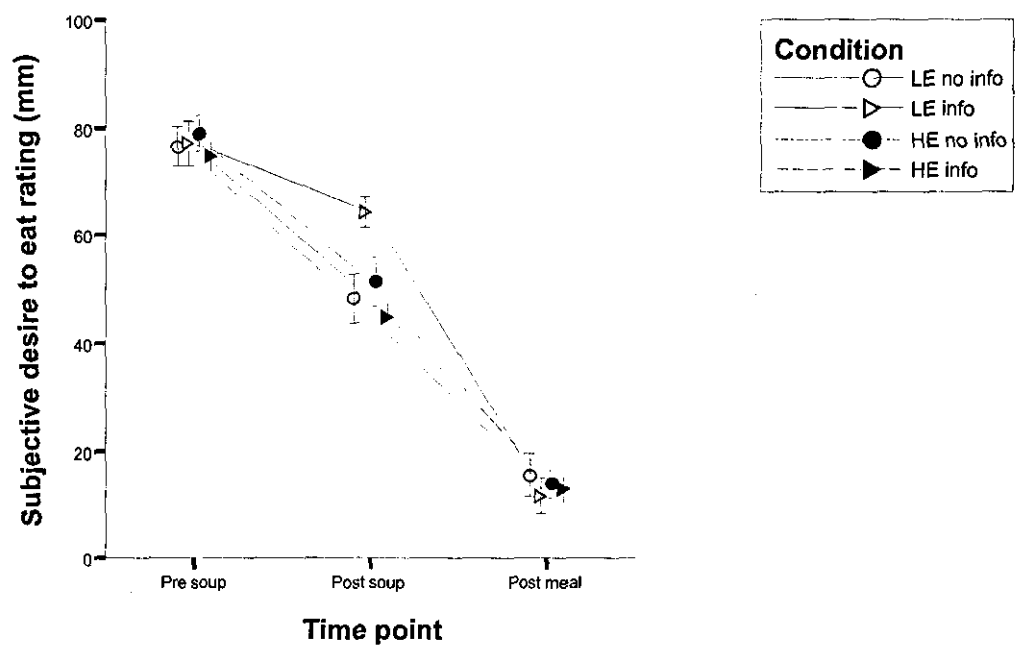


Figure 7.9 Subjective Desire to eat throughout the four test conditions. Error bars represent standard error about the mean.

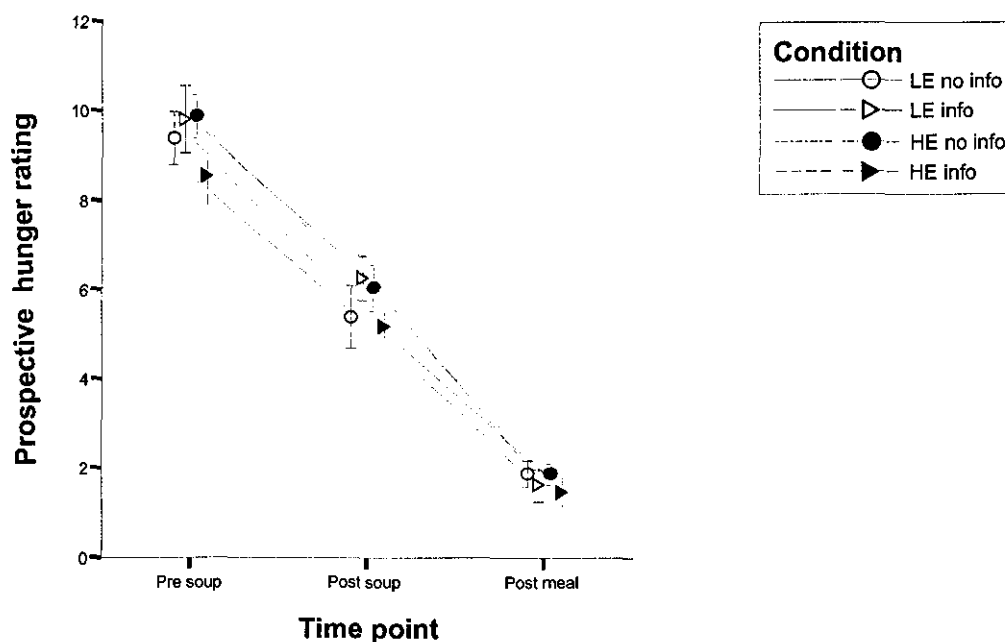


Figure 7.10 Prospective hunger throughout the four test conditions. Error bars represent standard error about the mean.

When the subjective and prospective ratings were considered relative to each participant's respective baseline value, fewer systematic differences were observed, with near-significant effects of preload energy density on fullness ( $F_{30,1} = 3.486$   $p = 0.072$ ) and desire to eat ( $F_{30,1} = 3.096$   $p = 0.089$ ) scores being the only notable results. The subjective measures represented as difference scores are illustrated in figures 7.10, 7.11, 7.12 and 7.13.

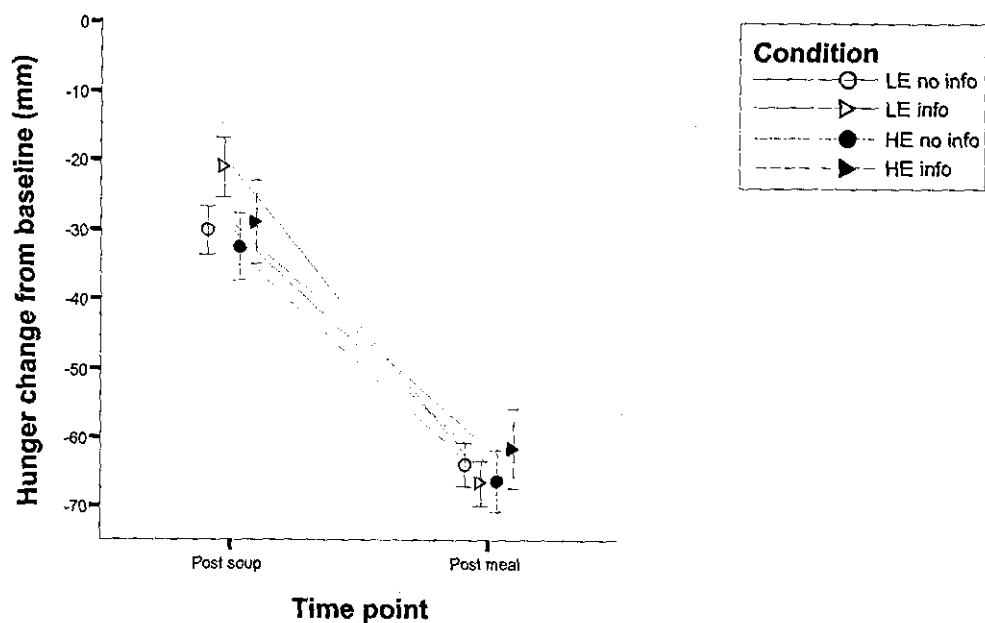


Figure 7.11 Change in subjective hunger from baseline throughout the four test conditions. Error bars represent standard error about the mean.

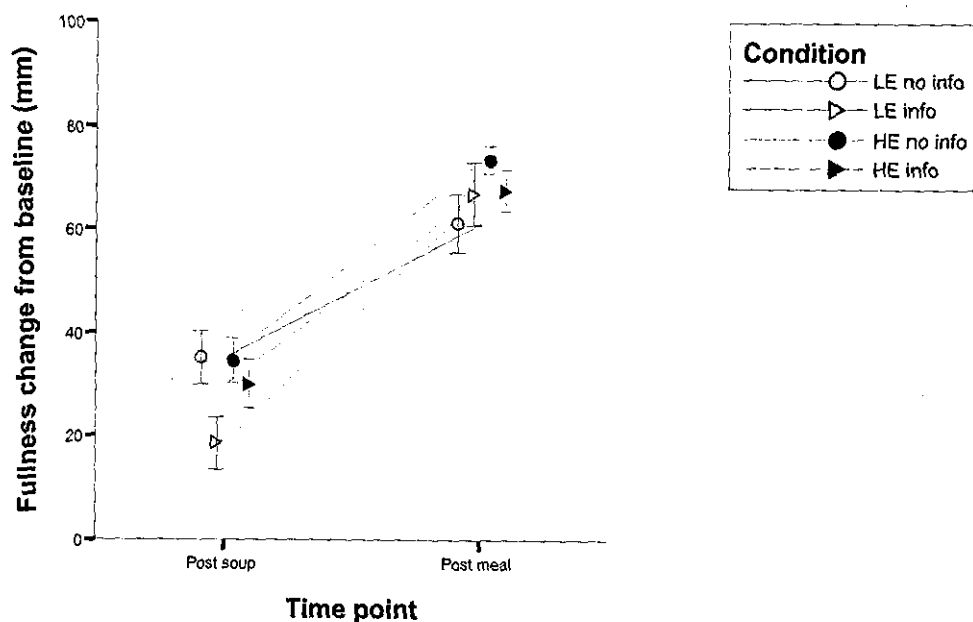
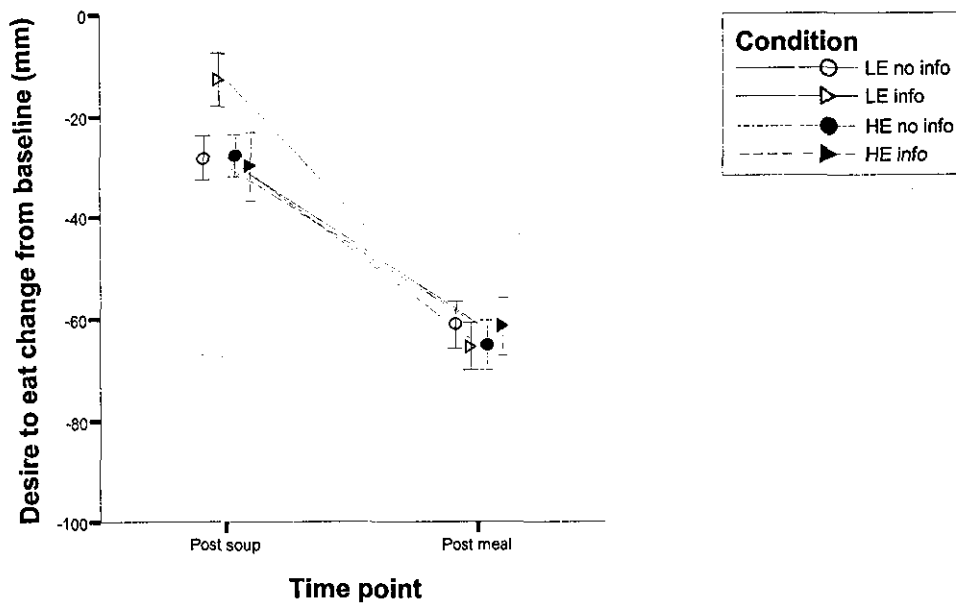
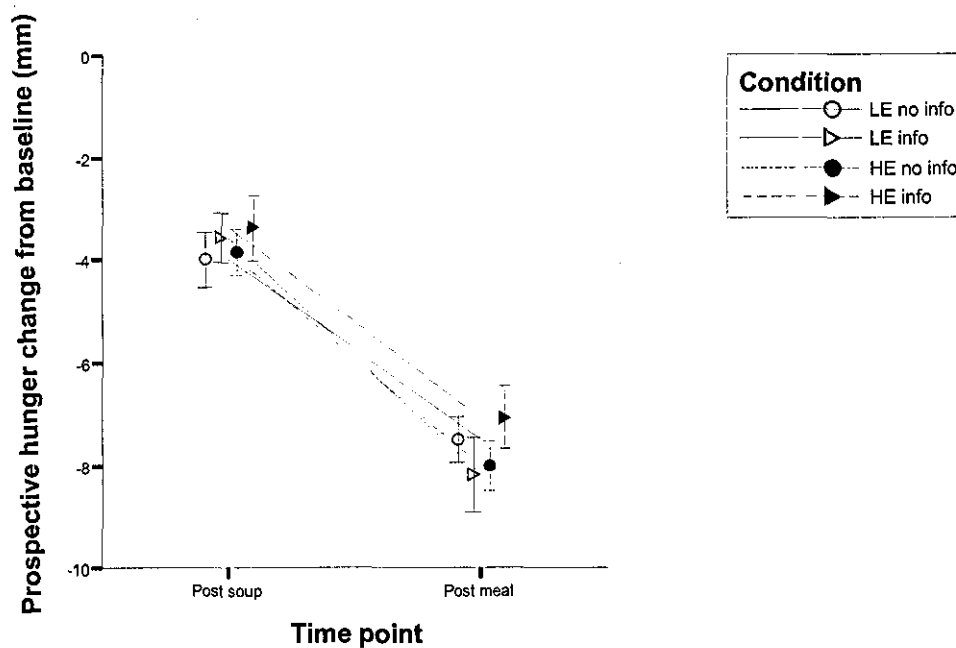


Figure 7.12 Change in subjective fullness from baseline throughout the four test conditions. Error bars represent standard error about the mean.



**Figure 7.13** Change in subjective desire to eat from baseline throughout the four test conditions. Error bars represent standard error about the mean.

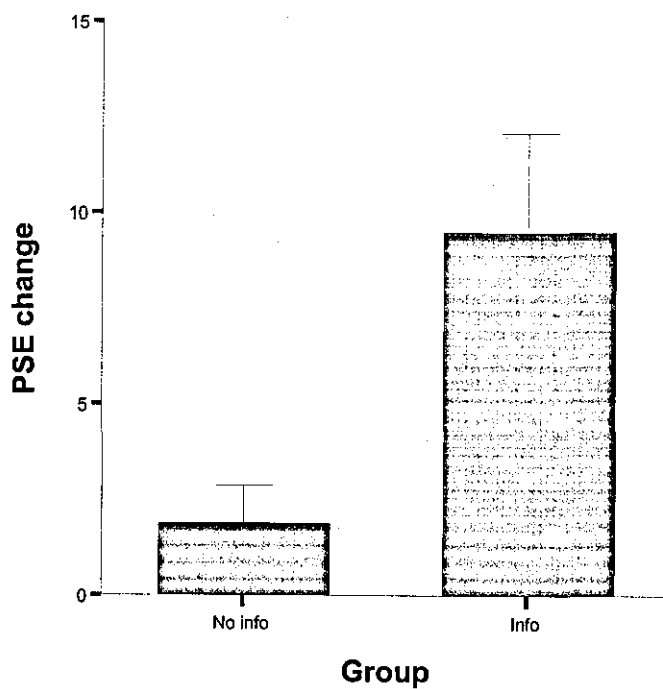


**Figure 7.14** Change in prospective hunger from baseline throughout the four test conditions. Error bars represent standard error about the mean.

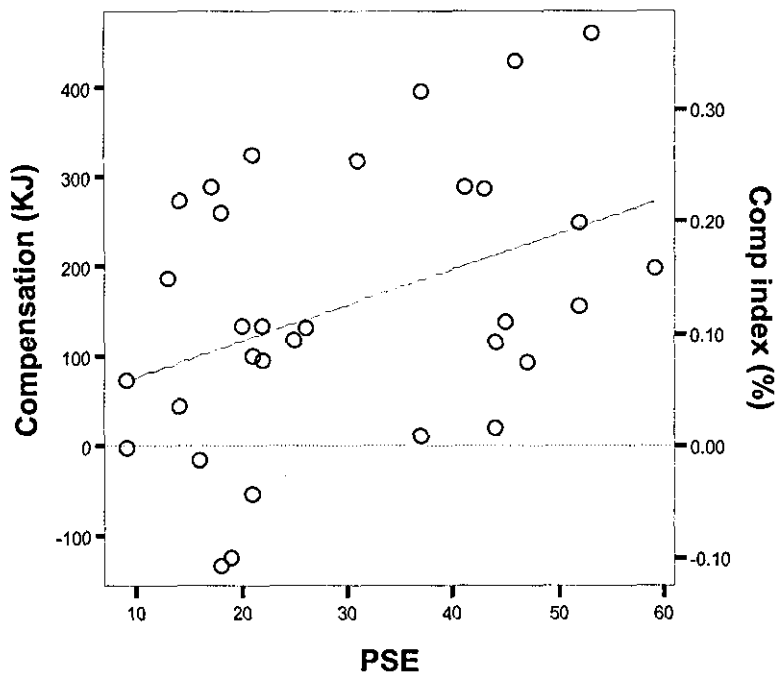
#### **7.2.2.4 Psychometric measurements and compensation**

Despite a whole - group finding of greater PSE scores after the information manipulation ( $df = 31$ ,  $t = -3.679$ ,  $p = 0.001$ ), this result is not supported when the data is divided into information and no information groups. Group mean PSE scores are not higher in the information group ( $F(31,1) = .435$   $p = 0.331$ ). This result may be skewed by a few participants in the information group who saw no increase in their PSE scores (and so presumably didn't believe the information presented to them). This can be illustrated by the association between belief change before and after the information stage of the study, and energy compensation ( $n = 32$ ,  $r = 0.437$ ,  $p = 0.012$ ). Figure 7.15 illustrates the differences in belief change between the two groups. A significant correlation was also observed between the second PSE score across the whole group and compensation ( $n = 32$   $r = 0.393$ ,  $p = 0.026$ ), which displays the relationship already observed in previous experiments of this thesis. This is illustrated in figure 7.16.





**Figure 7.15** Mean belief change in the information and no information test groups. Error bars represent the standard error about the mean



**Figure 7.16** Scatter plot illustrating the significant association between compensation and PSE scores after the provision of information to half of the participants.

Little correlation between the JND and compensation ( $df\ 31$ ,  $r=0.206$ ,  $p=0.258$ ), despite significant correlations between PSE and JND before ( $df\ 31$ ,  $r=0.594$ ,  $p<0.001$ ) and almost significant after ( $df\ 31$ ,  $r=.319$ ,  $p = 0.075$ ).

#### 7.2.2.5 Final Questionnaires

Participants were asked to rate (on a 100 mm VAS) how surprised they were at their hunger state after consuming each soup preload. Compensation was observed to be positively associated with surprise VAS ratings in the low-energy condition ( $r = 0.328$   $p=0.067$ ) and negatively associated in the high-energy condition ( $r = -0.402$   $p=0.022$ ). Greater compensation was also noted in participants who agreed with the statement that low energy preload had not filled them up at all ( $r = 0.529$   $p = 0.002$ ). This relationship was not noted when the same question was posed regarding the high-energy preload ( $r = 0.142$   $p = 0.440$ ). Agreement with the statement that participants

remembered either soup being particularly filling was not observed to be strongly correlated with observed compensatory ability ( $r = 0.076$   $p = 0.678$  LE;  $r = -0.206$   $p = 0.257$  HE). These correlations suggest that higher levels of compensation were observed when participants noticed high residual levels of hunger following the consumption of the low energy preload. Conversely, this relationship isn't observed when participants remember the high energy preload being effective at reducing their hunger. These two results both support the theory that an unexpected deficit in preload energy, rather than an unexpected surplus, will be more effective in producing compensation in response to a covertly manipulated preload.

### 7.2.3 Discussion

These two experiments aimed to revisit the experimental design employed in previous studies, to shed further light on the question of whether information about a food will influence an individual's short term ability to compensate for the energy contained in it. Experiment 7 aimed to establish a basic effect as seen in some previous studies, where information provided about a food was seen to influence eating behaviours. This experiment aimed to test the proposed model, based upon de Castro's general intake regulation model (2002), in which focussing attention towards visceral feelings during the preload consumption will mediate participants' ability to compensate. If attention to visceral sensations following food consumption can mediate eating regulation, it could be argued that any stimuli that causes participants to think about their internal hunger state should affect eating behaviours. Previous studies that have found appetite to be influenced by information provided about the test foods (e.g. Shide and Rolls 1995; Wooley, Wooley and Dunham 1973), test foods were labelled with nutritional information, and the model proposed here suggests that participants who expected a more challenging energy load would be more 'primed' to attend to their visceral sensations following the preload consumption. However, as has been mentioned before, there are still uncertainties associated with the use of labelling in this way, and so it is difficult to determine exactly what is creating the observed effect. In this study, a different methodology was employed that would direct participants' focus of attention towards their visceral state without the use of nutritional labelling. By asking participants to read a passage of text relating to eating

and digestion immediately after consuming the preload, it was hoped that the participants' attention could be focussed on to their appetitive state. If it is participants' focus of attention that is creating the association between compensation and PSE, one would expect that this method should create similar effects as in such previous studies as conducted by Shide and Rolls (1995). A specific questionnaire at the end of the study was also used to help determine the effectiveness of the information manipulation, by asking participants to recall what they were thinking about during the experiment.

This experiment was unable to display an association between the type of information given to participants and their eating behaviours at the test meal, or the subjective ratings they provided throughout the experiment. This finding cannot therefore support the theory that the focus of attention is mediating the relationship between PSE ratings and compensation at the test meal. However, it is possible that the effect was not apparent due to the ineffectiveness of the information manipulation. The final awareness questionnaire did suggest that reading the different text was successful in manipulating the extent to which participants considered their visceral feelings. Unfortunately, while this may give us some indication of the effectiveness of the manipulation, it cannot be relied upon as the sole proof that participants were thinking in a certain manner. These issues were carried forward when designing the next experiment

Experiment 8 aimed to assess whether a deliberate manipulation of participants' beliefs about a soup preload could influence their sensitivity to the energy content of the soup. By providing half the participants with information implying that the soup had a particularly high satiating value prior to its consumption, the effect of this information could be assessed. While this technique is similar to many previous studies using nutritional labels, by incorporating the psychophysical measure devised in experiments five and six, before and after measure of participants' perceptions towards the foods can be assessed. This allowed examination of the association between compensatory ability and preload related beliefs, and more importantly, it highlighted the actual effects of the information manipulation.

As has been observed throughout this series of experiments, intake at the test meal was significantly reduced following the high-energy preload. When the intake data

was compared against the data produced by the psychophysical measure, PSE estimates from the second test run were found to be significantly associated with compensation. It is possible that the lack of association between PSE and compensation following the first psychophysical run could be an anomalous result, with participants not fully accustomed to the procedure. However, this reasoning is not supported by experiment six, which found the first of four psychophysical runs to be the most representative of the measures which involved physically pouring portions of food.

One result that is contrary to the proposal that the information provided was responsible for the increased compensation observed at the test meal is that the PSE scores for the information group were not significantly higher than for the no-information group. Obviously if the provision of information was responsible for an increase in compensatory ability via a change in participant beliefs about the preload, one would expect higher PSE scores in the information group. The lack of such a result can have more than one implication. Firstly, it could indicate that the change in PSE scores are not responsible for improving compensation, or that the information provided was not effective in altering participant beliefs. However, upon further analysis of the data, another potential explanation became apparent. It is clear in the information group that a few participants did not exhibit a large change in PSE estimates before and after the provision of the information. This suggests that these participants either did not believe the information provided to them, or that they did not complete one or more aspects of the experiment properly. These participants also compensated relatively worse than the average for the information group. Therefore, these participants may have been artificially skewing the PSE mean downwards. The pattern of higher PSE scores equalling better compensation still fitted the data produced by these participants, but their relative insensitivity to the information made their responding more akin to the participants in the no-information group. Also, by examining each participant's belief change (second PSE – first PSE) this argument can be supported, as this was found to be positively associated with compensation at the test meal.

The data obtained from the subjective measures taken at points throughout the experiment also reveal an interesting pattern, which can also support the finding that

participants were reacting to information about the preload. If figures 7.7, 7.8, and 7.9 are considered, the three subjective measures can be observed at the three different time points (baseline, ten minutes after soup consumption, and at the termination of eating at the test meal). While baseline and post-meal ratings highlight no discernable difference between the four test conditions, the post-preload rating does exhibit some disparity. For each of the subjective ratings, participants who received the information about the preload reported a higher residual hunger and less residual fullness after consuming the low energy preload. This is reflected by the significant interactions reported between information and preload energy reported earlier.

These results in particular support the theory that the increase observed in compensation is observed in the participants who experienced an unexpected deficit in energy following the low-energy preload. Rated hunger, desire to eat and prospective consumption all displayed a significantly smaller reduction in the information condition following the low-energy preload, relative to the no information conditions or following the high-energy preload conditions. This highlights that by informing a participant that a food is particularly filling, their subjective sensitivity to the energy content of the food can be influenced. Furthermore, as it is only the ratings in the information/low-energy condition that have stood out from the other conditions, this implies that it is an unexpected deficit that has caused participants in this condition to report smaller reductions in hunger.

Further indication that participants were utilising information about the preload was observed when eating behaviours were compared along side participants' responses in the final questionnaire. Reported surprise at the satiating ability of the preload was observed to be significantly associated to participants' compensation across the two test sessions, following both the low- and high-energy preload conditions. It could be argued that remembering feeling surprised at the effects of a preload indicates that the participant were aware of their visceral feelings at this time. Feeling surprise at the effects of the preload also implies that participants had a pre-existing expectation of how the preload would make them feel. As recognition of a discrepancy between this expectation and the actual energy content of the preload was associated with an increased ability to compensate for the disguised preloads, it could be argued that this

supports the theory that the focus of attention is mediating participants' compensatory ability.

Within this study, there are several results that suggest that the results obtained are valid. The intake measure displayed a reduction in intake of 605 KJ which equated to 48.5 % of the extra energy contained in the preload. This is comparable with the results of experiments 1-4 of this thesis. Although it cannot be proven, examining the relationships between the different measures used in the final questionnaire can shed some light on the effectiveness of the questions asked here. As would be expected, a strong negative correlation existed between the responses to the statements 'the soup did not fill me up at all' and 'the soup completely satisfies my hunger'. This implies that for these two questions, participants were responding consistently. When participants were asked to give their opinion about the purpose of the study, of the sixteen participants given information about the preload, 87.5% thought the experiment was intended to test the effects of nutritional drinks. Conversely only 19% of the 'no-information' group reported the contents of the preload to be the focus of the study, suggesting that the information provided to participants was successful in making participants more aware of the preloads. Whether the experiment was successful in making participants believe the soup was more filling is somewhat less clear. As stated before, PSE scores between the two groups were not significantly different following the provision of information, although there is reason to believe that any potential effect may have been masked by a minority of participants who were insensitive to the manipulation (and therefore exhibited little change in PSE scores).

#### **7.2.4 Summary**

Although not entirely conclusive, there is evidence that experiment eight has produced results that concur with the findings of experiments three and four. Again an association was observed between participants' expectancies of the preload (measured via PSE scores) and their ability to adjust their intake at the test meal in response to the different energy preloads. Proof that the information manipulation worked lay in the greater change in PSE scores for the information group, and change in PSE was

also observed to be positively associated with test meal compensation. While the lack of observable difference in PSE scores between the two groups was disappointing, the overall trend may have been masked by two participants in the information group who did not exhibit any change in PSE, and so it is proposed that these participants did not believe the information provided to them. The final questionnaire devised for experiment eight highlighted that participants tended to compensate better if they remembered the low-energy preload being unsatisfying, but the same relationship was not noted for participants who remembered the high-energy preload as being very satisfying. This supports the previously proposed theory that participants were more reactive to unexpected deficits in their energy intake rather than unexpected surpluses.

While experiment seven did not produce results that support the theory that attentional focus may drive this association, there is some suggestion from the awareness questionnaire of experiment eight that this may have been an influencing factor in the results. Here, participants who reported surprise at the effects of the soup were observed to compensate more accurately than those who did not, and it could be argued that this surprise would prompt participants to attend to their visceral state.

The implications of these experiments are that participants in other studies of this kind may react differently to disguised high- and low-energy loads, dependent on their pre-existing expectations of the preload's satiating effects. Whether this effect is due to differences in participants' attentional focus to the preload cannot be proven, as from these results there is relatively little evidence to support this theory.



Chapter 8    **Observations and Discussion**

## 8.1 General Discussion

### 8.1.1 Overview

This series of experiments aimed to further explore how information about food influences appetite and eating behaviours, with specific reference to dietary preloading studies. In particular, the extent to which information about the energetic content or the satiating ability of foods can influence appetite still remains unresolved, and this thesis aimed to use novel approaches to examine this issue.

Several studies have examined this issue, and some disparity exists between their findings. Studies that are illustrative of the discordance in findings were conducted by Shide and Rolls (1995), and Yeomans et al., (2001). Shide and Rolls (1995) observed that participants appeared to be relying on informational cues at experimental meals, rather than the actual energy content of the foods used. Conversely, Yeomans et al., (2001), and Kral et al., (2002) have shown participants to be insensitive to the effects of fictional information about a food. The use of nutritional information to alter participants' beliefs about foods may be the cause of at least some of this variability. It has been argued that using such information (often in the form of nutritional labelling) will have an uncertain effect, as it is difficult to measure exactly how the provision of such information has influenced participants' beliefs. Previous studies have addressed this issue to some extent, as following the experiment participants are asked questions relating to their perceptions of the foods consumed. The validity of such questions has not as yet been fully explored, and it is possible that the questions lead participants to answer in a certain manner, or that the responses to these questions may have been misinterpreted. In the study conducted by Yeomans et al. (2001), for example, participants were asked at the end of the study which preloads they remembered as being high-energy. The uncertainty arises as it is difficult to know exactly how participants interpret this question. It may be perceived as the desired question 'can you remember which soup you thought was high-energy', but it may instead be interpreted as 'can you remember which soup you were told was high-energy'. Thus, due to the possible misinterpretation of the question, one cannot be

sure whether the information provided succeeded in changing participants' beliefs, even though the final questionnaire suggests that it had.

Further problems with this type of validation measure may also exist. Asking participants questions regarding the energy content of the soup may have caused participants to think about the soups differently – i.e. participants could feasibly have not noticed any difference between the soups, but in response to the question may have reconsidered their initial view. Again this would have created responses that could be misinterpreted as belief changes, but were in fact generated by the measures used. Retrospective questions about the properties of preloads will also be confounded by the memory of the post-ingestive effects of that food, and may create different responses when compared with measures taken before or during consumption.

In response to these concerns with the existing literature examining the effects of information upon short term intake regulation, alternative methods were sought to examine this issue.

## **8.1.2 Summary of experiments 1 – 8**

### **8.1.2.1 Experiments 1 and 2**

The development of a preloading paradigm provided a platform from which to test the hypothesis that information provided about a preload could influence participants eating behaviours. Initially, alternative ways in which the information about a preload could be manipulated were examined. Sensory information was highlighted as a major source of information about any preload consumed, and experiment two focussed upon investigating whether compensation may be influenced if the majority of this sensory information could be withheld from the participant.

Experiment 1 observed a significant reduction in intake following the high energy preload at a test meal of cheese and tomato pizza. Experiment 2 also observed a reduction in intake at a pasta test meal in the control condition. However, in the information-restricted condition of this experiment, the difference in intake following the high- and low-energy preload conditions was not observed to be significant.

Subjective ratings throughout the two experiments were not observed to vary systematically between any of the conditions.

#### **8.1.2.2 Experiments 3 and 4**

Experiments three and four investigated the potential effects of information about a preload from a different perspective. By observing participants' beliefs about the preloads prior to the compensation stage of the experiment, any associations between beliefs and eating behaviours could be observed. This method was introduced to offer an alternative paradigm that did not require manipulation of participants' beliefs via the use of labels.

These experiments both utilised novel prospective consumption measures to assess how hungry participants expected to be after consuming the preload, based only upon a small sample of it. In both experiments, participants displayed significant levels of compensation in response to the extra energy contained in the high-energy preload condition. Furthermore, a correlation was observed between this expectation and participants' ability to compensate, which provided the first indication of this relationship. A model was proposed to explain the observed findings, and attention towards the preload was highlighted as a potential mediator of compensation. Based upon de Castro's (2002) General model of intake regulation, it was proposed that a more certain belief of a particularly high energetic load cued participants to attend to their visceral sensations more than to an uncertain belief that the soup would have little or no energy content. As a result, participants would be better placed to compensate for the covertly manipulated energy content if they anticipated the preload to be particularly satiating. Within de Castro's (2002) model, the attention would take the form of an additional uncompensated factor.

From the findings of experiments three and four, two main research questions arose. Firstly, further clarification of the preload estimate measures were needed. Secondly, the proposed model that attentional focus can influence dietary preloading studies also required further investigation. Up to this point, the observed relationships between preload estimates, uncertainty and compensation were not proven to be causally linked.

### 8.1.2.3 Experiments 5 and 6

The psychometric procedures developed in experiments 5 and 6 provided an alternative method by which to assess participants' expectations of the soup preloads. This task also provided a more indirect way of asking participants how filling they expected the preload to be. Instead of actually asking how full the participant expected to feel, the psychometric approach asked participants to assess one type of food against another, avoiding having to specifically ask participants how they expected to feel after drinking the 500 ml preload. It could be argued that this type of question may be less likely to artificially direct the attention of the participant towards the effects of the soup during and after its consumption. This notion was supported by participants' responses to the post experimental awareness questionnaires. In the later experiments, fewer participants stated that manipulation of the preloads was the purpose of the experiment.

The first of these experiments used a traditional method of constant stimuli approach, which was chosen due to its simplicity, and its ability to estimate both PSE and JND values. The Point of Subjective Equality (PSE) refers, for a predetermined attribute, to a theoretical value between two stimuli where they are considered to be equal by the participant, and so the participant is equally as likely to respond one way or the other. In the present context, the stimuli used were images of portion sizes of two foods, and participants were asked to judge which food they expected to reduce their hunger the most. Thus each participant was able to provide an indirect estimate of how filling they expected the preload to be, by expressing this in terms of another food. The Just Noticeable Difference (JND) statistics refers to the sensitivity of participants to changes in the stimuli presented to them. In the present context, this can be described as the magnitude that the portion sizes judged as equal (PSE) have to deviate before they are considered as noticeably different. It was argued that these values of PSE and JND were equivalents to the preload estimate and uncertainty measures from experiments 3 and 4.

Experiment five involved asking participants to compare images of preload portions against other food portions at a fixed variety of levels in order that specific PSE and JND values could be calculated. Following a small-scale experiment using this methodology, further research revealed that the method of constant stimuli would not

provide a practical tool, due to the excessively large scale of testing required to produce reliable results. As this measure was intended to be used prior to a preloading study in one session, a less time-consuming design was required.

In response to this, an alternative procedure was used. Hall's (1981) hybrid procedure utilised an adaptive staircase technique to react to participants responses, and focus subsequent trials at the specific levels of interest. This dramatically reduced the number of trials needed to gain reliable results. Although adaptive procedures were initially considered, none were accessible that allowed both PSE and JND calculation without the purchase of commercial software. Hall's Hybrid Procedure incorporated two techniques: PEST (Parameter Estimation by Sequential Testing; Taylor and Creelman, 1967), a staircase technique widely-used to determine PSE values, and a maximum likelihood analysis to refine PEST's estimate, and to calculate JND values. The maximum likelihood element of the procedure could be conducted entirely separately using the results from the PEST trials, which reduced the amount of real-time calculation required, and simplified the computer algorithm needed. Experiment six trialled this method using food portion stimuli, and it was found to be practical for this type of application while producing consistent results over four test runs for a group of 16 participants.

#### **8.1.2.4 Experiments 7 and 8**

A model was proposed to explain the observed findings, and attention towards the preload was highlighted as a potential mediator of compensation. Previous studies such as those by Herman et al., (1999) and Bellisle and Dalix (2001) have illustrated that attention has the potential to influence appetite, although the role of attention towards a preload has not been previously explored. Based upon de Castro's (2002) general model of intake regulation, it was proposed that a more certain belief of a particularly high energetic load cued participants to attend to their visceral sensations more than an uncertain belief that the soup would have little or no energy content. As a result, participants would be better placed to compensate for the covertly manipulated energy content if they anticipated the preload to be particularly satiating.

Within de Castro's (2002) model, attention would take the form of an additional uncompensated factor.

In order to test the predicted model that attention is an influential variable in preloading studies, further investigation was needed to identify a causal link between attention and intake or compensation. Experiment seven took the form of an exploratory study to establish whether encouraging unrestrained participants to think about their internal hunger state could alter their ability to compensate at a test meal. As several novel methods have been introduced during this series of experiments, experiment 7 was intended to verify that the experimental design produced results that would be expected for male unrestrained participants. How this group of participants would respond to such a manipulation is unclear, due to the lack of previous research examining this specific question.

As would be expected for this group of participants, no significant reduction in intake or subjective ratings was observed when, during a preloading experiment, participants were given a passage of text intended to cue participants to think about their hunger and satiety, relative to a group who were given non-food related information to read. Final questionnaires suggest that the text was successful at diverting participants' attention towards their hunger state, and so from this experiment a role of attention in unrestrained males' eating regulation cannot be supported.

Experiment eight sought to bring together the findings of experiments three and four on the one hand, and experiment seven on the other. The two earlier studies had both indicated that attention may be able to mediate participants' intake in a preloading study, whereas experiment seven had not. Thus, experiment eight incorporated several different elements. The study was based around the preloading study developed in this thesis. In addition to this the psychometric test developed in experiment 6 was utilised to assess participants' belief surrounding the preload. The experiment also required some way in which the beliefs of participants could be changed. Following further research around the area, the use of nutritional labelling was revisited. Although this type of method was discounted early on in this thesis, the concerns related more to the validation of this type of manipulation, rather than the manipulation itself. By using the psychometric procedure to take thorough before and after values of participants' beliefs, some of the concerns associated with labelling

techniques could be addressed. In this experiment, it was claimed that a new meal-replacement was being trialled within the department. Notices were placed on the university notice board, and participants were provided with a fictional press release for the product, embedding the fictional product within examples of other, real products on the market.

As with the previous experiments of this thesis, intake following the high-energy preload was significantly reduced. A greater reduction in intake (and therefore more accurate compensation) was observed in the group who had received the fictional information about the preload, and this was also coupled with a greater change in PSE estimates in this group which indicates that a greater belief change had taken place for this group. Responses to the debriefing questionnaire suggest that participants who exhibited a greater degree of compensation for the energy difference in the two preload conditions tended to have been sensitive to the 'missing' energy in the low-energy condition, rather than the 'extra' energy added to the high-energy condition. This was suggested by the association between rated surprise at the effects of the low-energy preload and compensation at the test meal. The same association was not evident between the surprise following the high-energy condition and compensation.

### **8.1.3 Across-Experiment comparisons**

#### **8.1.3.1 Intake and Compensation**

As several of the experiments within this thesis follow similar experimental designs, comparing the results of these experiments may offer a further indication of the reliability of the methodology. The basic paradigm used in these experiments involved administering a preload to a participant 30 minutes before providing them with a test meal. Subjective ratings hunger, fullness, desire to eat and prospective consumption were also taken at predetermined points throughout the experiment, and the quantity of food eaten was weighed before and after the meal to determine the participants' consumption.



**Table 8.1** Across-experiment comparison of the preloading studies conducted during this thesis. SE refers to standard error about the mean. d refers to experimental effect size.

Experiment	Mean Intake (kJ)	Intake		SE	d
		Reduction (kJ)	% Reduction		
1	2840	512	40	204	0.81
2a	1790	440	35	171	0.31
2b	1727	178	14	190	
3	1755	297	24	77	0.37
4	1578	342	27	78	0.32
8a	2230	338	27	116	0.42
8b	2555	635	52	157	
Average		391	31		

From 8.1, it can be observed that while no obvious pattern is displayed in the levels of compensation seen in subsequent studies, the level of significance of the difference increases, with the later studies producing a more definite difference in test meal intake between the high and low-energy preload conditions. It is argued that the reason for this is that during the course of experimentation for this thesis, the procedure was gradually refined. Screening participants for their preference for or aversion to the test foods was introduced only in the later studies, as was testing only participants who exhibited baseline hunger VAS ratings above a predetermined level. Such measures helped to prevent spurious results generated by participants who found the test foods unpalatable, or those who did not follow the study requirements about fasting prior to the tests. Through experience of the earlier studies, extra care could be

taken when briefing participants about parts of the study that had been previously misunderstood.

The greatest intake reduction was observed following when pizza was presented as the test meal. Although as has been previously discussed, the methods used here were not optimal, an interesting finding was observed. As the pizza would be expected to be more palatable than the pasta meal, it would appear that the meal's palatability may have an influence on the degree of compensation observed. While Yeomans, Lee, Gray & French (2001) also found test meal palatability affected participants' ability to respond to high-energy preloads, the opposite was observed in this study, with blander foods observed to create a stronger preload effect. As experiment one was the only experiment to incorporate pizza as a test meal, the reason for this contrary finding cannot be determined. It does however suggest that further investigation of this relationship between palatability and compensatory ability may be worthwhile.

In one of the conditions of the last experiment, fictional information about a preload was provided to participants to make them believe a preload was more satiating than it should be, given its actual energy content. This experimental condition produced a greater mean level of compensation than any other during the course of this thesis. This group displayed a highly-significant difference between the two test conditions, along with a compensation rate markedly above the other comparable studies. If experiment one is discounted, as this used a more energy-dense test food (pizza) and so is not directly comparable, then this group of participants compensated an average of 195kJ (44%) more than the findings of the nearest other experiment. The fact that this method of information manipulation produced results which were distinct not only from the other group within this experiment, but also contrasted with the findings of all the previous experiments, suggests that this increase in compensation was not merely due to random between-participant variation. In turn, this lends further support to the validity of experiment 8, and the information manipulation used therein.

In conclusion, when the two test conditions that were intended to disrupt participant appetites are excluded, the variation in mean compensation is reasonably small, with only a 215kJ discrepancy between the highest and lowest average levels of energetic compensation. In terms of pasta, this equates to a variation of less than 64g. This level

of precision further supports the use of this experimental design for this series of experiments.

#### **8.1.3.2 Subjective appetite ratings**

VAS and other subjective measures were used throughout the experiments of this thesis. The results gained from these scales were somewhat less convincing than the intake data, as there were often few observable differences between the VAS scores for each test condition. VAS were included in the latter experiments because, in addition to providing another measure by which to gauge each participants appetite during the different tests, they also proved a useful tool for identifying outlying data points. In particular, VAS were a useful method of screening participants at the beginning of each test session to ensure they were in an appropriate hunger state. VAS could also highlight participants who did not eat to satiation during the test meals, along with any participants who found the foods unpleasant. Removing the VAS measures from the experiment could also prove problematic, as these experiments were concerned with participants attention during the eating episode, and it is unclear exactly how making VAS judgements influences participants attention during their meal.

There is no clearly-definable reason for the failure of the VAS measures to register consistent differences between the different conditions. Participants were given clear instructions on the use of the scales before starting each experiment (both written and verbal), and were given opportunity to ask questions should they remain unsure. It could be predicted that certain comparisons would be unlikely to register significant differences when using VAS. The between-group comparisons used in experiments 2, 8 and 9 were not suited to analysis using such scales due to the differences in each participants perceived maximum intensity for any given stimulus (Bartoshuk et al., 2003). Between-participant variability here would be expected to make any effects harder to identify.

## **8.1.4 Relation to previous literature**

### **8.1.4.1 Intake Measure**

The experiments of this thesis indicate that in the context of dietary preloading studies, a participant's expectation of the hunger reducing properties of a soup preload will influence their sensitivity to the actual energy content of the preload. Specifically, the experiments suggest that participants who expect the preload to have a high satiating ability relative of other foods tended to adjust their subsequent intake more accurately when the energy content of the preload was covertly varied.

This finding echoes previous studies that have also found participants to be sensitive to informational cues in laboratory-based ingestive behaviour experiments. In particular, these findings concur with early work by Wooley, Wooley and Dunham (1972) who observed participants to guide their intake of a judgement about the energy content of a preload, rather than the actual energy content of the preload. Shide and Rolls (1995) also found participants to be influenced by nutritional labels placed on preloads to suggest particular fat contents, rather than the preload's actual fat content.

The findings of this thesis are in direct contrast to more recent work in this area. Yeomans et al. (2001), found unrestrained males to be insensitive to label manipulations of a soup preload. Kral et al., (2002) also observed labels advertising different energy densities of foods to be ineffective at influencing participant appetitive behaviours. Wardle (1987) and Ogden and Wardle (1990) also presented results that suggested participants to be insensitive to nutritional labels presented with foods, while Miller et al., (1998) only saw an effect of such information on participants who exhibited high levels of dietary restraint. The participants in this series of experiments all displayed low levels of restraint

### **8.1.4.2 Subjective ratings**

Typically, studies have observed systematic differences in subjective appetite ratings between different preload conditions. The results obtained in this thesis were

somewhat unusual in that the experimental designs utilised consistently failed to display such differences, despite highly significant intakes at the test meals following the high- and low-energy preloads. Standard visual analogue scales were used of hunger fullness, and desire to eat, and ratings were taken at a variety of timepoints throughout the experiments. Participants were given clear and thorough instruction regarding the use of the scales. Following the lack of differences observed in the earlier studies of this thesis, particular emphasis was placed upon this for the latter experiments, still without a notable improvement. This continued failure to display observable difference in subjective ratings across different experiments with different participants suggests that a common aspect of the experiments may be responsible. It is possible that some aspect of the preloads used throughout this series of experiments is responsible for this failure. When compared to the similar soup preloads used by Yeomans et al., (2001), although the energy levels used in the two conditions were virtually identical, the energy densities of the two conditions are considerably different to the ones used by Yeomans et al., (2001) due to smaller portion of preload presented to participants therein. As Yeomans et al., (2001) used a 300ml preload vehicle, the range of energy densities between the high- and low-energy conditions (0.88 – 5.04KJ/g) are wider than for the current experiments of this thesis, which used a 500ml vehicle (0.53 – 3.03KJ/g).

Kral et al., (2002) specifically manipulated the energy densities of test foods, and again found significant differences in subjective ratings following the low and high energy density foods. Here, the energy density of the foods varied between 5.23 and 7.32 kJ/g. While this does not represent a greater difference in energy density compared with the preloads developed for this thesis, the densities used by Kral et al., are considerably higher overall. Therefore, it may be the case that greater energy differences, or an overall greater level of energy in the preload would create the systematic differences observed in the subjective ratings used in other studies. However, an alternative explanation for this observation also relates to the nature of the preload vehicle. For the development of this preload, a precaution not previously considered was taken to ensure that the different energy variants of the preload were indistinguishable. It was also argued that taking subjective taste ratings of preloads to illustrate the food's similarity may not be adequate. It is possible that using

discrimination tests to match the preloads to this extent may have influenced participants abilities to rate the different conditions differently. If this were the case, it would suggest that subjective ratings in this type of experiment are at least partly guided by sensory differences of the foods consumed, rather than the nutritional properties contained within the food. This in turn could explain why subjective rating differences can be observed relatively quickly following consumption of different energy loads. Further investigation would be required to determine whether this argument could be supported

### **8.1.5 Implications of these findings**

The finding that the eating behaviours of unrestrained participants can be influenced by information cues in dietary preloading studies is in direct contrast to the more recent research in this area of ingestive behaviour. Yeomans et al., (2001) and Kral et al., (2002) have found this group of participants to be insensitive to information provided in the form of nutritional labels, with both eating behaviours and subjective ratings guided by the actual energy content of the food used. Earlier work that also reached this conclusion was conducted by Wardle (1987) and Ogden and Wardle (1990). The null results obtained in these experiments have been justified by the use of brief questionnaires at the end of the study that support the authors claims that the information manipulations were effective. In both of these studies, participants were asked to identify the preloads they remembered as high energy, in order to check that participants beliefs about the preload had been shaped by information provided with the preload. However, as discussed earlier in this thesis, the results of such a question may be difficult to accurately interpret. It is possible that in the past, inadequate attention was paid to these questionnaires, and an ineffective information manipulation would produce the same null results.

Another problem with studies which incorporate nutritional labelling techniques is that following their use, it difficult to be sure that the participants believed the information that was presented to them on the label. Even when a debriefing questionnaire asks participants about the contents of the foods, it is difficult to be certain participants are responding with their own beliefs, or whether they are

responding to a demand effect i.e. the question 'which food was high fat?' may cause some participants to respond with the food they actually thought was high fat, while others may simply report that food they remember being told was high fat, irrespective of what they actually thought. As the effectiveness of this manipulation is a key aspect of this study, it can be seen that there may be methodological reasons why these studies have produced results that do not concur with the findings of this thesis.

From the evidence gathered in the last two experiments of this thesis, it cannot be proven that attention towards the preload is mediating compensation to the extent observed in these experiments. Instead the evidence may point towards the relationship between preload and compensation being a symptom of the inequality in human intake regulation, with greater visceral hunger signals being generated following unexpected deficits in intake, compared with the satiety signals generated by unexpected surpluses in energy intake. Participants who expected the soup to be filling appeared to be more sensitive to the 'missing' energy in the low-energy variant than participants who expected little satiation were to the 'extra' energy provided in the high-energy variant.

So, if it assumed that this theory can explain the results obtained in this thesis, what conclusions can be drawn? At first glance, it may appear that such a conclusion does not offer any further insight into eating regulation, as the phenomenon that human psychobiology more readily guards against hunger than satiety has been suggested many times before. However, the element of this research that may have not been considered before is that, according to the later experiments, how a food is considered by a participant will influence how they compensate for it following its consumption. Using the example of soup, the findings of these experiments suggest that the participant's relative expectancies of the soup may help determine how sensitive they are to its energy content. If they expect the soup to be satiating, they will be more likely to compensate well, and vice versa.

This introduces another element of individual difference between participants that to my knowledge has not been previously considered in preloading-type experiments. Participants who perceive a preload to be more satiating will not necessarily behave in the same manner as those who perceive it less so. This would not necessarily have

implications for previous studies, as it would be considered as a random variable, and so unlikely to cause bias in any particular direction. However, it may offer a further tool to help to reduce the amount of between-participant variability observed in compensation studies. This in turn may be useful for examining subtle effects on appetite that were previously masked by between-participant variation.

It is important to note that the findings within these experiments can currently only relate to the context of dietary preloading studies. Future experiments could adapt the methodology as such to make the experiment more valid to community settings. These studies were primarily concerned with influences upon the laboratory-based preloading paradigm, and what implications this has for controlling variance in future studies.

Taking a broader perspective of the issues at hand, what implications could these findings have for individuals with energy balance disorders, such as obesity? The notion that weight loss prevention mechanisms are stronger than weight gain prevention mechanisms seems to make biological sense. However, whether this translates to acute within-meal appetite has not been established. These findings can offer some empirical indication that humans will identify energy dilutions more readily than energy concentrations within food, thus indicating that satiety signals are not as potent a stimuli as hunger signals. This introduces an interesting perspective from which to view the strategy that making participants focus on their visceral sensations will help them to lose weight. Potentially, such actions could even counteract attempted weight loss as individuals would be encouraged to react to appetite signals that stimulate eating more than it prevents it.

Cephalic phase responses could offer a potential mechanism to underpin the theory that energy deficits are more readily identified than energy surpluses. Grehlin has been highlighted as an influential hormone in energy regulation, as plasma grehlin levels are higher in during fasting states and is associated with increased hunger. Drazen, Vahl, D'Alessio, Seeley & Woods (2005) have observed anticipatory rises in grehlin levels that matched meal patterns in rats, and Frecka & Mattes (2008) presented evidence in humans that grehlin levels surged in anticipation of food, rather than at conditioned meal times.



If grehlin levels are related to anticipation of food intake, the rise and fall of grehlin levels may be linked to the observed finding of this thesis, that humans are more sensitive to energy deficits than surpluses. As larger anticipated meals evoke larger grehlin surges, it could be argued that participants who expected the preloads to be satiating experienced larger grehlin surges than those who did not. Subsequently, the presence of higher levels of grehlin may induce participants to eat more following the low-energy preload, as the energy intake gained from the low-energy preload was less than was warranted by the anticipatory grehlin surge. This would create the effect that participants who expected the preload to be satiating would see greater levels of compensation, and that this compensation would be generated by an increase in intake following the low-energy preload.

It is important to consider that from the literature reviewed in this thesis, it is clear that appetite does not have just one, or even a few, determinants. In reality, the human body contains a multitude of different signals and stimuli that integrate to control body weight. In addition to this, the modern environment contains many external influences on eating and therefore appetite, some of which have no antagonistic influence to maintain energy balance. Participants' expectations of a food may take the form of one of these uncompensated factors. Elucidating more of these factors could prove invaluable when designing weight loss strategies.

#### **8.1.6 limitations of the present research and possible future directions**

When considering the findings of these experiments, their potential limitations must of course be considered. These issues will now be discussed, and the avenues in which further research could progress will be presented. Some general observations are made about preloading studies and their limitations, followed by issues particular to some of the experiments within this thesis.

### 8.1.6.1 General

The laboratory-based nature of this research makes the context in which the results of this thesis are relevant very focussed. The key aim of this thesis was to investigate how dietary preloading experiments can be influenced by the information about a preload, and as such the results cannot simply be generalised to 'normal' eating situations. The environment of the laboratory was undoubtedly different from participants' 'normal' home environment, and whilst it was ensured that this environment was kept constant throughout the experiments, it is possible that such an environment can influence eating behaviours. Similarly, the experiment itself may have altered participants' behaviours in some manner, as it difficult to hide the fact that their eating behaviours are being monitored when they are repeatedly asked questions about their appetite. The frequency of such questions may also have had a bearing on behaviours, and so to address this, the frequency of appetitive questionnaires was maintained as constant as possible across subsequent experiments.

In defence of laboratory-based satiety experiments, the term 'normal' eating behaviours may no longer be appropriate, as much of daily life involves eating episodes governed by external stimuli such as fixed lunch breaks. Such influences can encourage eating even in the absence of hunger, or conversely they can create situations where one does not eat even when hungry. Kissileff (1981) convincingly argued this point, highlighting the fact that when dining out and eating at work are taken into consideration, very little eating can be considered 'normal'. In response to criticism of the effectiveness of laboratory studies to identify why humans make food choices, Kissileff also argues that this is not the role of such studies. Rather than trying to answer the question; 'what makes us eat what we eat, when we eat it?' this type of experimental paradigm can be used to try to answer questions such as; 'when we are eating, what makes us stop?'

Another limitation of the experiments of this thesis relates to their statistical power. As the experiments of this thesis employed novel methodologies, it was not possible to predict how large the effects would be, as there is no previous data to refer to. The psychophysical experiments in particular were exploratory in nature, as this application of these tasks had not been undertaken before. Future experiments examining this

issue would be able to size the experiments more appropriately to obtain the desired statistical power.

#### **8.1.6.2 Experiment 2**

The second main experiment conducted in this thesis examined the effects of reducing the available sensory information to participants. The observed findings suggested that participants were less sensitive to the covertly-added energy in the high-energy preload, as they were not observed to compensate significantly for this addition of energy. Conversely, participants in the control condition of this experiment were observed to display a significant degree of compensation, reducing their intake by 35% of the extra energy in the high-energy condition. While this result indicates an interesting finding that sensory information is needed to facilitate compensation in preloading studies, when examined in detail, it is difficult to justify why this result should have occurred. In experiment 2, the same preload vehicles were used as had previously been devised in experiment 1. The high- and low - energy preloads had therefore previously been observed to be indistinguishable at greater than chance levels, and so any potential effect of the sensory profile of the preload should be cancelled out by this.

In this experiment, it was apparent that participants found wearing the noseclips during eating unpleasant, and it was suggested that at the test meal stage of this experiment, some participants were merely eating just enough to meet what they perceived was required of them, rather than eating to satiation. However, there is no evidence to suggest that intakes were lower in this experimental condition, relative to the other experiments of this thesis. The purpose of using nose clips was to attenuate taste as well as olfactory information about the preload, and so unsurprisingly, mean hedonic ratings of the test foods were lower here than in the other experiments. This creates difficulties for comparisons between this and the other studies, as it generates somewhat of a paradox: The experiment aims to attenuate these sensations, but in doing so creates further problems, as there is no precise way of knowing how this manipulation has altered participant sensory information. If it could be determined that all sensory information was removed, presumably creating a string of '50' scores

on all the VAS ratings, then it could be assumed that the effects of removing sensory information are being examined. However, this was clearly not the case, as both taste test and palatability ratings fluctuated within and between participants. As a result, there is some uncertainty about what the nose clips actually did. They may have simply suppressed the ratings that would be given normally, but similarly, they may have mislead the participant into thinking they had consumed a different food with different learnt associations. This in turn poses the question of whether useful information can ever be gained from this kind of manipulation. Can humans ever be orally fed a food from which they will not take some form of sensory cues from? If the answer is no, then it could be argued that for this type of experiment it can never be safely assumed that the effects of sensation vs. no sensation are being compared, rather than the effects of sensation x vs. sensation y. Even if a method can be found that will attenuate all smell, taste, temperature and texture sensory cues, it is doubtful that this could readily be compared against the control condition as it would be too far removed from a normal eating episode. In conclusion, The subsequent experiments of this thesis were correct to investigate different methods due to the uncertainties associated with this type of invasive manipulation.

#### **8.1.6.3 Experiment 3**

This experiment examined how participants' expectations of a soup preload were related to their subsequent eating behaviours. The novel measure employed in this experiment involved eight bowls of cornflakes varying in portion size from very small to very large. Participants were asked to estimate what quantity of cornflakes they expected to satisfy their hunger after consuming the preload. The most obvious limitation of this design was the atypical pairing of soup and cornflakes. Participants were being asked to imagine consuming the cornflakes after consuming the soup preload, which is obviously not a usual meal. Therefore whether this measure represents an ideal way in which to assess expectations is in some doubt, as it would have little ecological validity. However, there is no obvious reason why this choice of measure would have created the observed relationship between expectations and compensation, so the results should not be disregarded completely.

Another factor present in experiment 3 that may be somewhat less than ideal lies in the nature of the expectation measure. As the measure asked participants to imagine how hungry they expected to be after consuming the preload, this obviously will be affected by the participant's baseline hunger scores. A higher initial hunger will be likely to create a larger expected hunger after preload consumption. Thus it is possible that the results were not illustrating a association between expectancies and compensation, and they were instead actually reflecting a relationship between initial hunger and compensation. However, as already mentioned, the baseline hunger ratings did not exhibit an association with compensation at the test meal.

One final aspect of this experiment that could be improved upon was the timing of the expectation measure. By asking participants at the start of the experiment how filling they expected a preload to be, demand effects may be created that artificially influenced how participants actually responded to the preloads. Although the nature of this estimate may necessitate its placement at the beginning of a experiment (it is impossible to assess expectations of a preload *after* its consumption), there was room for improvement in the way in which expectations were assessed. By assessing expectations in a way that did not directly enquire how filling the preload was expected to be, the influence of demand effects may be lessened. This reasoning prompted the alterations made to the expectation measures in experiments 4, 5 and 6.

#### **8.1.6.4 Experiment 4**

While this experiment addressed several of the concerns raised following experiment 3, there were still some imperfections that became apparent following its implementation. These again stemmed from the measure used to assess participants' expectations. The technique utilised for this experiment consisted of making comparisons of sample amounts of the soup preload against other foods to determine which was the most filling, ultimately deriving a estimate for each participant's expectation of the preload. In essence, this study acted as a pre-cursor for the psychometric experiments devised in the next experiments. However, as this study involved making comparisons by actually pouring portions of different foods, it was somewhat unwieldy for use at the beginning of a preloading study, and anecdotally,

participants became very bored with the process towards its end. This may not have helped this measure to obtain reliable results. In addition to this, it also became apparent that explaining the upper and lower boundary estimates that participants were asked to make was often difficult. While each participant was trained as much as necessary on this element of the test, it is obviously of benefit to a study for the instructions to be as accessible as possible. Once again, this highlighted issue was later solved by the incorporation of a computer-based task in experiments 5 and 6, which used a very similar task, but quicker and more easy to understand.

#### **8.1.6.5 Experiments 5 and 6**

While the psychometric tasks developed in experiments five and six offer solutions to many of the problems encountered in the preceding chapter, there are still further alterations that could be made to the design. The practicality of actually using the task was much improved in experiment six, as it employed a psychophysical procedure that was suited for short test runs that could be easily incorporated into a preloading paradigm. Conversely, to be practical for this need, the constant stimuli method tested in experiment five required scaling down to appoint where its reliability suffered.

The certainty estimates represent a potential limitation for these experiments. The hunger reducing properties of one food were expressed in terms of another, and the sensitivity of participants to changes in the relative quantities of these two foods was proposed as the participant's certainty about their estimate. The problem arises due to the fact that the uncertainty of the participant can stem from uncertainty about the effects of either food, not just the soup preload. As a result, the uncertainty displayed by participants will be a function of participants uncertainty towards both foods used in the comparisons. For this reason, in its current form, the uncertainty estimates produced by the psychophysical measure are very much specific to the experimental situation they were obtained in. This aspect was considered prior to the experiments, and cornflakes were chosen as the comparison food to help minimise the uncertainty that would be expected from this food. The effect of variations in uncertainty towards the comparison food would not be expected to create systematic bias, as none of the participants reported an aversion towards cornflakes, and relative certainties about the

hunger reducing effects of cornflakes would be randomly spread throughout the conditions. In future studies, a further development of the psychometric tasks could be to take estimates of the preload against a 'basket' of other foods to obtain an average uncertainty estimate for the preload. This could potentially then be used to compare the uncertainty of different foods against one another. In turn, this could then be used to examine how participants respond to different preload vehicles with different associated uncertainties.

### **8.1.7 Potential future research**

Although it has been observed on several occasions that test-meal compensation is associated with preload estimates, what these estimations actually represent to the participants remains unexplored. From the existing data, it cannot be ascertained whether participants are merely reporting their previous experiences with this type of food, or whether they are responding to their own evaluations of the foods. Is this estimate of the satiating properties of a food a direct response based upon similar foods actual effects when consumed, or can the participant's perception of the food influence how satiating they predict it to be? Answering this type of question will allow a better understanding of what a preload estimate specifically is, and whether this relationship is determined by more basal biological responses to the food, or more cognitive associations between the food and its effects. Such answers would then subsequently lead to further questions of whether perceptions about a food can actually be changed, or whether trying to do so just causes a different food to be substituted by the participant. Potentially, if it can be established that participants' beliefs about a food can be changed, then interesting questions can be asked about being able to alter an individual's ability to regulate their intake of a food by changing their perception of it.

This theory can also fit with the findings of the majority of the research into soft drinks and satiety that have found imprecise intake regulation following drinks containing disguised energy loads. Typically, soft drinks are seen as providing little satiety, despite their often high energy content, and the current model would predict that this may contribute to their inability to stimulate adequate compensatory

responses. This may provide an alternative hypothesis to explain humans poor ability to compensate for energy bearing drinks. It has previously been proposed that the type of sugar used to sweeten soft drinks may be responsible for this failure to compensate. However, as highlighted by Shields et al., (2004), this pattern is not restricted to soft drinks.

Shields and colleagues examined the consumption of 'Gourmet Coffee Beverages', a relatively new trend amongst students. The study focussed upon 165 female students, using questionnaires and 3-day food diaries. The investigation revealed that students who consumed these beverages had a mean intake 861kJ higher than that of the participants who did not consume such drinks. de Castro (1993) also previously used diaries to track 323 participants' beverage intake over a period of seven days. This method highlighted that while the consumption of non-energetic drinks were associated with lower overall energy intakes, 15 different beverages and foods were highlighted that did not create a compensatory response in food intake. These findings suggest that the macronutrient content of a drink is not the determining factor in its ability to evoke satiety responses, rather that it is the fluid vehicle itself which dictates this.

As most beverages, with the exception of soup, are considered to have little satiating efficacy, the lack of compensation observed in response to liquid energy could also fit the pattern of results seen in this thesis. Furthermore, it could be argued that the correlations observed here between compensation and PE scores could reflect a range of perceptions of soup across the test group. Participants who perceived the soup as a meal compensated well, relative to participants who viewed the soup more as a beverage. Repetitions of the experiments conducted for this thesis using beverages other than soup may help to determine whether this reasoning is accurate. This theory can also fit with the findings of the majority of the research into soft drinks and satiety, that have found imprecise intake regulation following drinks containing disguised energy loads. Typically, soft drinks are seen as providing little satiety, despite their often high energy content, and the current model would predict that this may contribute to their inability to stimulate adequate compensatory responses.



## 8.2 Conclusions

This thesis aimed to revisit the question of whether, in a laboratory environment, information relating to the nutritional content of a preload could influence the appetite of unrestrained participants. While it has been well documented that participants who are concerned with their weight will be influenced by such information, traditionally, participants who exhibit low dietary restraint will be insensitive to this type of cue.

In particular, this thesis examined how participants' expectations of a preload were manipulated in the course of previous studies, and how any expectation change was assessed. By identifying possible limitations in previous techniques, this thesis was guided towards alternative methods that would address such problems. By utilising psychophysical analysis, a novel way in which to address this research question was devised, and it is suggested that this offers a useful tool for assessing participants' expectations of foods.

Over the course of three different experiments, an association was noted between participants who expected the foods to be highly satiating, and their sensitivity to changes in energy content of a preload in repeated measures experiments. The findings of this thesis support the argument that unrestrained participants can be influenced by informational cues, and suggest that methodological factors may have contributed towards the nil results obtained in some of the past research in the area.

Why the observed relationship is present is still not completely certain. A possible influence of attention was proposed as a potential causal variable, but the findings of the last two experiments of this thesis cannot support this suggestion. Another theory that appears to be more likely is that an inequality between hunger and satiety mechanisms caused participants to compensate for the change in preload energy differently. Participants who expected the soup to be filling in effect received an unexpected deficit in energy in the low-energy condition, while those who expected a soup with little satiating capacity in effect received an unexpected surplus of energy in the high-energy condition. As hunger-prevention mechanisms appear to have a more potent effect on behaviour than satiety mechanisms, this would explain why the first group of participants would be expected to compensate better for the change in energy load, as was observed in experiments three, four and eight of this thesis.

Further work would be required to completely elucidate why this association can be observed in laboratory-based preloading studies, but even the knowledge of its existence may prove useful for future studies. Participants' prior expectations of preloads have previously not been considered as an influential factor in satiety studies, and it may be an additional factor that contributes towards variability in this type of experiment. As such, identifying this association may offer useful information for the design of future experiments of this type.

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