The relationship between breakfast consumption, blood glucose levels, cognitive functioning and mood in healthy young females.

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THE RELATIONSHIP BETWEEN BREAKFAST CONSUMPTION, BLOOD GLUCOSE LEVELS, COGNITIVE FUNCTIONING AND MOOD IN HEALTHY YOUNG FEMALES

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Submitted to the University of Wales in fulfilment if the requirements for the Degree of Doctor of Philosophy

University of Wales Swansea
2003

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed:.. .. Date: 24th June 2003

Samantha L. Nabb MA (Hons)

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

Signed:.. .. Date: 24th June 2003

Samantha L. Nabb MA (Hons)

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed .... Date: 24th June 2003

Samantha L. Nabb MA (Hons)

ACKNOWLEDGEMENTS

Firstly, I would like to thank my supervisor Professor David Benton for his continued support and encouragement, both professionally and personally, throughout the duration of this project. The enthusiastic cry of "How's business?" will be a constant reminder of the enthusiasm that has kept this thesis evolving over the past few years.

Secondly, I would like to thank the International Life Sciences Institute of Japan and Groupe Danone, France for their financial contributions towards participant payment.

Thirdly, I would like to thank the hundreds of participants who graciously let me attack their fingers in return for various 'breakfasts' and their beer money. Without their support and interest in the studies this thesis would have been a non-starter.

Finally, I would like to thank my family, who have been there for me with their love and patience over the years, and never raised an eyebrow when I claimed my thesis would be finished 'by the end of the month' for nearly a year! I would also like to thank Richard and all my friends who have given me support and well-needed counselling on various occasions over the past few years.

SUMMARY

This thesis examined the effects of breakfast consumption and its subsequent influence on blood glucose levels, cognitive functioning and mood in healthy young females. The impact of a sucrose containing drink, or a placebo, and breakfast meals varying in macronutrient content were assessed.

No single dose of sucrose was beneficial across all measure of mood and cognitive performance. However, individual differences in glucose tolerance were clearly an important factor. Falling blood glucose levels were associated with enhanced mood and cognitive performance throughout the test session.

The impact of breakfasts differing in macronutrient contents were systematically investigated in two subsequent studies. Again glucose tolerance was an important factor. Low blood glucose levels throughout the morning were associated with enhanced memory performance. In addition, it was demonstrated that the critical aspect of breakfast for enhanced cognitive functioning and mood was the amount of carbohydrate present. Following the meta-analysis of all studies, it was demonstrated that 20.1-35g of carbohydrate was the optimal dose, and that doses of 50g and above were detrimental to mood and performance after two hours.

Two subsequent studies investigated the nature of the carbohydrate consumed within the breakfast. Two types of carbohydrate were investigated, Rapidly Available Glucose (RAG) and Slowly Available Glucose (SAG). It was concluded that the SAG breakfast, that failed to induce a great change in blood glucose levels over time, significantly improved memory. Individual differences in glucose tolerance were again of importance.

It was concluded that amount of carbohydrate and type of carbohydrate consumed at breakfast is crucial in enhancing cognitive functioning and mood throughout the morning. In addition, the interaction between the carbohydrate consumed and the glucose tolerance and physiology of the individual must also be taken into consideration.

Chapter 1: Introduction and Review of the Literature

1.1 GENERAL INTRODUCTION

The brain is the most metabolically active organ in the body. It accounts for 2% of total body weight, yet requires about 20% of the total energy of the resting organism (Siebert et al., 1986). Under normal circumstances, the energy requirements of the brain are met exclusively by glucose degradation (Weiss, 1986), however, the brain has limited stores (Marks and Rose, 1981) and is therefore dependent on a continuous supply of glucose from the blood. It is reasonable to consider, therefore, that the impact of glucose availability and utilisation may influence
cognitive functioning.

There is increasing evidence that the level of glucose in the blood is an important factor that influences cognitive functioning. It has been demonstrated in both young and aged rodents, that increases in blood glucose levels are associated with enhanced memory (Gold, 1992; 1991; 1986). Furthermore, a similar phenomenon has been demonstrated in healthy aged adults (Manning et al., 1990; Gonder-Frederick et al., 1987). More recent research has demonstrated that the memory of healthy young adults can also be enhanced by increased blood glucose levels (Benton et al., 1994; Benton and Owens, 1993a). The cognitive demand of the task, its complexity and duration (Donohoe and Benton, 1999a; Benton et al., 1994), and individual differences in glucose tolerance, are also critical factors in the enhancement of cognitive performance (Messier et al., 1999; Manning et al., 1997; Craft et al., 1994). Therefore, a major aim of the present studies was to further investigate the influence of different types of carbohydrate on mood and cognition.

Given the body of evidence the that consumption of a glucose drink has a beneficial effect on memory, the first experimental chapter examined the relationship between different doses of sucrose, mood and cognition. Sucrose is a disaccharide that yields glucose and fructose. Glucose readily crosses the blood-brain barrier, fructose does not, and both sugars have been demonstrated to enhance memory although the dose is critical (Messier and White, 1987). It was hypothesised, therefore, that differing levels of sucrose, like glucose, would differentially effect mood and cognition and that individual differences in glucose tolerance would also be an important factor. Individual differences were found to be an important factor, however, no single sucrose dose was identified as beneficial to either mood or cognitive performance.

There is extensive literature reporting the positive effects of breakfast consumption on mood and cognition (Benton et al., 2001a; 2001b; Lloyd et al., 1996; Smith et al., 1994a), therefore, the second aim of the present thesis investigated the influence of breakfast on these measures. In addition, the nature of the breakfast, the various combinations of foods and macronutrients, were investigated in an attempt to identify those macronutrients important in mood and cognitive enhancement.

Chapter 3 addressed the influence of varied amounts of dietary fibre and carbohydrate consumed as a breakfast on mood and cognitive performance. Fibre consumption has been shown to reduce the glycaemic and insulinaemic responses to foods in both normal and diabetic populations (Wolever et al., 1991). In addition, fibre slows the rate of gastric emptying over time, and therefore the rate of glucose and nutrient absorption. Manipulating the amount of fibre consumed failed to have a substantial effect on cognition, however, it was demonstrated that low fibre (1.5g) intake was associated with enhanced mood. Patterns were observed across carbohydrate groupings, with 30g of carbohydrate being beneficial.

Chapter 4 further investigated the influence of breakfast on mood and cognition, through the manipulation of the amount of carbohydrate, fat and protein consumed. Changes in blood glucose levels depend on the nutritional content of the food consumed. Furthermore, the consumption of pure macronutrient meals have been demonstrated to differentially influence measures of cognition and mood (Fischer et al., 2002; 2001; Kaplan et al., 2001). Low carbohydrate (25g) breakfasts were associated with enhanced mood, with high carbohydrate (60g) intake being detrimental later in the morning.

A recurrent observation was that the amount of carbohydrate was an important factor in the enhancement of mood and cognition. Therefore, chapters 5 and 6 investigated the influence of different types of carbohydrate on these measures. The classification of dietary carbohydrates into Rapidly Available Glucose (RAG) and Slowly Available Glucose (SAG) (Englyst et al., 1999; 1996) reflect the differences in digestion and absorption rates

(Englyst and Cummings, 1987; 1986), and the glycaemic response to a food (Wolever et al., 1991). The interactions between the amount and type of carbohydrate, and the individual's glucose tolerance, were found to be critical factors in the enhancement of mood and cognitive performance.

Twenty-four different breakfasts were consumed within the experimental studies reported. As each study followed the same experimental design, and similar time constraints, the studies were considered collectively to determine if a breakfast could be recommended to induce optimal mood and cognitive enhancement (Chapter 7). Consistent with the previous literature, it was demonstrated that consumption of breakfast, compared to fasting, significantly enhanced measures of mood and cognition.

Chapters 8 and 9 discussed the relative merits of the breakfasts investigated, focussing on the effects of the macronutrients consumed. It was demonstrated that the amount of carbohydrate consumed was found to be a critical factor for both mood and cognitive enhancement. High carbohydrate breakfasts had an overall negative effect on mood over the morning. SAG was significantly associated with enhanced memory towards the end of the morning. Furthermore, the interaction between the carbohydrate consumed and the individual's glucose tolerance and physiology was critical. Individuals with poor glucose tolerance demonstrated significantly different blood glucose profiles and cognitive performance compared to those with good glucose tolerance.

A more general objective was to recommend a breakfast that would be optimal for mood and cognitive enhancement. In the discussion chapters (8 and 9) it was suggested that consumption of a breakfast with less than 35g of carbohydrate was beneficial for enhanced mood, in conjunction with a low fibre intake. Light breakfasts, between 101and 300Kcal, appeared to beneficial to mood. The association between carbohydrate and protein was important in reducing hunger.

Rather than the amount of fat, protein, fibre and calories consumed, the memory effects observed reflected the macronutrients influence on blood glucose levels. The amount and type of carbohydrate consumed, and the relative changes in blood glucose levels, were major predictors of memory performance. Furthermore, when those with poorer memory were analysed, the ability to utilise blood glucose effectively, demonstrated by falling and low blood glucose levels towards the end of the morning, was predictive of enhanced memory. Those whose blood glucose levels remained higher over time demonstrated significantly lower recall scores. This is consistent with previous research (Donohoe and Benton, 1999b; Kaplan et al., 2000; Manning et al., 1990).

A point of interest is that the macronutrients and meals associated with enhanced performance on the Rapid Information Processing Task (RIPT) were not the same as observed with enhanced performance with respect to memory. It seems that different aspects of the diet may selectively influence particular aspects of cognition.

The present thesis concluded that the amount and type of the carbohydrate consumed, and the interaction with individual differences in the ability to utilise the carbohydrate consumed, were critical factors for the enhancement of mood and cognitive performance.

1.2 THE ENERGY REQUIREMENTS OF THE BRAIN

Although the adult human brain represents only 2% of total body weight, when at rest the brain accounts for about 20% of the resting metabolic rate, 15% of cardiac output, 25% of oxygen consumption and consumes approximately 17 calories per 100 grams brain tissue per minute (Siebert et al., 1986).

The brain has limited stores of glucose; cerebral stores would only satisfy demands for approximately 10 minutes (Marks and Rose, 1981), it therefore relies on a continuous supply of glucose from the blood (Krassner, 1986). Furthermore, the glycogen that is stored in small amounts in the brain (2-4mmol/L) would only sustain functioning for approximately 3 minutes (Siejso, 1978). Under normal conditions the energy requirements of the brain are met by glucose degradation (Weiss, 1986; Siejso, 1978), however, during prolonged starvation the brain is capable of utilising other metabolic fuels such as ketones (Owen et al., 1981; Gottstein et al., 1970).

The brain oxidises approximately 120 grams of glucose per day, thus it requires a high rate of blood supply, about 50ml of blood per 100 grams of brain tissue per minute. Skeletal muscle only requires 5ml per 100 grams of tissue per minute at rest and matches the brain during vigorous exercise.

Only 30% of glucose is required for direct energy production; the remainder being used for the synthesis of amino acids, lipids, peptides and nucleic acids (Siebert et al., 1986). For example, glucose is critical for the synthesis of serotonin, acetylcholine and noradrenaline.

1.2.1 GLUCOSE TRANSPORT MECHANISMS

With the exception of the Proximal Tubules of the Kidney and the Lumen of the small intestine, the transport of glucose across cell membranes occurs by a process of facilitated (carrier mediated) diffusion (Pessin and Bell, 1992). Facilitated diffusion is not energy dependent; it involves specific carrier proteins to take glucose across the membrane. To date seven membrane-spanning proteins have been identified: GLUT 1 (erythrocyte), GLUT 2 (liver, kidney and pancreatic β-cells), GLUT 3 (brain), GLUT 4 (heart, skeletal muscle, adipose tissue), GLUT 5 (small intestine), GLUT 7 (liver microsomes) and most recently GLUT 8 or GLUTX 1 (skeletal muscle, heart, small intestine and brain) (Choeiri et al., 2002).

GLUT 1, GLUT3 and GLUT4 are found in abundance in several brain regions (Choeiri et al., 2002; Vannucci et al., 1998; 1997; Rayner, 1996). Although GLUT 1 and GLUT 3 are the principle glucose transporters in the brain. GLUT 1 mediates transport across the blood-brain barrier (BBB). GLUT 3 is the principal neuronal glucose transporter, which has a higher affinity for glucose that GLUT 1, this ensures the efficient uptake of glucose by neurones even when extra-cellular levels of glucose are low (Pessin and Bell, 1992; see Vannucci et al., 1997 for a review).

GLUT 4 is an insulin-sensitive glucose transporter (Vannucci et al., 1997). The release of insulin into the blood stimulates GLUT 4 transporters to allow glucose entry into muscles for storage, however, the brain does not increase its uptake of glucose (Marks and Rose, 1981). Insulin does not influence transport across the BBB (Buschiazzo et al., 1970), however, insulin does cross the BBB and insulin receptors have been located in the brain (Schwartz et al., 1992).

1.2.2 FROM BLOOD TO BRAIN

Glucose transport across the blood-brain barrier is an equilibrating mechanism and as such, plasma glucose levels can be expected to reflect blood glucose concentrations (Lund-Anderson, 1979). As glucose can move in both directions the net glucose transport will be in the direction of the concentration gradient, normally from the blood to the brain. The rate of glucose transport across the barrier is two to three times that of the rate of glucose utilisation; glucose metabolism is not limited by transport into the brain (Pardridge, 1983; Lund-Anderson, 1979).

It has been calculated that it takes about 7-15 minutes for equilibrium to form after a change in the level of blood glucose (Lund-Anderson, 1979). At high glucose concentrations carrier-mediated transport is down regulated (Gjedde & Crone, 1981). Brain extra-cellular glucose levels follow the levels of glucose in the blood (Pelligrino et al., 1992; Duchrow,

1988) and typically are about 25% of blood concentration. As an example when an infusion of glucose increased the concentration in the blood by 300% there was a 200% increase in extracellular glucose in the hippocampus (Harada et al., 1993).

Once glucose enters the cell it is broken down by the process of glycolysis. The uptake of glucose into cells is limited by the phosphorylation of glucose by hexokinase, the rate limiting enzyme in the glycolytic pathway. When cerebral functioning is increased, or there is a marked reduction in circulating glucose levels (i.e. hypoglycaemia), glycolysis can become transport limited (Pardridge, 1983). When glycolysis in the brain exceeds the rate of transport into the brain, a reduction in the concentration of cerebral glucose will occur, that leads to an acceleration in the rate of glucose transported into the brain (Pardridge, 1983; Lund-Anderson, 1979). Capillary recruitment is the most likely mechanism by which glucose levels are increased in the brain (Hawkins et al., 1983; Lund-Anderson, 1979). It is well established that regional cerebral glucose utilisation and regional cerebral blood flow are coupled (Hawkins et al., 1983), and that more metabolically active nuclei contain more capillaries than the less active (Cragie, 1920).

1.2.3 GLUCOSE CONSUMPTION WITHIN THE BRAIN

Glucose consumption within the human brain has been measured by the use of Positron Emission Tomography (PET) studies. This technique monitors the uptake of the glucose analogue deoxyglucose (DG) by the brain. DG competes with glucose for the enzyme hexokinase and becomes trapped in the metabolically active tissue, allowing active brain areas to be established.

PET studies have demonstrated that when faced with cognitive demand, alterations in the rate of glucose utilisation within particular brain regions occur rapidly. Phelps et al., (1981) demonstrated that listening to music increased the use of glucose in the temporal lobes. As mentioned previously, increased blood flow via capillary recruitment increases the provision of blood glucose and hence metabolically active areas (Hawkins et al., 1983; Lund-Anderson, 1979).

An understanding of the supply of glucose to the brain has traditionally been based on two assumptions. Firstly that the brain can be viewed as a single compartment; that is the level of glucose is the same throughout the brain (Lund-Anderson, 1979; Sokoloff et al., 1977). Secondly that the level of glucose does not vary; the capacity to transport glucose exceeds the demands placed on the brain (Lund-Anderson, 1979). However these assumptions create substantial difficulties in explaining how the administration of glucose, both centrally and peripherally, can enhance cognition.

McNay et al., (2001) reported that the level of striatal extracellular fluid (ECF) in resting rats was lower than that measured in the hippocampus (0.71mM compared to 1.0mM; McNay and Gold, 1999). Furthermore, when measured during cognitive testing the level of glucose declined by 30% in the hippocampus, but increased by 9% in the striatum. McNay et al., (2001) suggested the fall in hippocampal glucose reflected cognitive load, as a comparable fall would have been observed in the striatum if the fall was due to motor activity. Thus, the level of glucose in the brain has been shown to vary from area to area.

McNay et al., (2000) demonstrated that the level of hippocampal extracellular glucose was susceptible to the cognitive demand of a task. Glucose levels declined by 32% while running a four-arm maze, compared to 11% when rats learned a simpler three-arm maze. Similar declines of approximately 30% were demonstrated in a subsequent study (McNay et al., 2001). Glucose administration prevented the fall in glucose levels and was found to enhance maze learning, however, when at rest the hippocampal concentrations showed no change. McNay et al., (2001) suggested that supply does not meet demand under periods of increased cognitive load but that pre-treatment with glucose allows a reserve to be stored.

Hence recent findings suggest that the brain can no longer be viewed as a single compartment; extracellular glucose is differentially controlled in various areas of the brain. Additionally these recent findings add credence to previous suggestions that administration of glucose enhances cognitive functioning by increasing the blood supply to metabolically active areas of the brain, and that pre-treatment prevents depletion during demand (McNay et al., 2001).

1.3 GLUCOSE AND COGNITIVE FUNCTIONING

1.3.1 THE ROLE OF ADRENALINE AND GLUCOSE IN MEMORY ENHANCEMENT

The role of glucose in memory modulation was first demonstrated in animal experiments investigating the modulation of memory by drugs and other treatments. It was demonstrated that adrenaline, a catecholamine released from the adrenal medulla in response to arousing situations, when administered shortly after training, could enhance memory consolidation (Gold, 1992; McGaugh and Gold, 1989; Gold et al., 1986; Gold and van Buskirk, 1975). Delayed injections of adrenaline, however, had no such effect, suggesting that its release needed to occur soon after the training experience.

Wenk (1989) introduced four related types of evidence supporting glucose as the mechanism by which cognitive-enhancing drugs and peripheral hormones (especially adrenaline) effect memory. Firstly, some cognitive enhancing drugs do not cross the blood-brain barrier, this is true of adrenaline. Secondly, others are effective when injected peripherally but not when injected centrally into the brain. Thirdly, many cognitive enhancing drugs are not effective following adrenalectomy, consistent with adrenaline being a mediating mechanism. Finally, cognitive functioning is correlated with glucose regulation in aged animals and humans.

Both adrenaline and glucose administration have been found to enhance memory storage in an inverted-U dose response manner (Hall and Gold, 1986) and is time-dependent (Gold, 1991). Messier and White (1987) demonstrated that injections of 2g/kg glucose enhanced memory in rats, but 1g/kg or 3g/kg did not. The inverted-U response demonstrates that low and high doses either interfere with or fail to effect memory, while intermediate doses enhanced memory processes (Gonder-Frederick et al., 1987). Parsons and Gold (1992) demonstrated that in healthy aged humans a dose of 25 grams significantly improved memory, whilst 0, 10 and 50 grams failed to produce an effect.

A major physiological consequence of adrenaline release is the release of glucose from hepatic stores (gluconeogenesis) and the suppression of insulin secretion (Nakaki et al., 1981). Gold (1992) demonstrated that when glucose was injected shortly after training the effects were comparable to those observed after adrenaline. Gold (1992) concluded that the effects observed by adrenaline on memory modulation were mediated by increases in blood glucose levels.

However an important difference between adrenaline and glucose is that adrenergic antagonists do not block the effects of glucose on memory (Hall and Gold, 1992; Hall, Vogt and Gold, 1986). Messier and Destrade (1988) and Hall and Gold (1990) demonstrated that post-training injections of glucose in de-medullated animals matched the results of normal animals. Furthermore Lee et al., (1988) demonstrated that intracerebroventricular microinjections of glucose enhanced memory in rats.

1.3.2 GLUCOSE AND THE ENHANCEMENT OF MEMORY IN ANIMALS

Raising peripheral blood glucose levels, either by injection or feeding, has been found to enhance various aspects of memory in rodents, with both appetitive and aversive tasks (Packard, Hirsh and White, 1989; Gold, Vogt and Gold, 1986; Messier and White, 1984; 1987; Huston, Mondadori and Waser, 1974). Additionally both pre- (Ragozzino, Parker and Gold, 1992) and post-training (Gold, 1986; Messier and White, 1984; 1987) glucose supplementation has enhanced subsequent memory performance.

Storage of new information with inhibitory avoidance tasks (Gold, 1986; Stone, Rudd and Gold, 1990), conditioned emotional response (Messier and White, 1987) and appetitive learning (Packard and White 1990; Packard Hirsh and White, 1989) has been improved after the administration of glucose. However, as mentioned previously, the effects of glucose, as with adrenaline, are time-dependent. Gold (1986) demonstrated that the efficacy of glucose weakens between 10-60 minutes after training. Gold (1992) reported that injections of glucose given 60 minutes post-training had little effect when compared to a saline control.

Glucose administration has also been demonstrated to enhance retrieval (Rodriguez et al., 1993; Stone, Rudd and Gold, 1990; 1992) and the encoding of information into working memory (Means and Fernandez, 1992).

1.3.3 GLUCOSE AND THE ENHANCEMENT OF MEMORY IN HEALTHY ELDERLY ADULTS

It has also become apparent that the ability to retain recently acquired information declines with age. Memory retention for a variety of tasks, for example inhibitory avoidance and spatial memory, decays quicker in aged rodents than in younger animals (Stone, Rudd and Gold, 1992; Sternberg et al., 1985).

Given the amelioration of memory in aged rodents, and the relative safety of glucose as a treatment, focus turned to examining the effectiveness of glucose consumption in regulating cognitive functioning in healthy elderly humans.

Gonder-Frederick et al., (1987) demonstrated that the consumption of a glucose beverage (50g) increased recall of the narrative memory sub-tests of the Wechsler Memory Scale. The same dose was found to enhance performance of logical memory (Manning et al., 1990; Hall et al. 1989) and long-term memory (Manning et al., 1990), suggesting that glucose influenced more than one aspect of declarative memory. Hall et al., (1989) noted in the elderly that although improvement in memory was observed following the glucose drink (50g), performance was still inferior to that observed in the young adult sample.

Subsequent studies by Manning et al., (1997) demonstrated that while glucose (50g) enhanced performance on explicit declarative memory (paragraph recall), no effect was observed with implicit verbal memory (word-stem completion), replicating previous findings (Hall et al., 1989; Manning et al., 1990). Manning et al., (1997) also compared the performance of a young adult sample on the same tests and found no difference in performance between the glucose and saccharin conditions.

Manning et al., (1992) demonstrated that recall was significantly improved 24hr later when glucose was administered before and after memory acquisition (50g). Glucose facilitated memory storage, effects were evident 24hr after treatment when blood glucose levels had returned to baseline. A subsequent study (Manning et al., 1998) demonstrated that glucose (50g) could also enhance memory retrieval 24hr after treatment.

With respect to declarative memory the studies reviewed above have therefore demonstrated that glucose enhances memory when administered both before and after learning, and immediately before retrieval. However, short-term memory and non-memory tasks in the elderly (Manning et al., 1990) have not been influenced by glucose administration.

1.3.4 GLUCOSE AND THE ENHANCEMENT OF MEMORY IN HEALTHY YOUNG ADULTS

Considerable evidence has been obtained in both animals and humans suggesting that the consumption of a glucose beverage can enhance memory. The extent to which this phenomenon also occurs in healthy young volunteers, with no prior memory, impairments has yielded mixed findings. Studies performed have used various designs, for example different sample sizes and time scales of the experiments. No systematic study has determined the dose-response in a young, healthy adult population. In addition, the tests used have often been specifically designed to detect abnormalities, such as memory deficits resulting from brain trauma, and not the normal functioning of healthy individuals.

Lapp (1981), using a paired-associate paradigm, demonstrated that those with high blood glucose levels (>7mmol/L) recalled more paired-associates following a carbohydrate rich breakfast than those with low levels (<4.4mmol/L). Subsequently, Benton and Owens (1993) and Benton et al., (1994) demonstrated that high blood glucose levels were associated with enhanced word list and story recall. Craft et al., (1994) reported that increased glucose provision was significantly associated with enhanced performance on declarative memory, but not procedural or working memory. Donohoe and Benton (1999a) reported increased verbal fluency following consumption of a glucose beverage (50g). In addition, high baseline blood glucose levels (prior to the glucose drink consumption) have also been found to enhance cognitive functioning (Donohoe and Benton, 1999a; Parker and Benton, 1995; Benton and Owens, 1993).

Foster et al., (1998) demonstrated that tests of long-term verbal memory (free and cued recall) were the most susceptible to glucose administration in young adults. In contrast, measures of long-term non-verbal memory (complex figure reproduction) and short-term verbal memory (digit recall) were unaffected. Previous research with healthy elderly samples has also demonstrated similar effects with long-term verbal memory (Messier and Gagnon, 1996; Manning et al., 1992; Hall et al., 1989). In animals, glucose has been found to influence tasks dependent on hippocampal functioning (Winocur and Gagnon, 1998), for example long-term declarative (verbal) memory.

Conversely, falling blood glucose levels have also been associated with the enhancement of cognitive functioning. Donohoe and Benton (1999a) reported quicker completion of the Block design and Porteus Maze tests when blood glucose levels were falling. In a subsequent study (1999b) the authors demonstrated that rapidly falling blood glucose levels were associated with enhanced memory and performance on the RIPT. Benton et al., (1994) reported enhanced memory and quicker reaction times, and Parker and Benton (1995) demonstrated enhanced performance on a dichotic listening task in those whose blood glucose levels were falling.

On closer examination of the test procedures, it was found that high blood glucose levels were associated with enhanced cognitive functioning when the participants were allowed to sit quietly for 15-20 minutes following consumption of the glucose beverage. When falling blood glucose levels predicted better performance, testing, or a practice test, took place immediately after the consumption of the drink. Donohoe and Benton (1999a; 1999b) suggested that when cognitive demands are placed on the participants, rapidly falling blood glucose levels predict enhanced performance.

Typically enhancement of memory through glucose consumption has been reported following overnight fast (Donohoe and Benton, 1999a; 1999b; Foster et al., 1998; Hall et al., 1989). However, Benton and Owens (1993) imposed no dietary restrictions and reported memory enhancement following glucose consumption (50g). Martin and Benton (1999) demonstrated that memory improvements were observed when glucose (50g) was administered following overnight fast, but not when breakfast was consumed prior to the glucose drink. The authors added that consumption of the glucose drink in those who fasted brought memory performance to levels comparable to those who consumed breakfast. Sunram-Lea et al., (2001) demonstrated that glucose administration (25g) enhanced memory following both an overnight and a two-hour fast, indicating the beneficial effects of glucose can be observed in a natural environment, as well as laboratory settings. Sunram-Lea et al., (2001) suggested a possible glucose 'overload' to account for the lack of memory enhancement following breakfast in Martin and Benton (1999).

1.3.5 COGNITIVE DEMAND

The cognitive demand of a task reflects the complexity and duration of the task. Complexity refers to the difficulty of the task: Benton et al., (1994) found glucose provision influenced the difficult (incongruent) but not easy trials of the Stroop test, whereas Benton and Owens (1993) found glucose enhanced choice but not simple reaction times. Donohoe and Benton (1999a) reported that the more difficult versions of the Porteus Maze and Block Design test were influenced by glucose administration. In addition blood glucose levels also influenced performance over time: Keul et al., (1982) found a glucose drink benefited performance on a driving simulator, but only after 70km. Benton (1990) and Benton et al., (1994) reported that blood glucose levels influenced performance on a vigilance task, but only towards the end of the test.

Kennedy and Scholey (2000) demonstrated that glucose (25g) only improved the task rated as the most demanding that created the greatest increase in heart rate. In a subsequent study, Scholey et al., (2001) demonstrated that glucose preferentially enhanced the task with the greatest cognitive demand, a serial subtraction task. The results are consistent with previous research that suggests a relationship between falling blood glucose levels and task performance when the cognitive demand of the task is high.

1.3.6 INDIVIDUAL DIFFERENCES IN GLUCOSE TOLERANCE AND MEMORY

Previous research therefore has suggested that cognitive facilitation is associated with an individual's ability to control blood glucose. Good glucose tolerance has been shown to benefit memory in healthy young adults (Donohoe and Benton, 2000; Messier et al., 1999; Parker and Benton, 1995; Benton et al., 1994), healthy aged adults (Messier et al., 1997; Manning et al., 1990; Hall et al., 1989), aged rodents (Stone et al., 1990) and diabetics (Meneilly et al., 1993).

Typically, blood glucose levels rise for about 30 minutes following consumption of a sugar-containing beverage, and then fall, returning to baseline levels after approximately two hours. The same pattern can be observed following food consumption. Individuals with poor glucose tolerance, whose blood glucose reaches high levels and then fall slowly, have been found to score more poorly on memory measures than those with good glucose tolerance.

Craft et al., (1994; 1992) demonstrated that the memory was significantly better in healthy aged participants whose blood glucose levels returned to baseline more quickly than those whose levels remained elevated. Craft et al., (1994) and Messier et al., (1999) reported that good glucose tolerance was beneficial for memory in both healthy elderly and young adults. In addition, Craft et al., (1994) demonstrated that the beneficial effects of memory were observed with declarative, rather than procedural or working memory.

In summary, it appears that the complexity and the duration of the task are susceptible to the level of circulating blood glucose in rodents, the healthy elderly and young adults. However, improvements with glucose administration in the elderly have not always been observed in a younger sample. Manning et al., (1997) suggested that the lack of enhancement in the young subjects was due to an already adequate and fully functional glucose transport system compared to the elderly, who may demonstrate difficulties with glucose regulation. The benefits of glucose may be more easily demonstrated using an elderly sample with a deteriorating memory, reflecting the inability to regulate the neuroendocrine systems responsible for memory storage, and poorer glucose tolerance and peripheral glucose regulation.

1.4 MECHANISMS INVOLVED IN MEMORY ENHANCEMENT

1.4.1 THE LIVER

Given its role in the control of blood glucose levels, the liver may play a role in the cognitive enhancing effect of glucose. Most of the autonomic nervous system messages from the liver to the brain pass through the coeliac ganglion. White (1991) demonstrated that coeliac ganglion lesions completely eradicated the memory enhancing effects of glucose.

The effects of fructose on memory have demonstrated further evidence of a peripheral action of glucose via the liver. Fructose does not cross the blood-brain barrier and does not significantly increase blood glucose levels, yet it has been shown to enhance memory (Rodriguez et al., 1994; Messier and White, 1987). Both fructose and glucose have been found to enhance memory at 2-3g/kg, but only glucose enhanced memory at a lower dose of 20-250mg/kg (White, 1991). These data suggest two mechanisms by which glucose modulates memory; a peripheral one, by which fructose also enhances memory, and a central action. The doses of 25-50g per person suggest the central pathway.
Messier and White (1987) also demonstrated that the glucose analogue 3-O-methylglucose could enhance memory. The analogue is taken into the cell using the same transporter

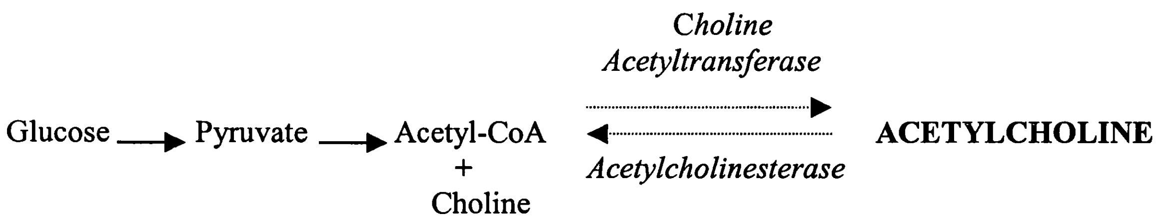
mechanism as glucose, but is not metabolised once in the cell (Jay et al., 1990) and does not increase blood glucose levels. These results demonstrated that the peripheral action of glucose could be initiated by a neural signal produced when glucose binds to a transporter mechanism (Messier and Gagnon, 1996). In addition, low doses of Phlorizin have been shown to enhance memory, suggesting the importance of glucose transport with respect to memory (Hall et al., 1992). Phlorizin has a high affinity for glucose transport molecules in the liver, even though is not transported and does not increase blood glucose levels.

1.4.2 ACETYLCHOLINE

Several studies have also suggested that glucose influences cognitive functioning by a direct action on the brain, independent of any peripheral effect. The association between acetylcholine mediated transmission and memory is well documented (Durkin et al., 1992; Kopelman, 1986). Glucose appears to enhance acetylcholine synthesis and/or release (Ragozzino et al., 1998; 1996; Messier et al., 1990), however, this follows cholinergic hippocampal neurone activation subsequent to learning and memory processing. In addition glucose administration can reverse the memory deficits induced by cholinergic blockade (Messier et al., 1990; Stone et al., 1988).

Acetylcholine is primarily located in the cerebral cortex (Krassner, 1986). It is synthesised in pre-synaptic cholinergic nerve terminals, where the precursors choline and acetylcoenzyme-A (acetyl-CoA) are combined by the enzyme choline acetyltransferase; glucose is the main source of the acetyl groups used in the formation of acetyl-CoA, through oxidation via pyruvate (Tucek, 1985; 1983). In the synaptic cleft acetylcholine is decomposed by the enzyme acetylcholinesterase, which hydrolyses acetylcholine into choline and acetyl-CoA (Figure 1.1). Altering the availabilty of either choline or acetyl-CoA changes the rate at which acetylcholine is synthesised (Fernstrom, 1977).

Figure 1.1 The Synthesis and Decomposition of Acetylcholine



Glucose availability has little effect on acetylcholine levels in continuously fed animals (Kuntscherova, 1972), however, when the demand for acetylcholine is high, an enhanced availability of glucose increases the rate of acetylcholine synthesis (see Messier et al., 1990 for a review). One such situation is learning, where the demand for acetylcholine is increased, particularly in the hippocampus (Durkin, 1989; Bartus et al., 1982).

Messier et al., (1990) demonstrated that glucose significantly reduced increases in choline uptake induced by training in animals, presumably by increasing the rate of acetylcholine synthesis. The release of acetylcholine can be stimulated by drugs that block pre-synaptic muscarinic receptors, as both atropine-induced (Dolezal and Tucek, 1982) and quinuclidinyl benzilate-induced (Ricny et al., 1992) acetylcholine depletion have been observed following glucose administration. Subsequently Durkin et al., (1992) provided the first direct experimental evidence that raised glucose levels facilitate acetylcholine synthesis under conditions of increased neuronal activity in the rat brain.

Taken with the evidence that glucose administration attenuates the amnesia induced by scopolamine (Kopf and Baratti, 1994; Messier et al., 1990; Stone, Rudd and Gold, 1990; Stone et al., 1988), it is clear that under periods of increased neuronal activity, glucose-induced increases in acetylcholine synthesis can benefit memory and cognitive functioning.

Furthermore, cholinergic mechanisms are important in the regulation of blood glucose levels; mechanisms in the hippocampus send neural messages to the adrenal medulla to release adrenaline, that stimulates the release of glucose into the blood stream from the liver. In aged rats the ability of hippocampal cholinergic mechanisms to stimulate the release of glucose from the liver declines (Umegaki et al., 2000).

1.4.3 OTHER CENTRAL MECHANISMS

Opiates

Opioids also inhibit the release of acetylcholine from cholinergic neurons. Injections of opioid agonists have been shown to decrease acetylcholine turnover in the hippocampus (Botticelli and Wurtman, 1982; Schmidt and Buxbaum, 1978). Stone et al., (1991) demonstrated that injections of glucose reversed the amnesic effects of morphine. Peripheral and central intraseptal injections of glucose attenuated deficits caused by intraseptal injections of morphine (Ragozzino et al., 1992). Ragozzino et al., (1994) reported that morphine significantly reduced the output of acetylcholine in the hippocampus, with glucose alleviating the effect. Glucose appears to act by reversing the decrease in cholinergic neuronal activity following morphine injection (Ragozzino and Gold, 1995).

Potassium Channel

Amoroso et al., (1990) hypothesised that increased glucose availability increases the level of ATP within neurones blocking K^+ATP channels; hyperglycaemia increases the level of ATP within neurones blocking K^+ATP channels, whereas hypoglycaemia results in a decreased release of the transmitter. As potassium channels are found in the cortex, striatum, hippocampus and septum (Zini et al., 1993), the blockage of these channels by glucose administration is another possible central mechanism by which glucose enhances cognitive functioning (Stefani and Gold, 2001; Stefani et al., 1999).

Dopamine

Blood glucose levels have been shown to alter the reaction to dopaminergic drugs such as amphetamine (Campbell and Fibiger, 1971) and haloperidol (Saller and Koppin, 1981). Both D1 and D2 agonists increase brain glucose concentrations and a D2 agonist increases the levels in the blood (Saller and Kreamer, 1991). Colantuoni et al., (2001) demonstrated in rats given a 25% glucose solution, that D1 binding increased in the accumbens core and shell, with D2 binding decreasing in the hippocampal regions. Excessive sugar intake sensitised dopamine receptors in a similar manner to drugs of abuse.

Galanin

Galanin is a peptide found in mammalian brains. In the rat brain galanin has been associated with acetylcholine in a sub-population of neurones that project to the hippocampus (Melander et al., 1986), galanin receptors are found throughout the forebrain, including the hippocampus and amygdala (Skofitsch and Jacobowitz, 1985). Hiramatsu et al., (1996) have demonstrated that intra-cranial administration of glucose reduces cholinergic activity and impairs the memory of rats. Stefani and Gold (1998) demonstrated that glucose could attenuate the deficit in memory and acetylcholine synthesis brought about by galanin.

Fibroblast growth factor

Oomura et al., (1993) reported that the level of acidic fibroblast growth factor (aFGF) increased 1000 times in the two-hours following either food intake or glucose administration, either peripherally or into the ventricles. Introduction of aFGF into the ventricles decreased food intake in a dose dependent manner. The ability of glucose to facilitate various learning tasks in rats was abolished by pre-treatment with aFGF antibody.

In conclusion, many mechanisms have been implicated in the role of glucose and its amelioration of memory deficits. Rather than one single mechanism acting alone, it appears that a sequence of effects subsequent to glucose administration act on both central and peripheral mechanisms.

1.5 INSULIN AND THE BRAIN

To date insulin has largely attracted attention because of its peripheral mechanism. However, Park (2001) argued that insulin can act via insulin receptors located in the brain. Traditionally the brain was thought to be insulin-insensitive, as insulin was not found to influence glucose transport across the blood-brain barrier (Betz et al., 1973; Buschiazzo et al., 1970) or affect brain glucose utilisation (Frank and Pardridge, 1983). However, Hoyer et al., (1996) more recently has demonstrated that insulin can promote glucose utilisation in the hippocampus, thus challenging earlier findings.

1.5.1 INSULIN AND ITS ACTIONS WITHIN THE BRAIN

Insulin, a peptide hormone, is released by the pancreas in response to increased levels of metabolic fuels in the blood. Any increase in glucose will be associated with a release of insulin. Many peripheral tissues are described as being insulin sensitive; insulin stimulates the uptake of metabolic fuels and their conversions to glycogen, triglycerides and protein (Kahn, 1985). The insulin-sensitive glucose transporter GLUT-4 controls the majority of glucose uptake into peripheral tissues (Simpson and Cushman, 1986).

GLUT 1, found in the blood-brain barrier, is not insulin-sensitive, however there is evidence that insulin influences other aspects of neural functioning. There are two main types of insulin receptor in the adult mammalian brain, the first and most immuno-reactive is found on neurones (Unger et al., 1991) and the second peripheral type is found on glial cells (Adamo et al., 1989). High levels of insulin receptors have been found in the olfactory bulb, cerebral cortex, hippocampus, cerebellum and hypothalamus (Baskin et al., 1993; Unger et al., 1991; Havrankova et al., 1978). In the hippocampus insulin binding sites are detected in the molecular layer of the dentate gyrus (Baskin et al., 1993; Unger et al., 1991). These areas within the brain also have the highest levels of extractable insulin (Schwartz et al., 1992; Baskin et al., 1983).

The insulin-sensitive transporter GLUT4 has also been located in the cerebellum, olfactory bulb and dentate gyrus of the hippocampus in the mouse brain (Vannucci et al., 1998), which confirms the presence of GLUT 4 in the rodent brain (McCall et al., 1997; Leloup et al., 1996; Campbell, et al., 1995). Exogenous insulin, which acts via the insulin receptors, has been demonstrated to stimulate glucose metabolism in the hippocampus (Hoyer et al., 1996).

More recently transport of insulin from plasma to CSF has been demonstrated in rodents (Banks et al., 1997a; Steffens et al., 1988), rabbits (Duffy and Pardridge, 1987) and dogs (Baura et al., 1993; Schwartz et al., 1990). In addition the transport of insulin into the brain has been observed both following a meal (Schwartz et al., 1992) and after peripheral glucose administration (Banks and Kastin, 1998; Banks et al., 1997a; Schwartz et al., 1990; Steffens et al., 1988). The uptake of insulin into the CNS reflects an active transendothelial transport across the blood-brain barrier (BBB) (Banks et al., 1997a; Schwartz et al., 1990), which is thought to be specific to insulin (Banks and Kastin, 1998) and is saturated at levels of insulin associated with euglycaemia (Banks et al., 1997b). Evidence for the synthesis of insulin in the adult brain has proved to be inconclusive (Park, 2001).

It therefore appears that the mechanisms controlling peripheral blood glucose are separate from those controlling insulin uptake in the brain. However insulin has been found at high levels in the brain, and areas dense in insulin receptors have been identified within the CNS, suggesting that insulin binding is a receptor-dependent process (Park, 2001).

1.5.2 INSULIN RESISTANCE

Hippocampal glucose metabolism has been demonstrated to be insulin-sensitive (Hoyer et al., 1996). Furthermore, insulin is thought to directly influence enzyme activity involved in various aspects of carbohydrate metabolism; glycolysis, glycogen synthesis and gluconeogenesis (Dimitriadis et al., 2000). Thus, the ability to control and regulate insulin efficiently is attracting increasing interest in the cortex of the glucose enhancement of cognitive functioning.

Insulin resistance is a reduced sensitivity of tissues to the action of insulin. When insulin resistance, or reduced insulin sensitivity exists, the body attempts to overcome this resistance by secreting more insulin from the pancreas. This compensatory state of hyperinsulinemia (high insulin levels in the blood) is a marker for insulin resistance.

Insulin resistant individuals can be glucose tolerant at the same time, if the pancreas secretes large amounts of insulin, however, this can predispose towards heart disease and often leads to Type II diabetes when the pancreas can no longer keep up the production of insulin. Hyperinsulinemia (high insulin levels in the blood) often precedes the onset of

Type II diabetes, however, only a minor proportion of individuals who are insulin-resistant develop Type II diabetes.

1.5.3 INSULIN AND COGNITION

More importantly, insulin resistance has been associated with disruption of cognitive functioning, and may play a role independently of glucoregulation in the brain. It has been suggested that the insulin receptor may be associated with age-related problems of memory. Given that high levels of insulin receptors have been found in the hippocampus, an area associated with memory processing and formation (Unger et al., 1991), insulin may play a beneficial role in cognitive enhancement.

Impaired insulin activity has been implicated in Alzheimer's Disease (AD), with the number of insulin receptors and insulin concentration being reduced (Frolich et al., 1998). Craft et al., (1998) reported that AD patients have lower CSF (cerebrospinal fluid) and higher plasma levels of insulin, so the ratio between CSF and plasma is lower. In addition Craft et al., (1996) found that the administration of insulin enhanced memory in AD patients whose plasma glucose levels were kept constant. Patients with AD also show impaired glucoregulation (Hoyer et al., 1991).

Animal studies have demonstrated that the beneficial action of glucose may be mediated, in part, by the associated release of insulin. Messier and Destrade (1994) reported that the anti-amnesic effects of scopolamine could be reversed by injections of insulin. Injections of streptozotocin, which decreases insulin release from the pancreas, have been found to impair memory (Lannert and Hoyer, 1998). Park et al., (2000) demonstrated that injections of insulin into the ventricles increased the memory of rats for a passive-avoidance task.

To date there are limited data in healthy subjects, however, Kern et al., (2001) demonstrated that insulin facilitated word list recall and performance on the Stroop task. The authors went on to suggest that insulin may act by increasing attention, rather than facilitating memory per se.

Frolich et al., (1998) demonstrated that a disturbance in the insulin/insulin receptor signal transduction pathway reduced the glucose/energy metabolism in the brains of AD patients. Thus the reduced insulin receptor responses may have a possible effect on memory processes through decreased glycolysis and hence decreased acetylcholine production (Hoyer, 1994).

1.6 CONTROLS OF FOOD INTAKE

Food intake is determined by a complex interaction of psychological, physiological, cultural, emotional and social factors (Melanson et al., 1999a; Blundell, 1991). Hunger, meal initiation, meal duration and satiety are major factors of what, and how much is consumed (Carlson, 1999). The mechanisms by which these processes are initiated and terminated have received much interest.

A number of factors have been implicated in the initiation and control of food intake. Research has focussed on peripheral cues of hunger and satiety, such as stomach contractions (Cannon and Washburn, 1912; Cannon, 1929), stomach distension and oral stimulation (Janowitz and Grossman, 1949), gastrointestinal factors, in particular CCK (cholecystokinin) (Weller, Smith and Gibbs 1990; Smith and Gibbs, 1994), pancreatic hormonal signals including glucagon (Flint et al., 1998) and insulin (Woods et al., 1996) and receptors along the gastric process, especially in the stomach and the intestines (Ritter, Brenner and Yox, 1992), sham feeding and intragastric feeding (Greenberg, Smith and Gibbs, 1990; Deutsch and Gonzalez, 1980). Attention has also focussed on specific sites within the brain; the lateral hypothalamus was implicated in hunger (Anand and Brobeck, 1951; Teitelbaum and Epstein, 1962) and the ventromedial hypothalamus with satiety (Hetherington and Ranson, 1942), however, both regions play excitatory and inhibitory roles with regard to food intake.

1.6.1 THE ROLE OF GLUCOSE IN FOOD INTAKE

The role of hunger in meal initiation has received great interest, especially related to increases and decreases in blood glucose levels. Mayer (1955; 1953) developed the Glucostatic Theory of Hunger which suggested that circulating blood glucose levels act as signals to the brain indicating when more energy is required. Blood glucose levels increase rapidly following food intake, and then gradually fall back to, or below, baseline. Using arteriovenous differences, Mayer (1953) found that blood glucose correlated with feelings of hunger and satiety in both normal and diabetic participants. However, subsequent studies failed to replicate the findings (Bellinger et al., 1977; VanderWeele et al., 1974;

Van Itallie and Hashim, 1960; see Van Itallie, 1990 for review), but did find that plasma insulin levels were at their lowest just prior to onset of food intake (Strubbe et al., 1977).

Niijima (1983) and Oomura (1983) identified several sites in the brain that receive direct messages regarding changes in blood glucose concentrations. As the brain needs a continual supply of glucose these receptors provide a complete picture of brain blood glucose patterns during the day (Campfield and Smith, 1990).

Further evidence for a glucose dependent process has been demonstrated with the use of 2-deoxy-D-glucose (2-DG) (Thompson and Campbell, 1977). Smith and Epstein (1969) demonstrated in rodents that following the injection of 2-DG, which deprives the cells of glucose, there was a dramatic increase in food consumption. However Ritter and colleagues (1978; see Ritter, 1986 for review) suggested that the glucoprivation might not be the sole reason for initiation of eating, it may be part of a pattern or bigger picture.

Louis-Sylvestre and Le Magnen (1980) demonstrated a decline in blood glucose levels just prior to meal on-set in free-feeding rats. Using a continuous online remote sampling of blood glucose, Campfield and colleagues (Campfield et al., 1996; 1986; 1985) replicated in normal, diabetic and obese rats, earlier findings of a "transient decline in blood glucose" that was causally related to meal initiation, but not the amount consumed (Campfield and Smith 1990a; 1990b). Campfield et al., (1985) demonstrated that an intravenous infusion of glucose undermined the pre-meal decline in blood glucose. A transient decline in blood glucose has been found to precede the onset of a meal even when the rat has been sleeping, once the blood glucose levels start to return to baseline food consumption begins (Campfield et al., 1990a).

This phenomenon has also been observed in humans, following both spontaneous and insulin-induced declines in blood glucose. Transient and dynamic declines have been observed just prior to meal requests in both postabsorptive (overnight fast) and postprandial (following meal) states (Melanson et al., 1999; Campfield et al., 1996).

1.6.2 THE METABOLISM OF THE FOODS CONSUMED

Energy expenditure is relatively constant throughout the day, however, food intake occurs on average between two and three times a day. Following a meal there is a plentiful supply of metabolic fuel entering circulation from the gut which lasts for approximately 3-4 hrs.

The fed state

Glucose from carbohydrate digestion and amino acids from protein digestion are absorbed into the hepatic portal vein and carried to the liver, which controls the amount released into peripheral circulation. Digested fats, however, are available to the peripheral tissues before the liver takes control, with the triacylglycerol going directly to adipose tissue to be stored.

The increased concentration of glucose and amino acids in the blood stimulates the secretion of insulin from the β-cells of the pancreas, and suppresses the secretion of glucagon from the α-cells. Insulin has four main actions following food intake:

- stimulates the uptake of glucose by muscle;

- stimulates the synthesis of glycogen;
- stimulates the uptake of glucose into adipose tissue for synthesis of triacylglycerol;
- stimulates the uptake of amino acids into tissues leading to increased protein synthesis.

Carbohydrate is the main precursor of postprandial glucose and insulin (Wolever and Bolognesi (1996). Wolever (2000) reported that large amounts of protein and fat added to glucose affected postprandial responses: protein increases insulin and decreases glucose levels (Gannon et al., 1988; Spiller et al., 1987) and fat is generally considered to reduce glucose and insulin because of delayed gastric emptying (Welch et al., 1987). Such observations have been demonstrated following 25-50g of protein and or 40g of fat when added to 50g glucose (Gannon et al., 1988; Nuttall and Gannon 1990), or by adding 0.5-1g fat and/or 1g protein per gram of carbohydrate to lentils or potato (Welch et al., 1987).

Wolever and Bolognesi (1996) have voiced concerns about the tranferability of laboratory results to normal day-to-day diets. The addition of protein or fat to starchy meals may elicit different effects when added to pure glucose or sucrose meals; it is unlikely that normal day-to-day diets will be protein or fat free. Furthermore, the British Dietary Reference Values suggest that males aged 19-50 years need 55g protein a day, females 45g (approximately 15% of energy intake), with fat intake consisting of 35% of food energy and carbohydrate intake of 50% to maintain a healthy nutritional status.

The fasting state

The postabsorptive, or fasting state, begins only when digestion has been completed, i.e. when the products of digestion have been totally absorbed. Metabolic fuels then enter into circulation from the stores of glycogen, triacylglycerol and protein conserved in the fed state.

Insulin secretion is suppressed when blood glucose levels levels begin to fall. This reduces the rate of glucose uptake into muscle, and glucagon secretion is stimulated.

Glucagon has three main actions:

- stimulates the breakdown of glycogen in the liver, and thus the release of glucose into circulation;
- stimulates lipase in adipose tissue, releasing fatty acids into circulation;
- stimulates the synthesis of glucose from amino acids via gluconeogenesis.

The brain and the red blood cells are dependent on glucose as a metabolic fuel, therefore, other tissues that can utilise other fuels do so sparing glucose for the most metabolically active areas.

Any metabolites that can be used for gluconeogenesis, the synthesis of glucose from non-carbohydrate precursors, supplement the small amount of glucose available from glycogen reserves. Total liver and muscle glycogen can only meet requirements for 12-18 hours. The main substrates for gluconeogenesis are amino acids and glycerol.

The utilisation of fatty acids by tissues occurs to a limited extent, however, the liver is able to oxidise fatty acids (acetoacetate and β-hydroxybutyrate) to a greater extent than required for its own energy requiremtents. Thus in the fasting state, the liver synthesises ketones into metabolic fuel for other tissues.

1.6 CARBOHYDRATE IN THE DIET

1.6.1 CLASSIFICATION OF DIETARY CARBOHYDRATES

Depending on the form of carbohydrate, (Cummings et al., 1997) and its preparation and cooking (Englyst & Cummings, 1987; 1986), dietary carbohydrates are digested and absorbed at different rates, and to different extents, in the small intestine. Englyst et al., (1996; Englyst and Hudson, 1996) presented a new classification of dietary carbohydrates, into sugars, starch and non-starch polysaccharides (NSP), based on *in vitro* measurement. The *in vitro* technique measures the amount of glucose released from a food over a timed period of incubation with enzymes similar to those in the digestive tract.

Dietary sugars and starches are the major suppliers of glucose to the blood. Sugars elicit a high glycaemic response reflecting an almost total and rapid absorption in the small intestine (Englyst et al., 1996). Starches are complex carbohydrates (polysaccharides) which are broken down into glucose by amylolytic enzymes in the small intestine. However all starches are not digested at the same rate and to the same extent.

How quickly the starch is digested differs from individual to individual, reflecting how much the food is chewed (Read et al., 1986), the amount of pancreatic amylase available in the gut (Chapman et al., 1985) and the transport time through the small intestine which may be hindered by other food elements, such as fat and non-starch polysaccharides (Wolever & Jenkins, 1992). Not only this, but the physical form of the starch itself also influences the rate of digestion. Englyst and Cummings (1987; 1986) demonstrated that cooked bananas and potatoes are more readily digested than the raw foods, due to the gelatinisation of the starch within the plant cells during the cooking process. Also Haber et al., (1977) demonstrated striking differences in the glycaemic response to equal amount of apples eaten as pulp, juice or in the natural state.

In classifying dietary carbohydrates, Englyst and colleagues (1999; 1996) have subdivided digestible starch into Rapidly Digestible Starch (RDS), Slowly Digestible Starch (SDS) and Resistant starch (RS). RDS and SDS reflect the magnitude and duration of the glycaemic response, whereas RS is the starch that passes straight into the large intestine (Englyst and Cummings, 1990) having little effect on the glycaemic response. Non-Starch Polysaccharides, or Dietary Fibre, have no glycaemic response themselves, but may effect the response to other carbohydrates.

In addition to this, two forms of glucose have also been classified in terms of their influence on the glycaemic response, Rapidly Available Glucose (RAG) and Slowly Available Glucose (SAG). RAG is the amount of glucose measured after the first 20 minutes of incubation with enzymes similar to those in the digestive tract. RDS values are obtained by correcting RAG for rapidly released free sugars (mono and disaccharides). SDS is the amount of starch digested between 20 and 120 minutes, again SAG is SDS corrected for slowly released free sugars. RS is the difference between starch hydrolysed by 120 minutes and total starch.

RAG and RDS have been found to correlate very highly with Glycaemic Indices for starchy foods with 61% of the glycaemic response measured *in vivo* being explained by RAG measurements *in vitro* (Englyst et al., 1996). Englyst et al., (1999) demonstrated that the percentage change in RAG was associated with the same change in glycaemic response, supporting the hypothesis that RAG is a major determinant of the glycaemic response (MacDonald, 1995).

Both RAG and Glycaemic Index values illustrate how food processing and its original form can influence the digestion and absorption of dietary carbohydrates, however, RAG values give a better indication of the total availability of glucose which may be absorbed.

1.7.2 THE GLYCAEMIC INDEX

The Glycaemic Index (GI) measures the effects of carbohydrate-containing foods on blood glucose (Jenkins et al., 1981), ranking carbohydrate foods based on the postprandial effects on blood glucose. The GI is defined as the area under the glycaemic response curve during a two-hour test period, following consumption of 50g available carbohydrate from the test food, expressed relative to the effect of 50g available carbohydrate from either glucose or white bread (Ludwig et al., 1999; Wolever et al., 1991). However, GI is technically different from the term 'glycaemic response', which refers to an individual's change in blood glucose level following food consumption.

The amount of carbohydrate consumed primarily determines the GI of a food. Other factors that effect food digestibility, such as carbohydrate type, food structure, fat, protein and fibre content, also contribute to the GI (Ludwig et al., 1999). Starch and fibre (Wolever and Jenkins, 1992) influence the rate of gastric emptying and the magnitude of the insulin response (Frost et al., 1993)

High-GI foods typically produce a rapid rise in blood glucose levels, which stay high and produce a large area under the glycaemic response curve. Such foods are rapidly digested, absorbed or transformed metabolically into glucose. Such foods are often highly processed, for example Cornflakes (GI = 84), jelly beans (80), Instant Potato (83) (Bjorck et al., 2000; Foster-Powell and Brand Miller, 1995). Conversely, low-GI foods release glucose at a much slower rate creating little change in blood glucose levels. Typically these are raw foods and intact grains, for example apple (GI = 36), Kidney beans (27), Wholemeal Spaghetti (37) (Bjorck et al., 2000; Foster-Powell and Brand Miller, 1995).

1.7.3 DIETARY FIBRE

Dietary Fibres, or Non-Starch Polysaccharides, are indigestible carbohydrates, which provide bulk in food and slow down the absorption of glucose and nutrients into the blood stream (Jenkins et al., 1984). Foods high in fibre tend to have lower Glycemic Indices and can be beneficial in the management of Diabetes and weight control problems.

It is well documented that high amounts of fibre in the diet decrease subsequent food intake and hunger (Holt et al., 1999; Levine et al., 1989). However, there are studies that have failed to find any effects of ingested fibre on appetite (Silberbauer et al., 1996; Levene and Billington, 1994; Burley, Leeds and Blundell, 1987) possibly due to the use of different doses, methods of administration and types of fibre (Blundell and Burley, 1987).

Fibre supplementation studies initially focused on the satiating effects of fibre given as a preload. Porikos and Hagamen (1986) demonstrated that 35-40 minutes after a high fibre (5.2g crude fibre) preload, obese participants' food intake in a test meal decreased. The preload in this example consisted of part of the test meal of sandwiches made with the appropriate amount of fibre within the bread.

Studies comparing the impact of soluble (psyllium gum) and insoluble fibre (wheat bran, sugar beet fibre) on subsequent food intake have produced mixed results. Stevens et al., (1987) found that ingestion of a high fibre (23g) either soluble or mixed fibre (soluble and insoluble) cracker meal over a two-week period, resulted in a 11% decrease in energy intake when compared to a low fibre (4g) control cracker meal. In additon, Delargy et al., (1997) found high insoluble fibre elicited a greater control on food intake in an ad libitum test session. A common finding is that it is a high dose of fibre (20-30g) reduces subsequent food intake and hunger ratings compared to a low fibre breakfast (0-4g) or fibre preload (Delargy et al., 1995; 1997; Burley et al., 1993).

Holt et al., (1999) reported that participants who consumed All Bran, a food naturally high in fibre (19.1g, present in 74g All Bran) were more alert and ate significantly less food over the test day when compared to another high carbohydrate breakfast (Cornflakes, 1.0g fibre present in 57g) or two high fat breakfasts (egg & bacon, 2.9g fibre; croissants, 1.5g fibre). Additionally, the All Bran breakfast was significantly less pleasant and palatable than the croissants, but significantly more filling than both high fat breakfasts. Similarly Levine et al., (1989) showed that participants who consumed a high fibre breakfast (22.2g present in 57g of Fiber One) significantly reduced their total energy intake over a four hour test period, and were significantly less hungry than those who consumed a low fibre meal (57g of Post Toasties Cornflakes, 0g).

The effects on hunger and food intake, observed after the consumption of fibre, are reported to be different depending on the type of fibre. Soluble fibre is said to delay satiety signals by slowing gastric emptying and nutrient absorption from the small bowel (Di Lorenzo et al., 1988; Read, 1992). Insoluble fibre firstly soaks up the contents of the stomach that produce the feeling of fullness through gastric distension. It also makes waste heavier and thus speeds gastric emptying (Bergmann et al., 1992). However feelings of satiety are not produced by gut distension alone but also reflect the effects of nutrients on chemoreceptors in the small intestine (Read et al., 1994).

1.8 DIETARY INTAKE AND COGNITIVE FUNCTIONING

1.8.1 BREAKFAST AND COGNITION

Studies analysing the effects of breakfast consumption on psychological and cognitive functioning within laboratory settings have reported mixed findings (see Table 1.1). Studies have documented that skipping breakfast has detrimental effects with respect to memory (Benton and Parker, 1998; Smith et al., 1994a; 1992; Benton and Sargent, 1992), yet others have reported no deficit (Cromer et al., 1990; Dickie and Bender, 1982; Richards, 1972), however, this may reflect the different methodologies and tasks used.

The Iowa Breakfast Studies (Tuttle et al., 1949; 1950; 1952; 1954) first demonstrated that skipping breakfast could be detrimental to both physical and cognitive performance in males and females of a variety of ages, however, the studies were relatively uncontrolled, used small sample sizes and produced inconsistent findings between the studies (Dickie and Bender, 1982).

Performance enhancement following breakfast consumption has been demonstrated in subsequent research. Pollitt et al., (1981; 1982/3) reported decreased problem solving ability late in the morning, and Conners and Blouin (1982/3) found decreased performance on arithmetic and continuous processing tasks when breakfast was omitted. Pollitt et al., (1982/3) also reported that the omission of breakfast resulted in better recall, yet this was thought to show an "ineffective cognitive strategy" (Pollitt et al., 1982/3, pp 137) due to the nature of the enhancement.

Table 1.1: The influence of Breakfast on Cognitive Functioning

Authors	N	Sex	Age	Study design	Cognitive Tests	Results
Pollitt et al., (1981)	32	M/F	10	BR/NBR served at 8:00-8:30; crossover after 1wk	IQ – PPVT & SIS; MFFT; HCIT @ 11:15	more errors on MFFT with NBR; higher recall with NBR on HCIT, especially last item
Pollitt et al., (1982/3)	39	M/F	10	BR/NBR served at 8:00-8:30; crossover after 1wk	IQ – PPVT & SIS; MFFT; HCIT @ 11:15	more errors on MFFT with NBR; higher recall with NBR on HCIT
Dickie & Bender (1982)	227; 260;	M/F	12.5; 15.3;	BR/ BR+S/ NBR/ NBR+S	Cancellation test @ 12:00; 14:00	no difference in performance
Dickie & Bender (1982)	108	M/F	16-17	BR/NBR at 7:45 crossover after 1wk	Addition & MAST (55); Sentence verification (53) @ 11:00 on 3 consecutive days	no difference in performance
Conners & Blouin (1982/3)	10	M/F	9-11	BR/NBR on four occasions 1wk apart	CPT; Arithmetic @ 9:50, 11:00, 12:10	both tasks better after BR than NBR
Cromer et al., (1990)	34	M/F	14	BR/NBR at 7:00	IQ; AVLT; MFFT; CPT; STAIC @ 8:00 & 11:00	no difference in performance; BG not correlated with performance
Benton & Sargent (1992)	33	M/F	21	BR (milk based drink)/NBR at 9:00	Spatial memory; Word List @ 11:00	NBR took more time to complete the tests;

BR – breakfast; NBR - no breakfast; AVLT – Rey Auditory-Verbal Scale; BPT – Brown-Petersen Trigram task; BVIP – Bakan Visual Processing Task; CPT – Continuous Processing Task; HCIT – Hagen Central Incidental Test; MAST – Memory and Search task; MFFT – Matching Familiar Figures Test; PPVT – Peabody Picture Vocabulary Test; RDVT – Repeated Digits Vigilance task; SIS – Slossom Intelligence Scale; STAIC – State-Trait Anxiety Scale.

Smith et al., (1992)	48	M/F	-	cooked BR/ NBR	Free recall; Recognition memory task; Logical reasoning; Semantic processing task; RDVT tested before BR, @ 11:30 & 14:00	decreased false alarms on recognition and accuracy on logical mid-morning
Smith et al., (1994)	48	M./ F	-	cooked BR/ NBR (also caffeine vs non)	(1) Simple & Choice RT; RDVT (2) Free recall; Recognition memory task; Logical reasoning; Semantic processing task;	(1) no differences in performance (2)increased word recall; decreased false alarms on recognition; decreased accuracy on logical;
Lloyd et al., (1996)	16	M/F	26	HCLF/ MCMF/ LCHF/ NBR at 8:30	BVIP; two-finger tapping; free recall; simple & choice RT @ 9:00, 10:00; 11:00	NBR no negative effects; no difference between the four conditions
Vaisman et al., (1996)	491	M/F	11-13	habitual BR	AVLT; memory for narrative prose; visual memory @ 8:55 & 9:35	BR increased immediate recall than NBR; no difference on other tests
Vaisman et al., (1996)	503	M/F	11-13	2wk breakfast suppl. study BR/NBR at 8:00-8:20; controls ate habitual B at home	AVLT; memory for narrative prose; visual memory @ 8:55 & 9:35 at end of 2wks	increased performance with BR at school compared to BR at home and NBR

BR – breakfast; NBR - no breakfast; AVLT – Rey Auditory-Verbal Scale; BPT – Brown-Petersen Trigram task; BVIP – Bakan Visual Processing Task; CPT – Continuous Processing Task; HCIT – Hagen Central Incidental Test; MAST – Memory and Search task; MFFT – Matching Familiar Figures Test; PPVT – Peabody Picture Vocabulary Test; RDVT – Repeated Digits Vigilance task; SIS – Slossom Intelligence Scale; STAIC – State-Trait Anxiety Scale.

Benton & Parker (1998)	80; 184	F M/F	23 22	Habitual BR/NBR before lab at 9:00, then 0 or 50g glucose drink	(1) BPT; (2) Word List; Wechsler story; Abstract reasoning test	(1) Glucose drink nullified skipping BR; (2) enhanced memory with BR
Smith et al (1999)	144	M/F	21	BR/NBR (caffeine vs decaff)	Categoric search task; Masked search task; Serial recall; Running memory task; Spatial memory; tested before BR, 30 min and 90 min after	BR better performance on spatial memory only; no effect of BR with search tasks
Benton et al., (2001a)	150	F	21	BR/ BR+S/ NBR/ NBR+S At 10:00	Word Recall BVIP Simple & Choice RT	No effects on memory
Benton et al., (2001b)	408	F	21	Various BR differing in macro and Glycaemic index/ NBR At 10:00	Word Recall BVIP Simple & Choice RT	Fibre associated with enhanced memory
Kissileff et al., (2001)	20	M/F	15-16	220 Kcal/ 350 Kcal (convention vs liquid) 5 trials	Word recall; BPT; testing 3hr after BR	BR enhanced performance

BR – breakfast; NBR - no breakfast; AVLT – Rey Auditory-Verbal Scale; BPT – Brown-Petersen Trigram task; BVIP – Bakan Visual Processing Task; CPT – Continuous Processing Task; HCIT – Hagen Central Incidental Test; MAST – Memory and Search task; MFFT – Matching Familiar Figures Test; PPVT – Peabody Picture Vocabulary Test; RDVT – Repeated Digits Vigilance task; SIS – Slossom Intelligence Scale; STAIC – State-Trait Anxiety Scale.

Richards (1972) reported that deviation from the normal routine with regards to breakfast produced the poorest cognitive performance. Habitual breakfast consumption, in particular breakfast cereal has been found to enhance memory in children (Vaisman et al., 1996) and the elderly (Smith, 1988). Yet Dickie and Bender (1982) reported no detrimental effects of skipping breakfast with respect to typical schooling tasks, arithmetic, sentence verification and memory and search tasks.

Using university students Benton and Sargent (1992) and Smith et al., (1994a) demonstrated that memory was enhanced following breakfast, however, performance on reaction times and vigilance tests was unaffected (Smith et al., 1994a). Smith et al., (1999) reported enhancement of spatial memory only following consumption of breakfast. Kissileff et al., (2001) found that breakfast enhanced trigram and word recall when compared to skipping breakfast. Additionally, Benton and Parker (1998) found that in participants who had skipped breakfast, a 50g glucose drink reversed the deficit in recall performance of trigrams (Brown-Peterson task).

Food deprivation studies have found no adverse effects of skipping a meal on cognitive functioning. Green et al., (1997) demonstrated that neither free recall, memory recognition, simple reaction time, nor sustained attention, were effected by omission of the previous meal. In addition Green et al., (1995) failed to find an effect with up to 24hr fasting prior to testing. However, dissociation between speed of processing and cognitive function was observed as found previously (Green et al., 1995; Pollitt et al., 1981) as deprived participants were quicker to perform the recognition test, but showed slower reaction times (Green et al., 1995)

In two recent studies Benton et al., (2001a; 2001b) demonstrated that breakfast failed to enhance memory, however the authors suggested this was an effect of the baseline measures taken. Previous studies have either failed to take baseline measurements (Benton and Parker, 1998; Benton and Sargent, 1992) or taken them the day before (Smith et al., 1994a; 1992). Yet Benton et al., (2001b) found that breakfasts high in fibre were associated with better recall.

However, most studies have found that the composition of the breakfast consumed has little effect on performance. Lloyd et al., (1996) demonstrated that the omission of breakfast had no detrimental effects with regards vigilance and choice reaction time tasks, when compared to breakfasts differing in fat and carbohydrate content. However, consumption of a meal similar to what participants normally consumed, ie. high-carbohydrate low-fat meals such as cereal, was associated with decreased ratings of dysphoria/fatigue. Similarly Smith et al., (1994a) found no differences when using a cooked breakfast, cereal and toast breakfast when compared to skipping breakfast. Conners et al., (1985) showed a reduction in reaction times following a high carbohydrate breakfast when compared to a high protein or no breakfast.

The amount of energy consumed at breakfast also effects performance. Michaud et al., (1991) reported that consuming a higher than normal energy breakfast (63% increase) improved immediate recall, however, concentration declined. In contrast, Cromer et al., (1990) reported no differences in short-term auditory memory and vigilance.

Breakfast interventions studies have demonstrated that cognitive functioning is more susceptible to skipping breakfast in those that are malnourished. Simeon and Grantham-McGregor (1989) and Chandler et al., (1995) reported that verbal fluency was poorer in malnourished children when they did not receive breakfast. Pollitt (1995) also concluded that regular breakfast intake in malnourished children enhanced performance on working memory tasks. However, one must consider the possibility that in such malnourished samples hunger may also play a part in the poor educational performance.

Conclusions concerning Breakfast and Cognition

- In general, the consumption of breakfast has been found to improve aspects of working memory, however, improvements following breakfast have usually focussed on more sensitive and demanding measures such as word and trigram recall. Care must be taken to establish and address the exact measures of memory that are enhanced.
- The mixed findings with well-nourished children mirror laboratory findings with University students. It is assumed that healthy young adults and children have adequate nourishment to grow both mentally and physically and thus do not present problems with cognitive functioning.
- Reversal of the memory deficit observed with skipping breakfast through consumption of a 50g glucose drink (Benton and Parker, 1998) suggests that

consumption of mid-morning snacks may prove to be beneficial in maximising the memory effects observed and possibly the duration of the enhancement.

1.8.2 MACRONUTRIENTS, BREAKFAST AND COGNITION

The effects of raising blood glucose levels on cognitive performance have already been well documented (see section 1.3). In addition it has been shown that consumption of a breakfast meal, when compared to no breakfast, can enhance some aspects of cognitive functioning (see section 1.8.1). The question arises as to whether the composition of breakfast can also be found to influence cognitive functioning.

To date few studies have systematically compared the effects of consuming pure carbohydrate, fat and protein meals, or a mixture of the three as a breakfast meal. Fischer et al., (2001) demonstrated that overall cognitive performance was better following ingestion of the pure fat meal (105g), rather than either pure carbohydrate (105g), or protein (105g), which were found to lower overall performance. Using 400 kcal spoonable creams, consumption of the pure carbohydrate meal resulted in enhanced short-term memory and accuracy on the tasks, however, the pure protein meal enhanced attention and efficiency. Marked metabolic changes were observed following carbohydrate and protein meals, and to a lesser extent with the fat meal, leading Fischer et al., (2001) to suggest that a good all-round cognitive performance is related to a more stable metabolic state, where great changes in blood glucose and insulin levels fail to occur.

Table 1.2: The influence of Carbohydrate, Fat and Protein on Cognitive Functioning

Authors	M	N	Sex	Age	Study design	Cognitive Tests	Results
Spring et al., (1983)	C/P	184	M/ F	18- 65	HC vs HP breakfast or lunch (265kcal; 57g C or P)	Auditory RT; Dichotic shadowing; DSST @ 2hr after intake	Impaired performance after HC vs HP >40yr when eaten as lunch
Liebermn et al., (1986)	C/P	40	M	18- 28	HC vs HP lunch 1wk apart C-661kcal P-674kcal	Auditory RT; Dichotic shadowing; DSST; Tested after lunch	Slower RT to auditiory stimulus; poorer performance on digit after HC
Lloyd et al., (1994)	C/F	18	M/ F	27	Lunch LCHF (720)/ MCMF (706)/ HCLF (694) on three occasions 1wk apart	BVIP; Two-finger tapping; Free Recall; Simple RT	Longer RT following HCLF and LCHF compared to MCMF which improved performance;
Smith et al., (1994)	C/F	46	M/ F	-	Lunch LF small (840 kcal) LF large (880) HF small (1290) HF large (1300)	Logical reasoning task; RDVT; Focused attention task; Categoric Search task;	HF responded to attention tasks and categoric search more slowly but accurately

C – carbohydrate; P – protein; F – fat; H – high; L – low; E – energy; BR – breakfast; RT – reaction time; BVIP – Bakan Visual Processing Task; DSST – Digit-Symbol Substitution task; RDVT – Repeated Digits Vigilance Task;

Lloyd et al., (1996)	C/F	16	M/F	26	NBR/ HCLF/ MCMF/ LCHF (600 kcal)	BVIP; Two-finger tapping; Free Recall Simple RT @ 30min before intake, 30, 90, 150 after intake	no difference in performance
Wells and Read (1996)	C/F	18	M	21-32	LCHF (760)/ HCLF (860) at least 3 days apart A ate at 10:30; B ate BR (8:15) and test lunch (12:30)	BVIP; Simple RT; Choice RT tested before and 3hr after	Increase in false alarms on BVIP after HCLF brunch
Cunliffe et al., (1997)	C/F/P	16			BR (400 kca) of pure F/C or mixed macro		Pure C lead to increased fatigue and slower RT; F decreased visual info-processing capacity (flicker-fusion)
Deijen et al., (1999)	C/P	21	M/F	22	Five daily doses of 220 kcal drink – HP vs HC	Memory comparison task; Tracking task; Continuous memory task; Tested before and after course	Enhanced performance with HP on memory and tracking task than HC
Markus et al., (1999)	C/P	43	M/F	19-26	HCLP/ LCHP (stress vs no-stress)	Memory scanning task following stressors	HCLP enhanced performance in high stress group

C – carbohydrate; P – protein; F – fat; H – high; L – low; E – energy; BR – breakfast; RT – reaction time; BVIP – Bakan Visual Processing Task; DSST – Digit-Symbol Substitution task; RDVT – Repeated Digits Vigilance Task;

Lluch et al., (2000)	C/F	32	M/F	-	BR (410 kcal) Lunch (M=990 kcal) (F=740 kcal) LC/HF HC/LF	Simple RT; Choice RT; Attention; Associative memory; Grammatical reasoning spatial task; Testing before intake and 30 min after intake	Slower RT after HF vs LF
Kaplan et al., (2001)	C/F/P	22	M/F	71	Pure C/F/P (185 kcal) drinks consumed in the morning, 1wk apart	Word list recall; Paragraph recall; Trails task; Attention task; @ 15 and 60 mins post-consumption	C/F/P all enhanced performance on paragraph recall; C enhanced trail task in men; F and G improved trail task in those with low baseline blood glucose levels; Fat enhanced attention; Protein reduced forgettingl
Fischer et al., (2001)	C/F/P	17	M	26.5	BR (400 kcal) of pure macro BR at 8:15	Simple RT; Choice RT; Combi-test (short-term memory, and a peripheral task) Before BR and for 3hr after	F enhanced overall performance; C/P lower overall performance; C enhanced short-term memory and accuracy; P enhanced attention and efficiency

C – carbohydrate; P – protein; F – fat; H – high; L – low; E – energy; BR – breakfast; RT – reaction time; BVIP – Bakan Visual Processing Task; DSST – Digit-Symbol Substitution task; RDVT – Repeated Digits Vigilance Task;

Fischer et al., (2002)	C/P	15	M	26	BR (400kcal) C (4:1, 84g:21g) bal (1:1, 53g:53g) P (1:4, 21g:84g) @ 7:00, 7:15, 7:30	Choice RT; Combi-test (short-term memory, and a peripheral task) Multitask (highly complex version of the Combi-test) Before BR and for 3hr after	memory accuracy best o/all with P – least change in blood glucose and GIR; attention and DT best in 1st hr with C, then bal & P; central task better with bal

C – carbohydrate; P – protein; F – fat; H – high; L – low; E – energy; BR – breakfast; RT – reaction time; BVIP – Bakan Visual Processing Task; DSST – Digit-Symbol Substitution task; RDVT – Repeated Digits Vigilance Task;

Low GI foods, that release glucose slowly, also create little change in blood glucose and insulin levels. It is possible that low GI foods may have a similar profile to that observed by Fischer et al., (2001) with a pure fat meal, and also be beneficial to cognitive performance. In a subsequent study, again using university students, Fischer et al., (2002) demonstrated that consumption of a protein rich (4:1, 84g:21g) or balanced carbohydrate and protein test meal (1:1, 53g:53g) resulted in the best overall cognitive performance (400kcal). The protein rich meal resulted in the greatest accuracy on the short-term memory task, with reaction times on the central tasks being fastest following the balanced meal. The authors suggested that these findings were related to small changes in glucose metabolism and the glucagon to insulin ration (GIR) following the test meals.

Fischer et al., (2002; 2001) also reported that the time between consumption and cognitive assessment influenced the reaction to the test meals. One hour after breakfast, the carbohydrate meal enhanced performance on the tasks. After two hours the protein meal enhanced performance. However, both meals resulted in poorer overall performance when compared to the fat meal (Fischer et al., 2001). In the second study (2002), the authors noted again that the carbohydrate rich meal was beneficial in the first hour, then the emphasis changed to the protein rich and balanced meals.

The changes in metabolism and the GIR following carbohydrate and protein meals help to explain this apparent 'trade-off' in performance between memory and attentional performance (Smith et al., 1994b; 1988; Pollitt et al., 1981). Glucagon and insulin concentrations are controlled by carbohydrate and protein contents in the diet (Tiedgen and Seitz, 1980). If one assumes a similar relationship between glucose regulation in man and rats, then protein rich and balanced meals will increase the activation of glycogen breakdown into glucose (glycogenolysis) and the synthesis of glucose from non-carbohydrate precursors (gluconeogenesis) and thus potentially heighten arousal through activation of the sympathetic nervous system following changes in the metabolic state. Increased short-term memory and accuracy may be mediated through a positive effect of a rise in plasma glucose in the first hour (Owens and Benton, 1994; also see section 13.3). The higher state of metabolic activation and thus arousal from protein (Fischer et al., 2001) and balanced meals (Fischer et al., 2002) may produce increased overall cognitive functioning following the first hour through the increased availability of glucose, via the mechanisms described above.

Using isoenergetic breakfasts (400 kcal), Cunliffe et al., (1997) reported that slower reaction times and increased fatigue were observed following ingestion of a pure carbohydrate meal, when compared to a pure fat or a mixed macronutrient meal. In addition, the pure fat drink decreased visual information-processing capacity as measured by the flicker-fusion task.

Cognitive functioning in a healthy elderly sample has also been assessed. Kaplan et al., (2001) suggested that using a population with an already declining memory could provide insight into the mechanisms by which macronutrients effect memory and cognitive functioning. The authors demonstrated that all three macronutrients enhanced paragraph recall compared with a placebo solution 15 minutes post-consumption, with improvements being stronger at delayed recall. Consumption of the pure protein drink (50.5g) resulted in significantly less forgetting between immediate and delayed paragraph recall at 15 minutes. Pure carbohydrate (50g) was beneficial in sustaining paragraph recall over the sixty-minute post-consumption period, it also preferentially enhanced performance on the trail task in males (Craft et al., 1994). Fat (41.1g) and carbohydrate increased improvement on the visuomotor trails task in those who had low baseline blood glucose levels. Kaplan et al., (2001) concluded that rather than increases in blood glucose levels, it may be the increase in energy which enhances cognition and that each macronutrient may have their own specific pathway by which cognitive functioning is influenced. This suggestion challenges earlier studies stating an increase in blood glucose levels to between 8-10mmol/L is critical for improvements in memory (Manning et al., 1993; Parsons and Gold, 1992).

In a previous study Kaplan et al., (2000) demonstrated that glucose regulation may play an important role in cognitive functioning. Using different dietary carbohydrates, a glucose drink, instant mashed potato and barley with 50g available carbohydrate, results showed that all three meals enhanced cognitive functioning compared to a placebo. The improvements observed were independent of increases in blood glucose levels, as memory improvement was strongest after consumption of the low GI barley meal, and the pure fat meal in the subsequent study (Kaplan et al., 2001). The authors concluded that poor β-cell functioning, low insulin resistance (good insulin sensitivity), low BMI and a large area under the blood glucose curve in response to the ingested meal were associated with poor baseline cognitive performance in the healthy elderly. Kaplan et al, (2000) further suggest that in this healthy elderly sample, poor β-cell functioning in the absence of insulin resistance, could be the factor which predisposes the sensitivity to the effects of glucose.

A variety of studies have observed the effects of varying the amount of two macronutrients with respect to cognitive functioning (Table 1.2), however, findings can not always be generalised between the studies, due to different meal sizes, energy contents, timing of subsequent testing and whether the meal was consumed as a breakfast or lunch.
Lloyd et al., (1996) demonstrated that a high-carbohydrate (99g)/low-fat (18g) meal resulted in slightly better performance on recall tasks, and that a low-carbohydrate (56g)/ high-fat (38g) meal was slightly worse on reaction time tests, but no clear significant differences in performance were observed between the conditions. The authors did note that ratings of fatigue/dysphoria were significantly reduced following the high-carbohydrate/low-fat meal. However, the study could be criticised as the meals contained substantially more caloric energy (600kcal) and did not constitute what would be normally consumed in a typical breakfast. However Lloyd et al., (1994) demonstrated that both high-

carbohydrate (100g)/low-fat (22g) and high-fat (50g)/low-carbohydrate (47g) lunches resulted in poorer performance than after a medium-carbohydrate (79g)/medium-fat (35g) meal.

Holt et al., (1999) noted that participants who consumed a breakfast of All Bran (77g carbohydrate/11g fat) reported increased alertness when compared to a breakfast of Cornflakes, eggs and bacon or croissants. Although the authors did not test this systematically, they suggested that a low GI breakfast could be beneficial with respect to alertness over the morning.

Deijen et al., (1999) demonstrated that participants who had consumed a high protein drink (42g proteins/2g tyrosine) at breakfast over a period of five days showed enhanced performance on a memory and tracking task, when compared to a high carbohydrate condition. Thomas et al., (1999) also found that tyrosine enhanced memory in multi-tasking situations when the demand on working memory was high. Tyrosine has been found to improve performance stress-sensitive attention tasks (Deijen and Orlebeke, 1994) and improve deficits in working memory (Shurtleff et al., 1994), possibly through the effects of catecholamines in the brain.

Following a carbohydrate-rich/protein-poor lunch, Markus et al., (1999) reported increased memory in participants performing a controllable stressful situation when compared to carbohydrate-poor/protein-rich meal. Markus et al., (2000) further demonstrated in participants prone to high stress, that a carbohydrate-rich (219g)/protein-poor (12g) breakfast flattened depression scores following both controllable and uncontrollable stress situations. The effects observed with high protein and high carbohydrate meals with mood are considered in Section 1.8.4.

Manipulations with carbohydrate and protein eaten at lunch demonstrated that high carbohydrate meals slowed reaction times and impaired performance on a substitution task (Lieberman et al., 1986c) and slowed the detection of peripheral targets (Smith et al., 1988). Smith et al., (1988) also found that a high protein lunch affected the ability to ignore distracting stimuli on a focused attention task.

Studies analysing the effects of carbohydrate and fat have also produced mixed findings. Wells and Read (1996) reported no differences in cognitive performance following manipulation of fat and carbohydrate at lunch, but a high-carbohydrate (202g)/low-fat (7g) meal consumed at brunch (10am) increased false alarms on the vigilance task when compared to a high fat (47g)/low carbohydrate (80g) meal. Smith et al., (1994b) demonstrated enhanced accuracy at the expense of speed following high fat lunches. The size of the meal did not effect the findings. Similarly Lluch et al., (2000) found slower reaction times following a high fat lunch.

Differences between the effects observed following breakfast and lunch manipulations are not just as a function of the macronutrients consumed. Folkard (1983) demonstrated that performance on perceptual search tasks improves over the day, reaching a maximum at 20:00. Additionally performance on short-term memory tasks climbed to a maximum at

11:00 but dropped off to reach a low at 20:00. This in addition to the sedative effects of high-carbohydrate and high-fat consumption can help understand the results observed (Smith et al., 1994b; 1988; Lieberman et al., 1986c; Spring et al., 1982/3).

Conclusions regarding Macronutrients and Cognition

- The studies reviewed generally suggest that a balanced macronutrient meal is the most beneficial with respect to cognitive performance. In addition, a meal with a low GI may also be beneficial cognitively. However, there is little study of the optimal balance of macronutrients and energy intake.
- Both pure protein and carbohydrate meals have been found to influence aspects of memory, however these meals also elicit great metabolic changes following ingestion.
- Timing may be crucial, as carbohydrate rich meals seem to provide an immediate benefit, with protein, fat and balanced meals being beneficial after the first hour.
- The use of iso-energetic meals creates an inverse relationship between fat and carbohydrate content, making it difficult to separate the actions of the macronutrients.
- Breakfasts consumed in the studies are often two to three times larger than most individuals would consume in a typical breakfast. There is a need to systematically test the typical size and macronutrient content of typical breakfasts.

1.8.3 MACRONUTRIENTS, BREAKFAST AND MOOD

Benton et al., (2001b) demonstrated that compared to fasting, consumption of any out of a range of eight breakfasts differing in macronutrient content, resulted in better mood. This picture is consistent with many other studies (Kissileff, 2001; Lloyd et al., 1996; Smith et al., 1999; 1994a; 1992). Breakfast also reduces self-reported fatigue (Bellisle et al., 1998).

Kissileff (2001) found consumption of any breakfast improved overall mood when compared to fasting. Smith et al., (1999) demonstrated that following breakfast, participants were more alert and less anxious before and after testing, compared to those who skipped breakfast (Smith et al., 1992). However, Benton et al., (2001a) failed to find an effect of breakfast on mood, yet consumption of a snack 90 minutes after breakfast resulted in participants feeling more agreeable, confident and energetic. Similarly, Benton et al., (1987) demonstrated that a glucose drink in the afternoon reduced irritability in frustrated children and Thayer (1987) reported decreased tiredness following an afternoon snack of candy (high carbohydrate).

Benton et al., (2001a) also reported that the impact of the snack depended on what meal had been consumed at breakfast. Consuming 50g of carbohydrate was associated with the poorest mood later in the morning when compared to a 10g carbohydrate or no breakfast, however, consumption of the 25g carbohydrate snack prevented this decline in mood.

Table 1.2: The influence of Carbohydrate, Fat and Protein on Cognitive Functioning

Authors	M	N	Sex	Age	Study design	Cognitive Tests	Results
Spring et al., (1983)	C/P	184	M/ F	18-65	HC vs HP breakfast or lunch (265kcal; 57g C or P)	Auditory RT; Dichotic shadowing; DSST @ 2hr after intake	Impaired performance after HC vs HP >40yr when eaten as lunch
Liebermnn et al., (1986)	C/P	40	M	18-28	HC vs HP lunch 1wk apart C-661kcal P-674kcal	Auditory RT; Dichotic shadowing; DSST; Tested after lunch	Slower RT to auditiory stimulus; poorer performance on digit after HC
Kelly et al., (1994)	C/F	6	M	(1) 28 (2) 27	LFLE (431 kcal) HFHE (844 kcal) LCLE/ HCHE	DSST; Number recognition task; Repeated acquisition task;	Both studies: Performance on tasks poorer after the meal than before; No effect ov macronutrients or energy intake
Lloyd et al., (1994)	C/F	18	M/ F	27	Lunch LCHF (720)/ MCMF (706)/ HCLF (694) on three occasions 1wk apart	BVIP; Two-finger tapping; Free Recall; Simple RT	Longer RT following HCLF and LCHF compared to MCMF which improved performance;
Smith et al., (1994)	C/F	46	M/ F	-	Lunch LF small (840 kcal) LF large (880) HF small (1290) HF large (1300)	Logical reasoning task; RDVT; Focused attention task; Categoric Search task;	HF responded to attention tasks and categoric search more slowly but accurately

C – carbohydrate; P – protein; F – fat; H – high; L – low; E – energy; BR – breakfast; RT – reaction time; BVIP – Bakan Visual Processing Task; DSST – Digit-Symbol Substitution task; RDVT – Repeated Digits Vigilance Task;

Lloyd et al., (1996)	C/F	16	M/ F	26	NBR/ HCLF/ MCMF/ LCHF (600 kcal)	BVIP; Two-finger tapping; Free Recall Simple RT @ 30min before intake, 30, 90, 150 after intake	no difference in performance
Wells and Read (1996)	C/F	18	M	21-32	LCHF (760)/ HCLF (860) at least 3 days apart A ate at 10:30; B ate BR (8:15) and test lunch (12:30)	BVIP; Simple RT; Choice RT tested before and 3hr after	Increase in false alarms on BVIP after HCLF brunch
Cunliffe et al., (1997)	C/F/ P	16			BR (400 kca) of pure F/C or mixed macro		Pure C lead to increased fatigue and slower RT; F decreased visual info-processing capacity (flicker-fusion)
Deijen et al., (1999)	C/P	21	M/ F	22	Five daily doses of 220 kcal drink – HP vs HC	Memory comparison task; Tracking task; Continuous memory task; Tested before and after course	Enhanced performance with HP on memory and tracking task than HC
Markus et al., (1999)	C/P	43	M/ F	19-26	HCLP/ LCHP (stress vs no-stress)	Memory scanning task following stressors	HCLP enhanced performance in high stress group

C – carbohydrate; P – protein; F – fat; H – high; L – low; E – energy; BR – breakfast; RT – reaction time; BVIP – Bakan Visual Processing Task; DSST – Digit-Symbol Substitution task; RDVT – Repeated Digits Vigilance Task;

Lluch et al., (2000)	C/F	32	M/F	-	BR (410 kcal) Lunch (M=990 kcal) (F=740 kcal) LC/HF HC/LF	Simple RT; Choice RT; Attention; Associative memory; Grammatical reasoning spatial task; Testing before intake and 30 min after intake	Slower RT after HF vs LF
Kaplan et al., (2001)	C/F/P	22	M/F	71	Pure C/F/P (185 kcal) drinks consumed in the morning, 1wk apart	Word list recall; Paragraph recall; Trails task; Attention task; @ 15 and 60 mins post-consumption	C/F/P all enhanced performance on paragraph recall; C enhanced trail task in men; F and G improved trail task in those with low baseline blood glucose levels; Fat enhanced attention; Protein reduced forgettingl
Fischer et al., (2001)	C/F/P	17	M	26.5	BR (400 kcal) of pure macro BR at 8:15	Simple RT; Choice RT; Combi-test (short-term memory, and a peripheral task) Before BR and for 3hr after	F enhanced overall performance; C/P lower overall performance; C enhanced short-term memory and accuracy; P enhanced attention and efficiency

C – carbohydrate; P – protein; F – fat; H – high; L – low; E – energy; BR – breakfast; RT – reaction time; BVIP – Bakan Visual Processing Task; DSST – Digit-Symbol Substitution task; RDVT – Repeated Digits Vigilance Task;

Fischer et al., (2002)	C/P	15	M	26	BR (400kcal) C (4:1, 84g:21g) bal (1:1, 53g:53g) P (1:4, 21g:84g) @ 7:00, 7:15, 7:30	Choice RT; Combi-test (short-term memory, and a peripheral task) Multitask (highly complex version of the Combi-test) Before BR and for 3hr after	memory accuracy best o/all with P – least change in blood glucose and GIR; attention and DT best in 1st hr with C, then bal & P; central task better with bal

C – carbohydrate; P – protein; F – fat; H – high; L – low; E – energy; BR – breakfast; RT – reaction time; BVIP – Bakan Visual Processing Task; DSST – Digit-Symbol Substitution task; RDVT – Repeated Digits Vigilance Task;

The type of breakfast has also been found to effect mood. Smith et al., (1994a) found that following a cooked breakfast of eggs and bacon, compared to cereal and toast or no breakfast, participants reported increased sociability and contentedness. Holt et al., (1999) demonstrated that a high fibre breakfast increased alertness when compared to a cooked, continental, or cereal breakfast.

Lloyd et al., (1996) also reported less dysphoria/fatigue following a high-carbohydrate (99g)/low-fat (18g) breakfast when compared to no breakfast, a low-carbohydrate (56g)/high-fat (38g) or medium-carbohydrate medium-fat meal. Similarly Fischer et al., (2001) demonstrated that consumption of a pure carbohydrate breakfast decreased depression when compared to a pure protein (105g) meal (Sayegh et al., 1995; Wurtman et al., 1989; Spring et al., 1982/3). The preferences for high carbohydrate foods have been reported in people suffering with PMS (Wurtman et al., 1989), SAD (Rosenthal et al., 1989) and from bulimic episodes (Rosenthal and Hefferman (1986).

However, Reid and Hammersley (1995) failed to find any differences in mood following consumption of a sucrose drink, however, orosensory factors were removed through use of an antiseptic lozenge. Similarly Deijen et al., (1989) Rosenthal et al., (1989) and Christensen and Redig (1993) have failed to demonstrate any effect on mood following manipulations of carbohydrate and protein meals.

It has been suggested that the improvement of mood observed following consumption of carbohydrate-rich meals is a function of changes in blood glucose levels, rather than serotonergic activity mediated through increased tryptophan availability (Benton and Owens, 1993b).

Consumption of meals can induce increased lassitude and drowsiness irrespective of macronutrient composition and circadian rhythms (Wells et al., 1998; Smith and Miles, 1986). Smith et al., (1988) reported increased feelings of lassitude and sleepiness, following consumption of a lunch providing one third of the daily energy requirements, irrespective of macronutrient composition.

Spring et al., (1982/3) and Rosenthal et al., (1989) (females only) demonstrated that both consumption of high-carbohydrate and high-protein lunches increase sleepiness, however, the effect was greater after carbohydrate. Wells and Read (1996) found that following a high–fat meal, participants reported less vigour than after consumption of an equicaloric high-carbohydrate meal. Following a high-fat meal, depression of alertness ratings were still observed 2.5 hours post-consumption when compared to a carbohydrate-rich meal

(Wells et al., 1997; Lloyd et al., 1994). Wells and Read (1996) also reported increased fatigue and less vigour following a high fat brunch.

Lloyd et al., (1994) reported that both a low-carbohydrate (50g)/high-fat (47g) and high-carbohydrate (100g)/low-fat (22g) lunch increased drowsiness compared to a medium carbohydrate (79g)/medium fat (35g) lunch. In addition, the high-carbohydrate/low-fat lunch reduced tension. Spring et al., (1982/3) demonstrated that males reported decreased tension following a carbohydrate-rich meal, females reported increased sleepiness. Additionally older participants reported decreased tension when the carbohydrate-rich meal was consumed as a breakfast, when compared to a protein-rich meal.

Studies analysing the long-term effects of carbohydrate on mood have reported that high levels of carbohydrate reduce levels of tension, depression and anger (Keith et al., 1991; De Castro, 1987). Smith et al., (1999) demonstrated that participants who consumed breakfast cereal everyday reported better mental and physical health than those who consumed cereal less frequently.

Conclusions regarding Breakfast, Macronutrients and Mood

- Breakfast consumption has been demonstrated to improve mood compared to fasting. However, the composition of the meal has been demonstrated to have various effects, as has macronutrient ingestion at lunch.
- Consumption of a mid-morning snack (25g carbohydrate) has been found to reverse the poor mood observed later in the morning following a large intake of carbohydrate

(50g). This may be a reflection of glucose tolerance and the macronutrient content of the breakfast.

- Fat rich meals have been found to increase contentment when consumed at breakfast and lunch, Carbohydrate-rich meals have been found to reduce fatigue at breakfast, but are associated with negative mood later in the morning.
- Food intake in general had been found to increase drowsiness and tiredness at lunch, however, care must be taken to dissociate meal effects from the circadian 'post-lunch dip'.

1.8.4 CARBOHYDRATE, PROTEIN AND MOOD

Serotonin has been implicated in the regulation of mood and appetite (Lieberman et al., 1986a; 1986b; 1989c; Wurtman 1990; Christensen, 1993). Brain serotonin levels are dependent on amino acids, in particular tryptophan (Fernstrom and Wurtman, 1972), an essential amino acid.

Amino acids are transported into peripheral tissues and the brain by carrier-mediated mechanisms (Pardridge, 1983), however, all LNAA's (large neutral amino acids) compete for these mechanisms. The other large neutral amino acids are tyrosine, phenylalanine, leucine, isoleucine and valine. Increases in protein consumption, however, does not increase the availability of tryptophan, as it is scarce in protein (1-1.5%, Wurtman and Wurtman, 1989) compared to the other LNAA's with which it competes for transportation across the blood-brain barrier (Fernstrom and Wurtman, 1972).

Meals high in carbohydrate have been found to increase the levels of plasma tryptophan by 65% in rats two hours post-consumption (Fernstrom and Wurtman, 1971). Insulin released as a function of the carbohydrate meal lowers the amino acids that compete for the blood-brain barrier transport system by enhancing penetration into peripheral muscle tissue and other cells (Teff et al., 1989a; 1989b). In contrast, plasma tryptophan binds to albumin molecules that are left free by insulin releasing the free-fatty acids that are usually albumin bound. Reduced LNAA concentration in the blood allows increased transport of plasma tryptophan into the brain (Fernstrom and Fernstrom, 1993). Fernstrom and Wurtman (1972) demonstrated that a diet omitting the competing amino acids increased levels of tryptophan in the brain.

Studies with human participants have also demonstrated that meals high in carbohydrate and low in protein (<2%) have produced significant increases in the levels of tryptophan available for transport (tryptophan to competing amino acid ratio - T:LNAA) (Teff et al., 1989a; 1989b; Lieberman et al., 1986a). Additionally this increase in the T:LNAA ratio may be a function of glucose response to the meal rather than the type and amount of carbohydrate consumed. Lyons and Truswell (1987) demonstrated a significant increase in brain tryptophan with a sucrose but not a starch meal (480Kcal), this may reflect an interaction with the palatability of the meal.

By contrast, consumption of a meal high in protein (>50%) produced significant decreases in the T:LNAA ratio (Leiberman et al., 1986a), but so did a meal containing 4% protein (Teff et al., 1989a). However, Sayegh et al., (1995) reported no decline in T:LNAA ratio following a meal of 33% protein, a finding consistent with animal studies (Fernstrom and Wurtman, 1971; 1972). Benton and Donohoe (1999) summarised over thirty human studies and found that 2-4% of calories present in a meal as protein hindered the increased availability of tryptophan.

The response of humans to tryptophan manipulation may be quite different to that of rodents, with smaller changes in serotonin synthesis being observed in humans, although the research is limited (Teff et al., 1989a; 1989b; Perez-Cruet et al., 1974). Using juvenile male rhesus monkeys (Macaca mulatta) Grimes et al., (2000) demonstrated that both plasma and CSF concentrations of tryptophan declined with decreases in chronic protein intake, in a similar manner to rodents, however, there was no acute response to meals. Repeated intake over a four-week period showed that high levels (16% or 22%) of protein, produced higher levels of CSF 5-HIAA (serotonin metabolite) when compared to meals containing 6% or 10%. In addition, changes in the ratio of blood tryptophan/LNAA did not predict CSF tryptophan or 5-HIAA as found in rats.

With the ratio of carbohydrate to protein in foods varying between four or five to one (De Castro, 1987), it is unlikely that the availability of tryptophan is an important mediator of mood and appetite regulation. In addition a chronic lack of protein in the diet would decrease rather than increase levels of tryptophan, as tryptophan cannot be synthesised by the body.

1.9 AIMS AND OBJECTIVES

The purpose of the present thesis was to extend the basic phenomenon that glucose influences mood and measures of cognition, in particular memory, by considering the consumption of different meals consumed after an overnight fast. More specifically the aims of the present thesis are to:

1. Investigate the influence of different types of carbohydrate on mood and cognition.

2. There are reports that breakfast consumption influences mood and cognition. The second aim of the thesis was to investigate the effect of macronutrient content of breakfast on these measures.

3. A more general objective is to recommend a breakfast that would be optimal for mood and cognitive enhancement.

Chapter 2: The effects of differing amounts of Sucrose on Cognition

2.1 INTRODUCTION

The effects of sucrose on behaviour and cognitive performance have failed to yield many significant results (see White and Wolraich, 1995, for a review), however, virtually all the studies have looked at the effects of sucrose on hyperactivity in young children. To date there has been a failure to examine the effects of sucrose and cognitive performance in young adults, or an elderly population. The majority of the literature has focused on the effects of glucose, strangely favouring this sugar instead of the commonly used table sugar sucrose.

Glucose has been found to influence cognitive function and mood through changes in blood glucose levels in animals (section 1.3.2), healthy aged adults (section 1.3.3) and healthy young adults (section 1.3.4). Furthermore, there is increasing evidence that individual differences in glucose tolerance also have an impact on mood and cognitive functioning (section 1.3.5). Therefore, it is reasonable to consider whether similar observations in performance can be demonstrated following the ingestion of sucrose.

Sucrose, cane or beet sugar, is a disaccharide that yields glucose and fructose on acidic hydrolysis in the ratio 1:1. Glucose crosses the blood-brain barrier, through glucose transporters (section 1.2.1; 1.2.2); fructose does not. Glucose increases blood glucose levels, however, fructose does not. Both sugars have been demonstrated to enhance memory (section 1.4.1), suggesting that memory enhancement may be modulated by two mechanisms; peripherally in the liver, and centrally in the brain, however, the dose used is critical.

2.1.1 AIM

The present study aimed to examine the effects of different doses of sucrose on mood, hunger and cognition. In addition, it aimed to examine the effects of a secondary top-up drink on the test measures. It was hypothesised that, as with glucose, different levels of sucrose would differentially effect mood and cognition. Furthermore, it was hypothesised that individual differences in glucose tolerance, the ability to effectively utilise the carbohydrate load, would be associated with enhanced mood and cognitive performance.

2.2 METHOD

2.2.1 PARTICIPANTS

220 female undergraduate students, mean age 20.26 years (SD 2.32), acted as participants. All were recruited through advertisements within the University of Wales, Swansea.

Groups of participants were compared under five conditions in the first hour. After 60 minutes, the participants received one of two drinks, resulting in 10 conditions in total:

1. 0g – 0g (N=19; mean 20.269yrs; SD 2.13)
2. 0g – 20g (N=22; mean 20.68yrs; SD 3.00)
3. 10g – 0g (N=16; mean 20.00yrs; SD 1.86)
4. 10g – 20g (N=19; mean 20.11yrs; SD 1.66)
5. 30g – 0g (N=21; mean 19.81yrs; SD 1.86)
6. 30g – 20g (N=22; mean 20.50yrs; SD 2.32)
7. 50g – 0g (N=19; mean 20.63yrs; SD 3.79)
8. 50g – 20g (N=21; mean 20.48yrs; SD 2.52)
9. 70g – 0g (N=21; mean 19.48yrs; SD 1.08)
10. 70g – 20g (N=22; mean 20.59yrs; SD 2.06)

All participants fasted overnight, and once in the laboratory consumed the first allocated drink. All participants gave written consent and the local Ethics Committee approved the procedure.

2.2.2 SUCROSE/PLACEBO BEVERAGES

The four active drinks (10g, 30g, 50g, 70g) and the active top-up drink (20g) contained the different amounts of sucrose dissolved in a mixture of water, sugar free orange squash (35ml) and lemon juice (15ml) to make up a volume of 250ml in each drink. In addition to this, the active drinks had various amounts of Hermestas Sweetener added, a low calorie artificial sweetener that contains aspartame and saccharin (Crooks Health Care Ltd), to give a similar taste (10g – 7 tablets; 20g – 6 tablets; 30g – 5 tablets; 50g – 4 tablets; 70g - 3 tablets). The placebo drinks contained sugar free orange squash (150ml), lemon juice (10ml) 10 tablets of artificial sweetener mixed with water to make up a volume of 250ml.

2.2.3 WORD LISTS

Two lists of 30 words, each having five letters, were chosen to be high in frequency and imagery (Quinlan, 1992) (Appendix 1). The list was presented aurally, at a rate of one word per two seconds using a tape recorder. All responses were written on sheets within the questionnaire pack, and the time taken was noted.

2.2.4 MOOD

The dimensions of the bipolar form of the Profile of Mood States questionnaire (McNair et al., 1971) were used to assess how participants felt at that moment in time. The POMS produced six scores that correspond to six basic dimensions of mood: Composed/Anxious, Agreeable/Angry, Elated/Depressed, Confident/Unsure, Energetic/Tired, Clearheaded/Muddled. Adding all six scales created the Total mood score. Participants were also asked to rate how hungry they were, with the dimension extremely hungry/not at all. All dimensions were assessed on a 10cm visual analogue scale (Appendix 1).

2.2.5 HICK PARADIGM – Reaction times

The reaction time procedure was based on that of Jensen (1982). A response console was connected to a computer that automatically recorded the responses of the subjects in milliseconds. The console consisted of a matt black panel (35cm by 45cm approx.), tilted at a 30 degree angle. At the lower centre of the panel was the 'home' key around which 8 faceted amber lamps were arranged in a semi-circle. Below each lamp were buttons equidistant from the 'home' key (1650mm). The Hick Paradigm enables the separation of Decision Time (DT) from Movement Time (MT). DT is defined as the time interval between onset of the reaction stimulus, the lamp, and release of the 'home' key. MT is defined as the time interval between the release of the 'home' key and the depression of the button, which extinguishes the lamp.

All subjects completed a practice session of 20 trials utilising all eight lamps. Simple reaction time was measured for 20 trials using one lamp. Choice reaction time was measured over 20 trials for each of 2, 4 and 8 lamps.

A single trial consisted of the subject placing a finger on the 'home' key. Within one to two seconds an auditory warning signal sounded (a 'beep' of one second duration). A random interval of one to four seconds elapsed, followed by the lighting of one of the lamps. The subject was required to extinguish the light as quickly as possible by moving their hand to the button directly below the lamp and depressing it. The position of the lamp that lights in any given trial was random, with the constraint that each lamp lit 20 trials in each session. Each subject received the same 'random' order of lamp positions.

Anticipatory responses were impossible, if the subject's finger left the 'home' key before a lamp was lit, the lamp would not light, nothing was recorded and the trial cycle was repeated.

Values recorded were medians as the mean values are not a true representation of central tendency, "Because the distribution of single-trial RTs for a given subject is always skewed to the right (i.e., toward longer RTs) its arithmetic mean is not as good a measure of central tendency as the median, which is relatively insensitive to extreme values or outliers." (Jensen, 1987, pp110). The most sensitive values for the Reaction Time measures are the Standard Deviations, which enable the calculation of intra-individual variability, which is the square root of the sum of the standard deviations at each lamp squared.

Another measure is the Intercept, which makes use of the regression equation, $RT = a + b\log_2 n$, where 'a' is the intercept, and 'b' is the slope of the regression of RT on $\log_2 n$. The median decision times of the four lamps were used to calculate the equation. "The intercept is interpreted as representing the best estimate of the total tine required for the processes of attention and sensory registration of the reaction stimulus, transmission of the signal to the brain via the afferent nerves, central reception or encoding of the reaction stimulus, transmission via the efferent nerves of the impulse to respond, and muscle lag in response execution. The slope is interpreted as the amount of time for the central processes of discrimination. Because the length of time increases at a constant rate as a function of $\log_2 n$, the slope can be termed the binary processing time." (Jensen, 1987: pp105).

2.2.6 RAPID INFORMATION PROCESSING TASK (RIPT)

A computer generated a series of digits on a VDU at the rate of 100 digits per minute. Subjects were instructed to press the space bar when they detected target sequences of three consecutive odd or consecutive even digits. Approximately eight target sequences were presented every minute. Following the presentation of the third consecutive digit, 1500 msec was allowed for a correct response to be made. Responses made at any other time were recorded as errors. Any variation in sample numbers with reaction times is a reflection of data not being generated when reactions did not take place within 1500 msec. A minimum of 5 and a maximum of 30 digits separated any two target displays. The number of sequences correctly detected, the time taken to respond to a target display and the numbers of errors were recorded.

Mean Reaction times (time taken) were recorded, as opposed to Median reaction times (section 2.2.5), as there was a cut-off of 1500msec imposed on responses. Therefore, a more normal distribution would be obtained in the results.

2.2.7 BLOOD GLUCOSE

Blood glucose determinations were made with the use of an ExacTech sensor, made by Medisense Britain Limited. The sensor uses an enzymic method coupled with microelectronic measurement that has been shown to give valid measures (Matthews et al., 1987).

2.2.8 PROCEDURE

Table 2.1 illustrates the procedure. Blood glucose levels were determined on entering the laboratory. Informed consent was given and Mood questionnaires were completed. As only one participant could have blood levels assessed at a time, questionnaires were completed simultaneously by those not giving blood. Subjects were allocated to one of five conditions, receiving one of the four sucrose drinks or the placebo drink. The subjects sat for 20 minutes to allow the sucrose to be absorbed into the blood stream. Approximately 30 minutes after entering the laboratory, blood glucose levels and Mood were measured for a second time.

After all the participants had completed the Mood questionnaires, the word list was then presented aurally and immediate recall assessed. Subjects then completed the RIPT (6mins), Hick Paradigm (10 mins) and the RIPT (2) on the computers. On completion of the tests, delayed recall was assessed, followed by the third blood glucose reading and completion of the Mood questionnaires.

Please note that the test session, in total, took approximately 28 minutes. 40 minutes were allocated between BGL2 and the 20 minute wait (at 70 minutes) to complete all the tasks and ensure enough time for participants to consume the top-up drink and have blood taken.

At 70 minutes, participants were then given one of the two top-up drinks, sucrose or placebo, and again sat for 20 minutes to allow uptake into the blood stream. Blood glucose levels and Mood were measured for the fourth time at 90 minutes. The second word list was then presented aurally and immediate recall (2) was assessed. Participants then completed the Hick Paradigm (2) and the RIPT (3), and on completion delayed recall (2) was assessed. The final Mood and blood glucose level was taken and the participants were debriefed.

Table 2.1: Profile of the testing procedure for Chapter 2.

10:00	*BGL 1 / MOOD / CONSENT*		0 minutes
10:10	BEVERAGE (0, 10, 30, 50, 70g) 20 MINUTES WAIT		10 minutes
10:30	*BGL2 / MOOD*		30 minutes
10:40	**TEST SESSION 1**		40 minutes
	IMMEDIATE RECALL 1	(~4mins)	
	RIPT 1	(~6mins)	
	HICK 1	(~10mins)	
	RIPT 2	(~6mins)	
	DELAYED RECALL 1	(~2mins)	
11:00	*BGL3 / MOOD*		60 minutes
11:10	BEVERAGE (0, 20g) 20 MINUTES WAIT		70 minutes
11:30	*BGL4 / MOOD*		90 minutes
11:40	**TEST SESSION 2**		100 minutes
	IMMEDIATE RECALL 2	(~4mins)	
	HICK 2	(~6mins)	
	RIPT 3	(~10mins)	
	DELAYED RECALL 2	(~2mins)	
12:00	*BGL5 / MOOD / DEBRIEFING*		120 minutes

2.3 STATISTICAL ANALYSIS

2.3.1 EFFECT OF BEVERAGE

- Measures of Blood Glucose, in the 1st hour, were analysed using a two-way ANOVA:

  Drink (placebo/sucrose) X Time (0, 30, 60) (repeated measure).

  After the 2nd drink, Blood Glucose was analysed using a three-way ANOVA:

  Drink (placebo/sucrose) X Top-up (placebo/sucrose) X Time (90, 120) (repeated measure).

- Difference scores were firstly calculated for the measures of Mood (Composed/Agreeable/Elated/Confident/Energetic/Clearheaded) and Hunger using the following calculation:

  Mood at 30, 60, 100, & 150 minutes – baseline.

  These measures were then analysed in the 1st hour using two-way ANOVAs:

  Drink (placebo/sucrose) X Time (30, 60) (repeated measure).

  After the 2nd drink, measures of Mood and Hunger were analysed using three-way ANOVAs:

  Drink (placebo/sucrose) X Top-up (placebo/sucrose) X Time (90, 120) (repeated measure).

- Measures of Word recall and Recall Times were analysed using two-way ANOVAs:

Drink (placebo/sucrose) X Recall (immediate/delayed) (repeated measure). After the 2nd drink, measures of Word recall and Recall Times were analysed using three-way ANOVAs:

Drink (placebo/sucrose) X Top-up (placebo/sucrose) X Recall (Immediate/Delayed) (repeated measure).

- Measures of Decision and Movement Times on the Hick Paradigm were analysed using two-way ANOVAs:

  Drink (placebo/sucrose) X Number of Lamps (1, 2, 4 ,8) (repeated measure).

  After the 2nd drink, measures of Decision and Movement Times on the Hick Paradigm were analysed using three-way ANOVAs:

  Drink (placebo/sucrose) X Top-up (placebo/sucrose) X Number of Lamps (1, 2, 4, 8) (repeated measure).

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using one-way ANOVAs:

  Drink (placebo/sucrose) X Measure.

  After the 2nd drink, measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVAs:

  Drink (placebo/sucrose) X Top-up (placebo/sucrose) X Measure.

- Measures of Correct responses, Wrong responses and Reaction time on the RIPT were analysed using three-way ANOVAs:

  Drink (placebo/sucrose) X Session (1, 2) X Minute (1, 2, 3, 4, 5) (repeated measure).

After the 2nd drink, measures of Correct responses, Wrong responses and Reaction time on the RIPT were analysed using three-way ANOVAs:

Drink (placebo/sucrose) X Top-up (placebo/sucrose) X Minute (1, 2, 3, 4, 5) (repeated measure).

- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

2.3.2 EFFECT OF BLOOD GLUCOSE LEVELS AND CHANGE

Stepwise Linear Regressions, with Independent variables of blood glucose levels (0, 30, 60, 90, 120 minutes) and changes in blood glucose levels, were performed on the data set. Changes in blood glucose levels were calculated using the following equations:

- Change 1 = BG 30 – BG 0
- Change 2 = BG 60 – BG 30
- Change 3 = BG 90 – BG 60
- Change 4 = BG 120 – BG 90

The regressions were performed on the data separately for the each condition. The following Dependent variables were used:

- Mood at each time point (Difference score)
- All aspects of Memory (Immediate and Delayed) for each session
- Total Decision times for each session
- Intercept and Intra-Individual Variability at each time point
- Total Correct, Wrong responses and Reaction times for each session

2.4 RESULTS

For clarity only significant results involving macronutrients or condition will be reported. It may be assumed that main effects and higher order interactions that are not reported were non-significant and are documented in Appendix 2.

18 participants were removed from the data set due baseline blood glucose levels over 7.4mmol/L. It was assumed that either participants had eaten before arriving at the laboratory, or had a metabolic problem.

2.4.1 EFFECT OF BEVERAGE

Sucrose and Blood Glucose Levels

One must note that the five groups significantly differed at baseline [$F (4,197) = 2.63$, $p<0.05$]. Post-Hoc tests failed to reveal significant differences, however, participants who consumed 50g of sucrose tended to have higher blood glucose levels than either 30g ($p=0.08$) or 70g ($p=0.06$). All five conditions had mean baseline values between 4.4mmol/L and 5.2mmol/L, within the range for fasting blood glucose levels.

Figure 2.1 illustrates that the interaction Drink X Time reached significance [$F (8,394) = 8.39$, $p<0.001$]. Simple Main Effects (SME's) demonstrated significant differences in blood glucose levels at 30 minutes [$F (4,197) = 14.40$, $p<0.001$] and 60 minutes [$F (4,197) = 5.98$, $p<0.001$]. Table 2.2 illustrates the findings. Furthermore, SME's demonstrated significant changes over time for all groups except 0g [$F (2,394) = 0.88$, p=n.s.]

Figure 2.1: Profile of Blood Glucose Levels over Time for the first hour (means +/- s .e.m)

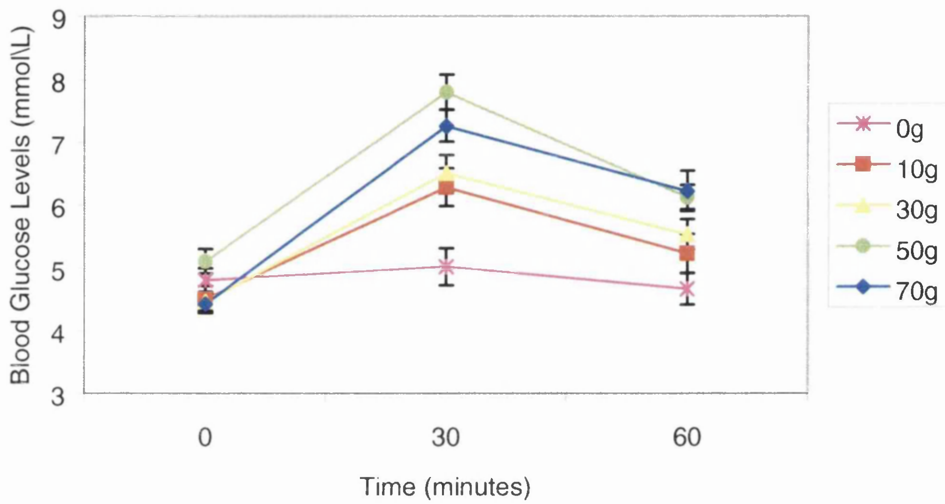


Table 2.2: Summary table for the significant differences between conditions with respect to Blood Glucose Levels at the three time points

Time	F-ratio, Sig.	Differences
0 minutes	[F (4,197) = 2.63, p<0.05]	- trend for 50g to have higher blood glucose levels than 30g (p=0.08) 70g (p=0.06)
30 minutes	[F (4,197) = 14.40, p<0.001]	- placebo (0g) significantly lower than all other groups - 50g significantly higher than 0g, 10g and 30g (p<0.01)
60 minutes	[F (4,197) = 5.98, p<0.001]	- placebo (0g) significantly lower than 50g and 70g (p<0.001)

When the second hour was analysed, the interaction Drink x Time reached significance [$F(4,192) = 5.39$, $p<0.001$]. SME's demonstrated that following the Top-up, the placebo and the 30g groups' blood glucose levels did not significantly differ during the second hour ([$F(1,197) = 0.27$, p=n.s.]; [$F(1,197) = 0.88$, p=n.s.]). Additionally, at 90 minutes the placebo ($p<0.01$), and at 120 minutes those who consumed 70g, had significantly higher blood glucose levels than those who consumed 50g ($p<0.05$).

The effects of the Top-up reached significance [$F(1,192) = 4.90$, $p<0.05$]. At 90 minutes the participants who had consumed the active Top-up showed a significant increase in blood glucose levels compared to the placebo [$F(1,192) = 6.76$, $p=0.01$].

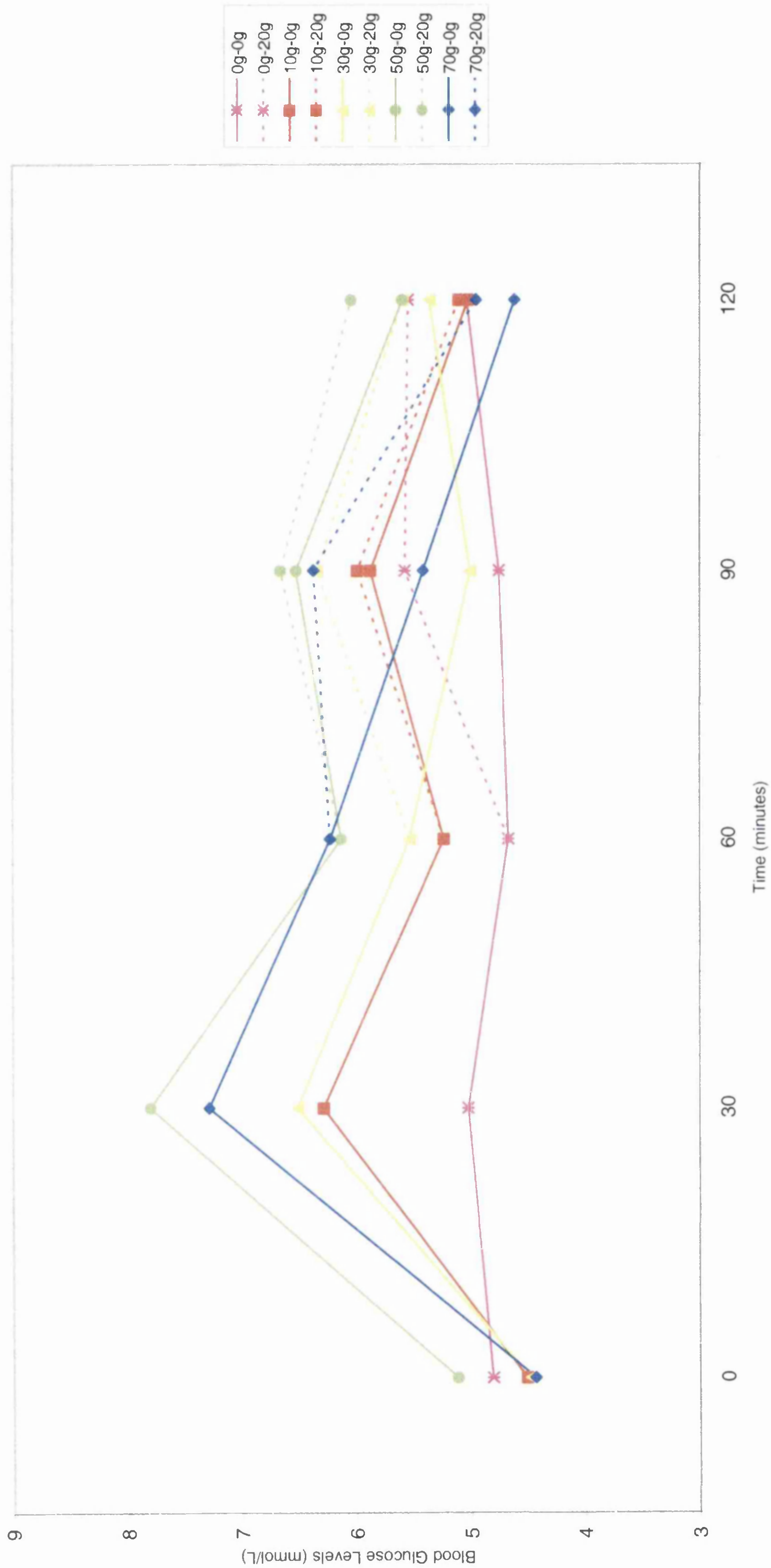
Figure 2.2 illustrates that 10g and 30g groups had similar blood glucose profiles over the two-hour period, despite consuming different amounts of glucose. Furthermore, the 50g group had the highest blood glucose levels over the first 60 minutes. This was not expected, as 50 grams was not the highest dose.

Sucrose and Mood

Mood failed to be influenced by the consumption of the first drink.

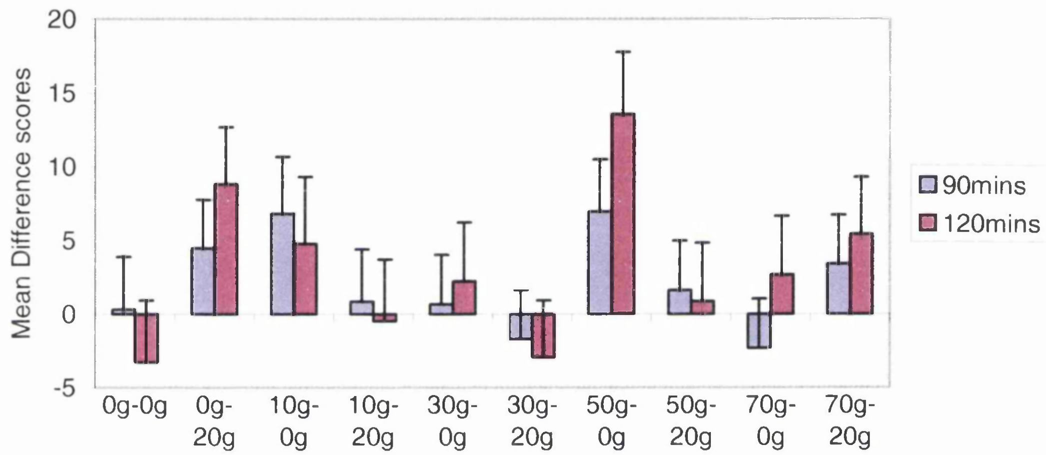
The interaction Drink X Top-up X Time just reached significance with respect to Elation [$F(4,192) = 2.43$, $p<0.05$]. Figure 2.3 and Simple Simple Main Effects (SSME's) show that at 120 minutes, participants who consumed 0g-20g, compared to 0g-0g were significantly more elated [$F(1,196) = 4.45$, $p<0.05$]. In those who consumed 50g, the

Figure 2.2: Profile of Blood Glucose Levels over Time



pattern was opposite; those who consumed 50g-0g were significantly more elated than 50g-20g at 120 minutes [F (1,196) = 4.56, p<0.05]. Furthermore, increases in elation were observed between 60-120 minutes for those who consumed 0g-20g [F (1,192) = 3.06, p=0.08], 50g-0g [F (1,192) = 6.11, p<0.05] and 70g-0g [F (1,192) = 3.84, p=0.05].

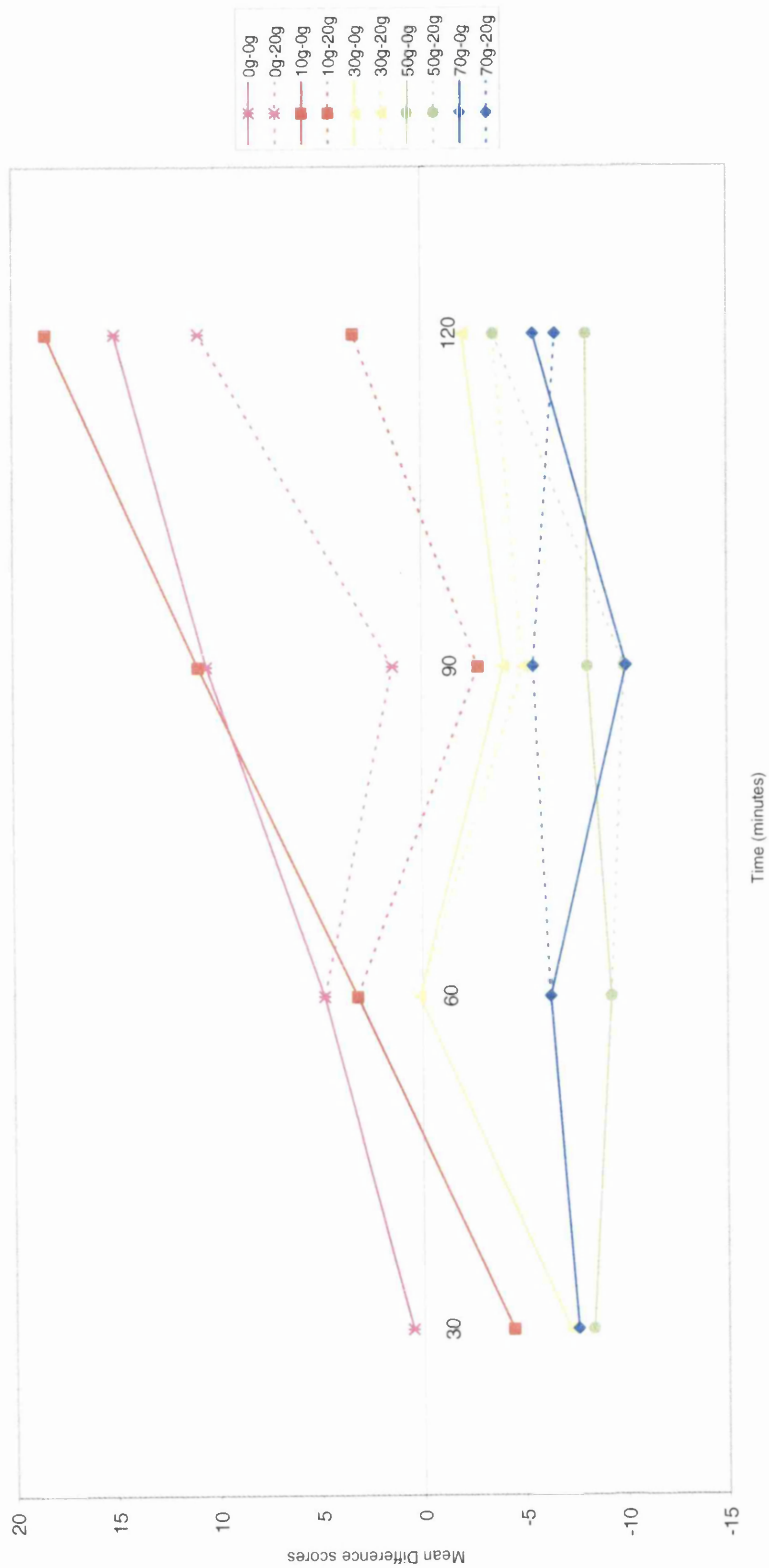
Figure 2.3: Profile of Elation ratings over Time for Drink and Top-up (mean +/- s.e.m)



Sucrose and Hunger

The effect of the drink consumed just missed significance in the first hour [F (4,197) = 2.19, p=0.07]; there was a trend for participants who consumed 50g to be less hungry than those who consumed 0g (p=0.08). After the first 60 minutes, the 1st drink continued to significantly influence hunger [F (4,192) = 2.99, p<0.05]. However, Post-Hoc tests demonstrated that those who consumed 50g and 70g (p=0.09) of sucrose reported less hunger than the placebo in the second hour, regardless of Top-up drink. The consumption of the Top-up drink failed to influence hunger [F (1,192) = 0.84, p=n.s.]. Figure 2.4 illustrates these findings.

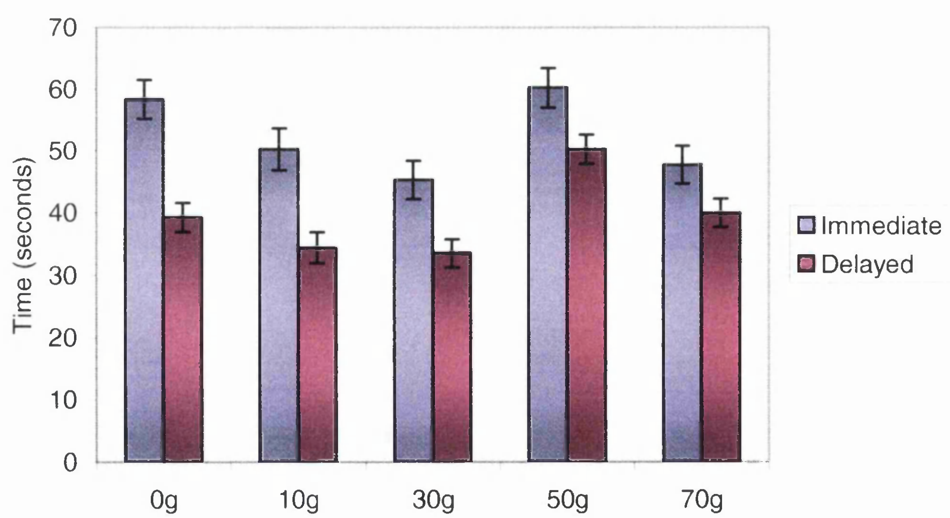
Figure 2.4: Profile of Hunger ratings over Time



Sucrose Dose and Memory

Drink failed to influence the number of words recalled on the first memory test, [F (4,197) = 1.54, p=n.s.]. The interaction Drink X Recall Time taken trying to recall the first word list reached significance [F (4,197) = 3.76, p<0.01]. Figure 2.5 and SME's demonstrated that at immediate recall, those who consumed 50g of sucrose took significantly longer to recall the word list than the 30g and 70g groups (p<0.05) and the placebo condition took significantly longer than the 30g (p<0.05). Furthermore, the 50g group, compared to the other four conditions, took significantly longer at delayed recall to recall the word list (p<0.05).

Figure 2.5: Profile of the time taken to recall the first word list for the Drink conditions (means +/- s.e.m)



When attention was turned to second hour, neither drink affected the number of words recalled ([F (4,192) = 1.48, p=0.21]; [F (1,192) = 1.53, p=0.22]). As in the first hour, the drinks ingested produced differences in the time taken to recall the word list. The interaction Drink X Recall reached significance [F (4,192) = 4.78, p<0.01]. SME's demonstrated that the 50g group took significantly longer to recall the word list than all other groups when immediate recall was considered (p<0.05), and the placebo condition took significantly longer than 30g (p<0.05). At delayed recall the placebo, 50g and 70g groups took significantly longer trying to recall the words (p<0.05). The interaction Top-up X Recall also reached significance [F (1,192) = 4.29, p<0.05]. SME's demonstrated that at delayed recall, those who consumed the placebo top-up took significantly longer to recall the words than the 20g top-up [F (1,200) = 7.88, p<0.01].

Sucrose and the Hick Paradigm

7 participants were removed from the data set with respect to the first Hick test, and 4 with respect to the second, due to missing results and negative slope values.

Drink failed to influence decision times on the first Hick test [F (4,190) = 0.78, p=n.s.]. The interaction Drink X Lamps reached significance for movement times [F (12,570) = 1.92, p<0.05]. SME's demonstrated that on the 8 lamp test, participants who consumed 0g took significantly longer than those who consumed 70g [F (4,190) = 2.65, p<0.05]. Increases in movement times were observed for those who consumed 0g [F (3,570) = 18.81, p<0.001], 30g [F (3,570) = 6.69, p<0.001] and 50g [F (3,570) = 5.56, p=0.001]. Drink also failed to influence Intercept [F (4,190) = 1.07, p=n.s.], Slope [F (4,190) = 0.44, p=n.s.] or Intra-Individual Variability [F (4,190) = 0.86, p=n.s.].

When attention was turned to the second Hick test, neither Drink [F (4,188) = 0.23, p=n.s], nor Top-up influenced decision times [F (1,188) = 1.52, p=n.s]. Drink consumed influenced movement times [F (4,188) = 2.98, p<0.05], with participants who consumed 0g taking significantly longer than those who consumed 50g (p<0.05). Neither drink influenced the Intercept {[F (4,188) = 0.32, p=n.s.], [F (1,188) = 0.24, p=n.s.]}, Slope {[F (4,188) = 1.05, p=n.s.], [F (1,188) = 1.81, p=n.s.]} or Intra-Individual Variability {[F (4,188) = 0.37, p=n.s.], [F (1,188) = 0.20, p=n.s.]}.

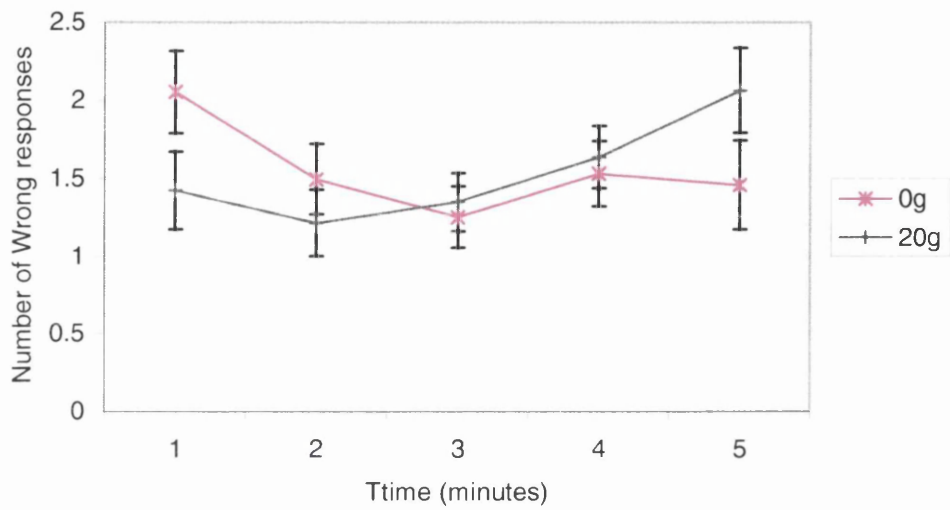
Sucrose and the RIPT

13 participants were removed from the data set with respect to the first two Vigilance tests, and 8 from the third test, due to incomplete data or incorrect performance on the task (>20 wrong responses per minute).

Drink failed to influence correct responses [F (4,184) = 0.39, p=n.s.], wrong responses [F (4,184) = 1.26, p=n.s.] or reaction times [F 4,184) = 1.71, p=n.s.] in the first two Vigilance tests.

Neither correct responses {[F (4,184) = 1.60, p=n.s.]; [F (1,184) = 0.19, p=n.s.]}, nor reaction times {[F (4,184) = 0.42, p=n.s.]; [F (1,184) = 0.37, p=n.s.]}, were influenced by either drink in the second hour. The interaction Top-up X Minute reached significance for wrong responses [F (4,736) = 5.23, p<0.001]. SME's demonstrated a significant decrease in the number of wrong responses over the test for those who consumed the placebo top-up drink [F (4,768) = 3.78, p<0.01], with a significant increase in wrong responses over the test for those who consumed 20g [F (4,768) = 5.73, p<0.001].

Figure 2.6: The effect of Drink on Wrong responses on the third RIPT (means +/- s.e.m)



2.4.2 EFFECTS OF BLOOD GLUCOSE LEVELS AND CHANGE

Stepwise linear regressions were performed on the data, with blood glucose levels, and the four periods between as the independent variables, and the measures of Mood, Hunger and Cognition as the dependent variables. Patterns observed within the breakfast conditions are reported, however, in the first hour there were 4 active groups and in the second hour, with the addition of the top-up drink, 9 active groups.

0-60 MINUTES

10g

Slow rising blood glucose levels over the first 30 minutes were associated with participants taking longer to recall the first word list. High blood glucose levels at 30 minutes were associated with increased Confidence and total mood over the first 30 minutes. Rapidly falling blood glucose levels (30-60mins) were associated with increased Clearheadedness over the first hour, Total mood (60mins) and enhanced performance on the first Hick Paradigm.

30g

Low blood glucose levels at 30 minutes were associated with increased energy over the first half hour. Low blood glucose levels at 60 minutes were associated with an increased number of wrong responses on the second RIPT. No effects were observed with the first memory test or Hick Paradigm.

50g

Rapidly rising blood glucose levels over the first 30 minutes were associated with increased Composure, Agreeability and Elation over the first 30 minutes. Rapidly falling levels (30-60mins) were associated with increased Composure and Total mood over the first 30 minutes. Low blood glucose levels at 60 minutes were associated with increased Composure and Agreeability over the first hour, and Confidence and Total mood at 60 minutes. High blood glucose levels at 30 minutes were associated with increased time taken trying to recall the first word list. Rapidly rising blood glucose levels (0-30mins) were associated with less Intra-Individual Variability on the Hick Paradigm.

70g

Rapidly falling and low blood glucose levels (30-60mins) predicted increased Confidence, Energy and Total mood over the first hour. Slow falling blood glucose levels (30-60mins) predicted increased Hunger over the first hour. Low blood glucose levels at 30 minutes were associated with enhanced performance on the Hick Paradigm. No effects were observed with memory test or the RIPT in the first hour.

60-120 MINUTES

0g – 20g

Low blood glucose levels at 90 minutes were associated with increased Agreeability (120mins) and Total mood over the last hour. Low levels at 120 minutes were associated with enhanced Clearheadedness over the last hour. Rapidly falling blood glucose levels (30-60mins) were indicative of quicker decision times and lower intercept values on the second Hick test. High blood glucose levels at 60 minutes were indicative of quicker reaction times on the third RIPT. No associations were observed with memory.

10g – 0g

Rapidly falling blood glucose levels (60-90mins) were associated with enhanced Confidence (120mins). Rapidly falling blood glucose levels (90-120mins) were associated with increased Clearheadedness over the last hour, with low levels at 120 minutes associated with increased Composure (120mins). Low blood glucose levels at 60 minutes were indicative of quicker reaction times on the second Hick Paradigm, with slowly falling levels (30-60mins) associated with less Intra-Individual Variability. No associations were observed with measures of memory or the RIPT in the second hour.

10g – 20g

High blood glucose levels at 30 minutes were indicative of increased Elation (90mins), Clearheadedness and Confidence over the last hour. Low blood glucose levels at 120 minutes were associated with increased Agreeability and Clearheadedness (120mins). Rapidly rising (0-30mins) and subsequent rapid falls in blood glucose levels (30-60mins) were indicative of enhanced Total mood over the last hour. Rapidly falling levels (30-60mins) were indicative of quicker decision times and lower intercept values on the second test. Falling blood glucose levels (60-90mins) were associated with quicker reaction times on the third RIPT. No associations were observed with memory.

30g – 0g

Rapidly rising blood glucose levels (0-30mins) were indicative of enhanced Clearheadedness (90mins) and Composure (120mins). Low blood glucose levels at 90 minutes were associated with increased Energy (90mins), with low levels at 60 minutes indicative of increased Energy (120mins). Low blood glucose levels at 120 minutes were associated with increased Clearheadedness over the last hour. High levels at 90, and 120 minutes were associated with increased hunger over the last hour. High blood glucose levels at 90 were associated with longer time taken to recall the second immediate word list. Measures of the Hick Paradigm and RIPT failed to be associated.

30g – 20g

Rapidly falling blood glucose levels (30-60mins) were indicative of increased Composure (120mins). High blood glucose levels at120 minutes were associated with increased Energy over the last hour. Low blood glucose levels at 30 minutes were indicative of quicker decision times on the second Hick Paradigm. Rapidly falling levels (60-90mins) were associated with an increased number of words recalled on the second memory test, with low levels at 90 minutes associated with an increased number of correct responses on the third RIPT.

50g – 0g

Rapidly falling blood glucose levels (90-120mins) were associated with increased Composure (90mins). High blood glucose levels at 90 minutes were associated with increased Energy (90mins). Slow falling blood glucose levels (60-90mins) were associated with increased Total mood (90mins). High blood glucose levels at 30 minutes were associated with increased time being taken trying to recall the second delayed word list. Low blood glucose levels at 60 minutes, and rapidly falling levels (90-120mins) were associated with less Intra-Individual Variability on the second Hick Paradigm. Measures of the third RIPT failed to be influenced.

50g – 20g

Rapidly rising blood glucose levels (0-30mins) and low blood glucose levels at 60 minutes were indicative of increased Composure (90mins), with low levels at 60 minutes also indicative of increased Agreeability (90mins) and Composure (120mins). Rapidly rising levels following the Top-up (60-90mins) were associated with increased Agreeability (120mins) and with increased Clearheadedness and Total Mood over the last hour. High levels at 120 minutes were associated with increased Elation (90mins) and increased Hunger (120mins). Rapidly falling blood glucose levels (60-90mins) were associated with less Intra-Individual Variability on the second Hick Paradigm. No associations were observed with measures of memory or the RIPT in the second hour.

70g – 0g

Slow rising blood glucose levels (0-30mins) were associated with increased Clearheadedness (120mins). Low blood glucose levels at 60 minutes were indicative of increased Agreeability, Energy and Total mood (120mins). Slow falling levels (90-120) were associated with increased Elation and Energy (90mins). Slow falling blood glucose levels (90-120mins) were associated with an increased number of immediate words recalled, and increased time taken to recall the delayed test, on the second memory test, however rapidly falling levels (60-90mins) were associated with an increased number of delayed words recalled on the second test. Slow falling blood glucose levels (60-90mins) and low levels at 120 minutes were associated with flatter slopes on the second Hick Paradigm. Low blood glucose levels at 30 minutes were indicative of an increased number of correct, and less wrong responses on the third RIPT.

70g – 20g

Rapidly falling levels (30-60mins) were indicative of increased Clearheadedness and Total mood over the last hour. Slow falling blood glucose levels (30-60mins) were indicative of increased hunger over the last hour. Rising blood glucose levels following the Top-up were associated with increased Confidence over the last hour, with a subsequent fall and low levels at 120 associated with increased Confidence (120mins). Low levels at 60 and 90 minutes were associated with increased Energy over the last hour. Slow falling and high blood glucose levels (90-120mins) and rapidly rising blood glucose levels (0-30mins) were associated with enhanced memory performance on the second test. Rapidly falling blood glucose levels (30-60mins) were indicative of quicker decision and movement times, and lower intercepts on the second Hick Paradigm. Slow rising blood glucose levels (0-30mins) were indicative of flatter slopes, with slow falling levels (90-120) being associated with less intra-individual variability. Rapidly falling blood glucose levels (60-90mins) were associated with an increased number of correct responses on the third RIPT, with rapidly rising levels (0-30mins) and rapidly falling levels (90-120) being associated with less wrong responses.

2.5 SUMMARY

Sucrose and Blood Glucose Levels

- 50g of sucrose rose blood glucose levels higher than 70g of sucrose over the two-hour experiment.

- 10g and 30g of sucrose show similar profiles in blood glucose levels.

0-60 minutes

- Rapidly falling blood glucose levels between 30 and 60 minutes was associated with increased mood over the first hour in all conditions.
- Slow rising and low blood glucose levels between 0 and 30 minutes were associated with better mood in those who consumed 10 and 30g, and rapidly rising levels in those who consumed 50g.

60-120 minutes

- Falling blood glucose levels between 30 and 60minutes were associated with enhanced mood and cognition across the sucrose doses over the final hour.
- Low and falling blood glucose levels over the second hour were associated with better mood in those who had consumed the lower doses of sucrose (Control-20g, 10g-0g, 10g-20g & 30g-0g).
- Rising blood glucose levels (60-90mins) and/or slow falling levels (60-120mins) minutes were associated with increased mood and Energy in those who had consumed the higher doses (50g-0g, 50g-20g, 70g-0g & 70g-20g).

Sucrose, Mood and Hunger

- Participants who consumed 0g followed by the 20g Top-up, were significantly more Elated than those who consumed the 0g Top-up. Conversely participants who consumed 50g, followed by the 0g Top-up, were significantly more Elated than those who consumed the 20g Top-up.

- Consumption of the higher dose drinks, 50g and above, significantly reduced hunger compared to 0g. Furthermore, the Top-up had no effect on hunger.

Sucrose and Cognition

- Participants who consumed the 50g dose took the most time trying to recall the word lists, with those who consumed the 30g dose taking the least.
- Drink and Top-up failed to influence any aspect of the Hick Paradigm.
- Participants who consumed the 0g Top-up recorded significantly less wrong responses over time, whereas in those who consumed the 20g Top-up the pattern was opposite.

2.6 DISCUSSION

The finding of the present study failed to demonstrate a single sucrose dose that was beneficial across measures of mood, hunger and cognition. However, support was found for the hypothesis that falling blood glucose levels were associated with enhanced mood and cognitive performance. The majority of studies previously reported have focussed on the beneficial influence of glucose with respect to cognition and mood (section 1.3). Hence, examining the effects of sucrose was a rather novel experiment.

It can be suggested from the results that differential doses of sucrose have a limited effect on measures of mood and cognitive performance. The effectiveness of the dose was variable, so no single dose was identified as benefiting mood and cognitive performance throughout the study. In addition, the consumption of a Top-up drink failed to produce substantial differences in performance over the test measures, except with increased wrong responses in the RIPT in the second hour compared to the placebo (Figure 2.6).

White and colleagues (White, 1991; Messier and White, 1987) demonstrated that both fructose and glucose were found to enhance memory when given independently. Glucose was suggested to act at lower doses via a central mechanism, with fructose acting peripherally via the liver. One could suggest, therefore, that the consumption of the sucrose compound failed to activate either pathway sufficiently. Or alternatively, that the signals from the two pathways may have interfered with each other.

It is interesting to note that there was little difference between the blood glucose profiles following consumption of either 10g or 30g of sucrose in the first hour. During the second hour, there was no difference in blood glucose profiles in those who consumed 10g following consumption of the top-up drinks. Yet, in those who consumed 30g, the profiles were noticeably different following the top-up drinks. One can suggest that in the 10g conditions, it was the act of consuming the drink that elicited the observed changes in blood glucose levels. The marked difference between the 30g - 0g and 30g – 20g conditions could be suggested to reflect actual physiological responses to the sucrose load.

Furthermore, the profiles observed following consumption of the 50g and 70g doses warrant further explanation. One must remember that there were significant differences between the blood glucose levels at 0 minutes ($p<0.05$), with those participants who consumed 50g of sucrose having higher blood glucose levels than either 30g ($p=0.08$) or 70g ($p=0.06$). Therefore, one can suggest that the profiles over the first hour are quite similar. Again there are marked differences following the top-up drinks. One could suggest that as the initial dose was greater, the physiological responses were still primed and ready to deal with a subsequent load of sucrose.

Individual differences in glucose tolerance were clearly an important factor. It is clear from the results, that falling blood glucose levels, indicating an effective utilisation of the carbohydrate load, were associated with enhanced mood and cognitive performance throughout the test session (section 2.4.2). Low and falling blood glucose levels were associated with better mood, better memory, quicker reaction times, lower intercept values and more correct answers on the Vigilance Task. This replicates previous findings following glucose consumption (Benton et al., 1994; Donohoe and Benton, 1999a; Messier et al., 1999).

2.6.1 CONCLUSION

The present findings are consistent with the suggestion that individual differences in glucose tolerance are an important factor influencing mood and cognitive functioning. This concept is investigated in more depth in subsequent chapters.

Table 2.3: Summary table with respect to measures of Mood between baseline and 60 minutes (+/- s.e.m)

MOOD	DRINK	30mins – baseline	60mins – baseline	RESULT
Composure	0g	7.463 (3.065)	-3.000 (3.931)	***Drink*** F (4,197) = 1.242, p=0.294
	10g	3.029 (3.317)	-3.657 (4.255)	***Time***
	30g	6.279 (2.993)	-2.674 (3.839)	F (1,197) = 39.874, p<0.001
	50g	9.475 (3.103)	2.575 (3.980)	***Drink X Time*** F (4,197) = 0.280, p=0.891
	70g	0.884 (2.993)	-8.209 (3.839)	
Agreeability	0g	3.488 (2.787)	-6.829 (3.646)	***Drink*** F (4,197) = 0.629, p=0.642
	10g	0.543 (3.016)	-5.343 (3.947)	***Time***
	30g	-.0442 (2.721)	-7.093 (3.561)	F (1,197) = 37.638, p<0.001
	50g	0.300 (2.821)	-4.225 (3.692)	***Drink X Time*** F (4,197) = 0.779, p=0.540
	70g	-2.907 (2.721)	-11.767 (3.561)	
Elation	0g	4.366 (2.318)	2.341 (2.578)	***Drink*** F (4,197) = 0.893, p=0.469
	10g	2.829 (2.508)	-0.429 (2.791)	***Time***
	30g	0.767 (2.263)	-0.209 (2.518)	F (1,197) = 10.659, p=0.001
	50g	4.625 (2.346)	2.300 (2.610)	***Drink X Time*** F (4,197) = 1.008, p=0.404
	70g	1.605 (2.263)	-4.535 (2.518)	
Confidence	0g	9.927 (2.638)	2.707 (3.319)	***Drink*** F (4,197) = 0.447, p=0.774
	10g	6.114 (2.856)	3.286 (3.593)	***Time***
	30g	6.395 (2.576)	3.302 (3.241)	F (1,197) = 17.489, p<0.001
	50g	6.100 (2.671)	2.750 (3.361)	***Drink X Time*** F (4,197) = 0.782, p=0.538
	70g	4.907 (2.576)	-2.093 (3.241)	

Energy	0g	9.341 (3.278)	0.610 (3.774)	***Drink*** F (4,197) = 0.728, p=0.574 ***Time*** F (1,197) = 23.798, p<0.001 ***Drink X Time*** F (4,197) = 1.494, p=0.205
	10g	6.114 (3.548)	-0.314 (4.085)	
	30g	2.093 (3.201)	0.00 (3.685)	
	50g	14.575 (3.319)	1.450 (3.821)	
	70g	5.837 (3.201)	-0.302 (3.685)	
Clearheaded	0g	1.878 (2.726)	-6.683 (3.544)	***Drink*** F (4,197) = 0.230, p=0.921 ***Time*** F (1,197) = 46.694, p<0.001 ***Drink X Time*** F (4,197) = 0.374, p=0.827
	10g	2.486 (2.950)	-4.600 (3.835)	
	30g	2.814 (2.661)	-7.326 (3.460)	
	50g	4.400 (2.759)	-5.750 (3.588)	
	70g	2.116 (2.661)	-10.186 (3.460)	
Total Mood	0g	36.463 (10.680)	-10.854 (13.863)	***Drink*** F (4,197) = 1.178, p=0.322 ***Time*** F (1,197) = 68.215, p<0.001 ***Drink X Time*** F (4,197) = 0.577, p=0.679
	10g	21.114 (11.560)	-11.057 (15.004)	
	30g	17.907 (10.429)	-14.000 (13.537)	
	50g	39.475 (10.813)	-0.900 (14.035)	
	70g	12.442 (10.429)	-37.093 (13.537)	
Hunger	0g	0.512 (2.918)	4.780 (3.837)	***Drink*** F (4,197) = 2.185, p=0.072 ***Time*** F (1,197) = 9.771, p<0.01 ***Drink X Time*** F (4,197) = 1.764, p=0.138
	10g	-4.429 (3.158)	3.171 (4.153)	
	30g	-7.209 (2.849)	0.140 (3.747)	
	50g	-8.350 (2.954)	-9.275 (3.885)	
	70g	-7.581 (2.849)	-6.302 (3.747)	

Table 2.4: Summary table with respect to measures of Mood between 60 and 120 minutes (+/- s.e.m)

MOOD	DRINK	90mins - baseline	120mins - baseline	RESULT
Composure	0g-0g	10.895 (5.842)	6.474 (5.680)	***Drink*** F (4,192) = 0.979, p=0.420
	0-20g	-4.182 (5.429)	-6.364 (5.279)	***Top*** F (1,192) = 2.114, p=0.148
	10g-0g	7.000 (6.367)	0.625 (6.190)	***Drink X Top*** F (4,192) = 0.748, p=0.560
	10g-20g	0.368 (5.842)	-4.947 (5.680)	***Time***
	30g-10g	4.048 (5.557)	4.381 (5.403)	F (1,192) = 6.469, p<0.05 ***Drink X Time***
	30g-20g	-1.045 (5.429)	-1.545 (5.279)	F (4,192) = 1.466, p=0.214 ***Top X Time***
	50g-0g	11.158 (5.842)	3.737 (5.680)	F (1,192) = 0.102, p=0.750 ***Drink X Top X Time***
	50g-20g	7.667 (5.557)	2.571 (5.403)	F (4,192) = 0.100, p=0.982
	70g-0g	-6.286 (5.557)	-5.190 (5.403)	
	70g-20g	-2.227 (5.429)	-2.182 (5.279)	
Agreeability	0g-0g	-3.684 (5.122)	-9.211 (5.247)	***Drink*** F (4,192) = 0.443, p=0.777
	0-20g	-4.500 (4.760)	-1.091 (4.877)	***Top*** F (1,192) = 0.360, p=0.549
	10g-0g	4.688 (5.582)	1.750 (5.718)	***Drink X Top*** F (4,192) = 0.455, p=0.769
	10g-20g	-4.421 (5.122)	-7.579 (5.247)	***Time***
	30g-10g	-3.286 (4.872)	-2.143 (4.991)	F (1,192) = 0.180, p=0.672 ***Drink X Time***
	30g-20g	-5.182 (4.760)	-5.955 (4.877)	F (4,192) = 0.657, p=0.622 ***Top X Time***
	50g-0g	-5.579 (5.122)	-4.158 (5.247)	F (1,192) = 0.001, p=0.982 ***Drink X Top X Time***
	50g-20g	-4.286 (4.872)	-4.095 (4.991)	F (4,192) = 1.764, p=0.138
	70g-0g	-9.095 (4.872)	-5.238 (4.991)	
	70g-20g	-7.864 (4.760)	-9.364 (4.877)	

Elation	0g-0g	0.316 (3.557)	-3.263 (4.187)	***Drink*** F (4,192) = 0.793, p=0.531 ***Top*** F (1,192) = 0.289, p=0.591 ***Drink X Top*** F (4,192) =2.030, p=0.092 ***Time*** F (1,192) = 1.635, p=0.203 ***Drink X Time*** F (4,192) = 1.299, p=0.272 ***Top X Time*** F (1,192) = 0.303, p=0.583 ***Drink X Top X Time*** F (4,192) = 2.428, p<0.05
	0-20g	4.455 (3.305)	8.818 (3.891)	
	10g-0g	6.812 (3.876)	4.750 (4.562)	
	10g-20g	0.842 (3.557)	-0.474 (4.187)	
	30g-10g	0.667 (3.383)	2.238 (3.982)	
	30g-20g	-1.682 (3.305)	-2.955 (3.891)	
	50g-0g	6.947 (3.557)	13.579 (4.187)	
	50g-20g	1.619 (3.383)	0.857 (3.982)	
	70g-0g	-2.333 (3.383)	2.667 (3.982)	
	70g-20g	3.409 (3.305)	5.409 (3.891)	
Confidence	0g-0g	6.947 (4.916)	6.263 (4.781)	***Drink*** F (4,192) = 0.231, p=0.921 ***Top*** F (1,192) = 0.124, p=0.725 ***Drink X Top*** F (4,192) = 0.149, p=0.963 ***Time*** F (1,192) = 0.054, p=0.816 ***Drink X Time*** F (4,192) = 1.955, p=0.103 ***Top X Time*** F (1,192) = 0.076, p=0.784 ***Drink X Top X Time*** F (4,192) = 0.206, p=0.935
	0-20g	6.000 (4.568)	8.364 (4.443)	
	10g-0g	9.563 (5.357)	7.938 (5.210)	
	10g-20g	8.263 (4.916)	7.158 (4.781)	
	30g-10g	9.524 (4.676)	5.190 (4.548)	
	30g-20g	5.545 (4.568)	0.182 (4.443)	
	50g-0g	4.579 (4.916)	4.632 (4.781)	
	50g-20g	5.333 (4.676)	7.333 (4.548)	
	70g-0g	3.190 (4.676)	7.238 (4.548)	
	70g-20g	2.318 (4.568)	4.636 (4.443)	

Energy	0g-0g	5.632 (5.943)	2.474 (6.422)	***Drink*** F (4,192) = 0.782, p=0.538 ***Top*** F (1,192) = 0.214, p=0.644 ***Drink X Top*** F (4,192) = 0.925, p=0.451 ***Time*** F (1,192) = 4.108, p<0.05 ***Drink X Time*** F (4,192) = 0.539, p=0.707 ***Top X Time*** F (1,192) = 0.658, p=0.418 ***Drink X Top X Time*** F (4,192) = 0.569, p=0.686
	0-20g	0.182 (5.523)	-3.318 (5.968)	
	10g-0g	1.562 (6.477)	-4.813 (6.998)	
	10g-20g	6.947 (5.943)	5.526 (6.422)	
	30g-10g	2.381 (5.653)	2.952 (6.108)	
	30g-20g	-1.636 (5.523)	-5.273 (5.968)	
	50g-0g	14.421 (5.943)	12.579 (6.422)	
	50g-20g	7.143 (5.653)	-0.048 (6.108)	
	70g-0g	0.810 (5.653)	3.952 (6.108)	
	70g-20g	8.955 (5.523)	6.818 (5.968)	
Clearheaded	0g-0g	1.895 (5.148)	-3.105 (6.107)	***Drink*** F (4,192) = 0.394, p=0.813 ***Top*** F (1,192) = 0.124, p=0.725 ***Drink X Top*** F (4,192) = 0.850, p=0.495 ***Time*** F (1,192) = 7.754, p<0.01 ***Drink X Time*** F (4,192) = 0.309, p=0.872 ***Top X Time*** F (1,192) = 2.572, p=0.110 ***Drink X Top X Time*** F (4,192) = 0.882, p=0.476
	0-20g	-9.045 (4.784)	-12.136 (5.675)	
	10g-0g	0.250 (5.610)	-4.500 (6.655)	
	10g-20g	-3.684 (5.148)	-8.842 (6.107)	
	30g-10g	-0.524 (4.897)	-0.524 (5.809)	
	30g-20g	-1.364 (4.784)	-4.318 (5.675)	
	50g-0g	-5.316 (5.148)	-3.474 (6.107)	
	50g-20g	7.238 (4.897)	-0.667 (5.809)	
	70g-0g	-7.619 (4.897)	-6.333 (5.809)	
	70g-20g	-1.273 (4.784)	-6.773 (5.675)	

Total Mood	0g-0g	22.000 (20.286)	-0.368 (22.382)	***Drink*** F (4,192) = 0.537, p=0.709
	0-20g	-7.091 (18.852)	-5.727 (20.800)	***Top*** F (1,192) = 0.878, p=0.350
	10g-0g	29.875 (22.106)	5.750 (24.390)	***Drink X Top*** F (4,192) = 0.292, p=0.883
	10g-20g	8.316 (20.286)	-9.158 (22.382)	***Time***
	30g-10g	12.810 (19.296)	12.095 (21.289)	F (1,192) = 4.168, p<0.05 ***Drink X Time***
	30g-20g	-5.364 (18.852)	-19.864 (20.800)	F (4,192) = 1.187, p=0.318 ***Top X Time***
	50g-0g	26.211 (20.286)	26.895 (22.382)	F (1,192) = 0.418, p=0.519 ***Drink X Top X Time***
	50g-20g	24.712 (19.296)	5.952 (21.289)	F (4,192) = 1.234, p=0.298
	70g-0g	-21.333 (19.296)	-2.905 (21.289)	
	70g-20g	3.318 (18.852)	-1.455 (20.800)	
Hunger	0g-0g	10.526 (6.490)	15.000 (7.541)	***Drink*** F (4,192) = 2.992, p=0.020
	0-20g	1.409 (6.031)	10.909 (7.008)	***Top*** F (1,192) = 0.844, p=0.359
	10g-0g	10.937 (7.072)	18.375 (8.217)	***Drink X Top*** F (4,192) = 0.495, p=0.739
	10g-20g	-2.789 (6.490)	3.316 (7.541)	***Time***
	30g-10g	-4.048 (6.173)	-2.048 (7.173)	F (1,192) = 11.300, p=0.001
	30g-20g	-5.000 (6.031)	-3.545 (7.008)	***Drink X Time*** F (4,192) = 0.932, p=0.447
	50g-0g	-8.158 (6.490)	-8.105 (7.541)	***Top X Time*** F (1,192) = 0.101, p=0.751
	50g-20g	-9.952 (6.173)	-3.571 (7.173)	***Drink X Top X Time*** F (4,192) = 0.836, p=0.504
	70g-0g	-10.048 (6.173)	-5.524 (7.173)	
	70g-20g	-5.500 (6.031)	-6.591 (7.008)	

Table 2.5: Summary table with respect to measures of Memory between baseline and 60 minutes (+/- s.e.m)

MEMORY	DRINK	Immediate	Delayed	RESULT
Word Recall	0g	9.927 (0.468)	6.902 (0.453)	***Drink*** F (4,197) = 1.544, p=0.191 ***Recall*** F (1,197) = 460.791, p<0.001 ***Drink X Recall*** F (4,197) = 1.133, p=0.342
	10g	8.771 (0.506)	6.229 (0.490)	
	30g	9.186 (0.457)	6.558 (0.442)	
	50g	9.350 (0.474)	6.875 (0.458)	
	70g	10.093 (0.457)	7.837 (0.442)	
Time Taken	0g	58.366 (3.150)	39.268 (2.340)	***Drink*** F (4,197) = 6.060, p=0<0.001 ***Recall*** F (1,197) = 147.463, p<0.001 ***Drink X Recall*** F (4,197) = 3.757, p<0.01
	10g	50.257 (3.410)	34.400 (2.533)	
	30g	45.326 (3.076)	33.535 (2.285)	
	50g	60.250 (3.190)	50.275 (2.369)	
	70g	47.744 (3.076)	39.977 (2.285)	

Table 2.6: Summary table with respect to measures of Memory between 60 and 120 minutes (+/- s.e.m)

MEMORY	DRINK	Immediate	Delayed	RESULT
Word Recall	0g-0g	9.158 (0.726)	5.474 (0.702)	***Drink*** F (4,192) = 1.476, p=0.211 ***Top*** F (1,192) = 1.526, p=0.218 ***Drink X Top*** F (4,192) = 0.295, p=0.881 ***Recall*** F (1,192) = 510.718, p<0.001 ***Drink X Recall*** F (4,192) = 1.628, p=0.169 ***Top X Recall*** F (1,192) = 1.406, p=0.237 ***Drink X Top X Recall*** F (4,192) = 0.643, p=0.632
	0-20g	8.045 (0.675)	5.000 (0.653)	
	10g-0g	8.188 (0.791)	4.937 (0.765)	
	10g-20g	8.421 (0.726)	5.263 (0.702)	
	30g-10g	8.429 (0.690)	4.286 (0.668)	
	30g-20g	8.061 (0.675)	3.909 (0.653)	
	50g-0g	9.895 (0.726)	5.579 (0.702)	
	50g-20g	8.143 (0.690)	5.143 (0.668)	
	70g-0g	10.000 (0.690)	5.762 (0.668)	
	70g-20g	9.500 (0.675)	5.182 (0.653)	
Time Taken	0g-0g	51.895 (4.395)	38.632 (3.354)	***Drink*** F (4,192) = 9.558, p<0.001 ***Top*** F (1,192) = 2.803, p=0.096 ***Drink X Top*** F (4,192) = 1.073, p=0.371 ***Recall*** F (1,192) = 179.581, p<0.001 ***Drink X Recall*** F (4,192) = 4.777, p=0.001 ***Top X Recall*** F (1,192) = 4.289, p<0.05 ***Drink X Top X Recall*** F (4,192) = 0.137, p=0.968
	0-20g	46.500 (4.084)	28.500 (3.117)	
	10g-0g	42.375 (4.789)	30.250 (3.655)	
	10g-20g	46.368 (4.395)	32.632 (3.354)	
	30g-10g	35.667 (4.181)	24.571 (3.190)	
	30g-20g	38.364 (4.084)	22.955 (3.117)	
	50g-0g	63.211 (4.395)	45.368 (3.354)	
	50g-20g	59.810 (4.181)	35.286 (3.190)	
	70g-0g	47.381 (4.181)	42.333 (3.190)	
	70g-20g	42.182 (4.084)	32.773 (3.117)	

Table 2.7: Summary table for Decision Times and Movement Time on the Hick Paradigm between baseline and 60 minutes (+/- s.e.m)

	DRINK	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Decision Times	0g	397.338 (6.066)	311.613 (5.877)	338.075 (5.800)	363.375 (7.314)	***Drink*** F (4,190) = 0.778, p=0.541
	10g	302.765 (6.579)	315.338 (6.374)	339.882 (6.291)	365.368 (7.933)	
	30g	305.357 (5.290)	321.214 (5.735)	342.774 (5.660)	368.155 (7.138)	***Lamps*** F (1,190) = 289.948, p<0.001
	50g	294.179 (6.143)	317.333 (5.952)	336.885 (5.874)	358.231 (7.407)	***Drink X Lamps***
	70g	317.688 (6.066)	320.513 (5.877)	3403.61 2 (5.800)	374.612 (7.314)	F (4,190) = 1.200, p=0.279
Movement Times	0g	189.238 (7.252)	187.800 (6.970)	193.625 (6.833)	212.737 (6.616)	***Drink*** F (4,190) = 0.903, p=0.463
	10g	184.809 (7.865)	183.044 (7.560)	188.529 (7.411)	192.706 (7.176)	
	30g	189.524 (7.077)	187.452 (6.802)	194.631 (6.668)	202.524 (6.456)	***Lamps*** F (1,190) = 25.649,
	50g	181.231 (7.344)	175.205 (7.058)	180.949 (6.920)	190.538 (6.700)	p<0.001 ***Drink X Lamps***
	70g	181.775 (7.252)	180.450 (6.970)	183.975 (6.833)	185.663 (6.616)	F (4,190) = 1.924, p<0.05

Table 2.8: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm between baseline and 60 minutes (+/- s.e.m)

	0g	10g	30g	50g	70g	RESULT
Intercept	293.910 (5.954)	298.991 (6.035)	302.888 (5.302)	294.390 (6.254)	308.478 (6.261)	F (4,190) = 1.074, p=0.370
Slope	22.463 (1.651)	21.238 (1.941)	20.998 (1.697)	21.938 (2.065)	19.090 (2.362)	F (4,190) = 0.441, p=0.779
Inta	147.130 (13.438)	143.487 (11.374)	133.437 (8.672)	122.959 (9.365)	142.296 (9.262)	F (4,190) = 0.856, p=0.492

Table 2.9: Summary table for Decision Times on the Hick Paradigm between 60 and 120 minutes (+/- s.e.m)

	DRINK	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Decision Times	0g-0g	299.605 (7.882)	312.684 (7.901)	331.474 (8.800)	354.921 (10.263)	***Drink*** F (4,188) = 0.233, p=0.920 ***Top*** F (1,188) = 1.518, p=0.219 ***Drink X Top*** F (4,188) = 0.718, p=0.581 ***Lamps*** F (3,564) = 348.767, p<0.001 ***Drink X Lamps*** F (12,564) = 1.263, p=0.237 ***Top X Lamps*** F (3,564) = 1.724, p=0.161 ***Drink X Top X Lamps*** F (12,564) = 1.576, p=0.094
	0-20g	285.795 (7.325)	306.682 (7.343)	340.841 (8.178)	348.432 (9.538)	
	10g-0g	291.844 (8.589)	301.188 (8.610)	323.844 (9.590)	356.988 (11.184)	
	10g-20g	289.895 (7.882)	316.684 (7.901)	332.395 (8.800)	362.184 (10.263)	
	30g-10g	300.857 (7.497)	313.476 (7.516)	329.690 (8.370)	358.119 (9.763)	
	30g-20g	284.773 (7.325)	305.705 (7.343)	336.886 (8.178)	366.091 (9.538)	
	50g-0g	279.895 (7.882)	303.684 (7.901)	317.053 (8.800)	341.553 (10.263)	
	50g-20g	296.429 (7.497)	314.140 (7.516)	324.833 (8.370)	363.810 (9.763)	
	70g-0g	279.184 (7.882)	294.289 (7.901)	321.632 (8.800)	358.632 (10.263)	
	70g-20g	296.875 (7.682)	312.325 (7.701)	340.275 (8.577)	362.650 (10.004)	

Table 2.10: Summary table for Movement Time on the Hick Paradigm between 60 and 120 minutes (+/- s.e.m)

	DRINK	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Movement Times	0g-0g	200.684 (10.370)	200.842 (10.834)	208.895 (10.553)	219.184 (10.460)	***Drink*** F (4,188) = 2.977, p<0.05
	0-20g	194.841 (9.637)	208.205 (10.068)	211.182 (9.807)	217.295 (9.271)	***Top*** F (1,188) = 0.371, p=0.543
	10g-0g	162.250 (11.300)	171.062 (11.806)	176.094 (11.500)	185.469 (11.398)	
	10g-20g	185.026 (10.370)	189.868 (10.834)	198.947 (10.553)	194.711 (10.460)	***Drink X Top*** F (4,188) = 1.728, p=0.145
	30g-10g	198.476 (9.864)	196.024 (10.305)	208.452 (10.038)	214.690 (9.949)	
	30g-20g	170.795 (9.637)	178.250 (10.068)	180.023 (9.807)	190.091 (9.721)	***Lamps*** F (3,564) = 32.739, p<0.001
	50g-0g	165.737 (10.370)	170.158 (10.834)	179.289 (10.553)	186.605 (10.460)	***Drink X Lamps*** F (12,564) = 0.885, p=0.563
	50g-20g	169.857 (9.864)	173.619 (10.305)	187.095 (10.038)	193.595 (9.949)	
	70g-0g	172.395 (10.370)	170.684 (10.834)	167.447 (10.553)	181.789 (10.460)	***Top X Lamps*** F (3,564) = 1.331, p=0.263
	70g-20g	185.510 (10.107)	191.275 (10.559)	194.400 (10.286)	196.575 (10.195)	***Drink X Top X Lamps*** F (12,564) = 0.657, p=0.793

Table 2.11: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm between 60 and 120 minutes (+/- s.e.m)

		0g	10g	30g	50g	70g	RESULT
Intercept	0g	296.979 (7.698)	285.744 (8.388)	297.343 (7.322)	280.805 (7.698)	273.605 (7.698)	***Drink*** F (4,188) = 0.316, p=0.867 ***Top*** F (1,188) = 0.243, p=0.623 ***Drink X Top*** F (4,188) = 2.042, p=0.090
	20g	286.682 (7.154)	290.395 (7.698)	282.086 (7.154)	282.881 (7.322)	294.230 (7.503)	
Slope	0g	18.468 (2.608)	21.813 (2.842)	18.805 (2.481)	19.832 (2.608)	26.558 (2.608)	***Drink*** F (4,188) = 1.047, p=0.384 ***Top*** F (1,188) = 1.807, p=0.181 ***Drink X Top*** F (4,188) = 1.656, p=0.162
	20g	21.759 (2.424)	23.274 (2.608)	27.523 (2.424)	21.300 (2.481)	22.525 (2.542)	
Intra	0g	123.316 (17.669)	139.525 (19.254)	135.868 (16.806)	113.166 (17.669)	139.030 (17.669)	***Drink*** F (4,188) = 0.368, p=0.831 ***Top*** F (1,188) = 0.201, p=0.655 ***Drink X Top*** F (4,188) = 1.012, p=0.402
	20g	127.159 (16.420)	114.478 (17.669)	151.693 (16.420)	153.706 (16.806)	128.494 (17.222)	

Table 2.12: Summary table for Correct responses on the RIPT between baseline and 60 minutes (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Correct 1	0g	4.675 (0.306)	3.700 (0.263)	3.550 (0.308)	3.400 (0.284)	3.275 (0.276)	***Drink*** F (1,184) =
	10g	4.794 (0.331)	3.588 (0.285)	3.882 (0.334)	3.529 (0.308)	3.059 (0.300)	0.391, p=0.815
	30g	5.147 (0.333)	4.176 (0.303)	3.824 (0.321)	3.735 (0.292)	3.912 (0.675)	***Session*** F (1,184) =
	50g	4.514 (0.327)	3.943 (0.281)	3.400 (0.330)	3.457 (0.303)	2.943 (0.295)	32.416, p<0-.001 ***Drink X Session***
	70g	4.268 (0.302)	3.780 (0.259)	3.488 (0.305)	3.073 (0.280)	2.951 (0.615)	F (4,184) = 1.906, p=0.111
Correct 2	0g	4.125 (0.307)	3.925 (0.279)	3.550 (0.296)	3.900 (0.269)	3.500 (0.623)	***Minute*** F (4,736) =
	10g	5.147 (0.333)	4.176 (0.303)	3.824 (0.321)	3.735 (0.292)	3.912 (0.675)	23.353, p<0.001 ***Drink X Minute***
	30g	4.923 (0.311)	4.385 (0.283)	3.744 (0.300)	3.718 (0.273)	3.385 (0.631)	F (16,736) = 0.975, p=0.483
	50g	5.343 (0.328)	4.486 (0.298)	4.029 (0.316)	4.000 (0.288)	4.029 (0.666)	***Test X Minute*** F (4,736) =
	70g	4.293 (0.303)	3.902 (0.276)	3.829 (0.292)	3.805 (0.266)	4.951 (0.615)	2.102, p=0.079 *Drink X Test X Minute* F (16,736) = 1.062, p=0.389

Table 2.13: Summary table for Wrong responses on the RIPT between baseline and 60 minutes (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrong 1	0g	3.175 (0.469)	2.750 (0.435)	1.875 (0.356)	1.850 (0.397)	1.825 (0.388)	***Drink*** F (1,184) =
	10g	3.235 (0.509)	2.735 (0.472)	2.118 (0.387)	2.412 (0.431)	1.794 (0.421)	1.258, p=0.288
	30g	3.667 (0.475)	2.667 (0.441)	2.282 (0.361)	2.410 (0.402)	2.218 (0.393)	***Session*** F (1,184) =
	50g	2.143 (0.501)	1.886 (0.465)	1.714 (0.381)	1.886 (0.424)	1.314 (0.414)	53.231, p<0-.001 ***Drink X Session***
	70g	3.512 (0.463)	3.073 (0.430)	2.390 (0.352)	2.730 (0.392)	2.146 (0.383)	F (4,184) = 2.225, p=0.068
Wrong 2	0g	2.350 (0.344)	1.800 (0.342)	1.750 (0.379)	2.075 (0.343)	1.650 (0.327)	***Minute*** F (4,736) =
	10g	2.118 (0.373)	2.206 (0.371)	1.941 (0.411)	2.059 (0.372)	1.882 (0.543)	17.198, p<0.001 ***Drink X Minute***
	30g	1.590 (0.348)	1.358 (0.346)	1.615 (0.384)	1.538 (0.348)	1.359 (0.331)	F (16,736) = 0.609, p=0.880
	50g	1.143 (0.367)	0.971 (0.365)	0.971 (0.405)	1.143 (0.367)	0.886 (0.349)	***Test X Minute*** F (4,736) =
	70g	1.927 (0.339)	1.976 (0.337)	1.537 (0.374)	2.122 (0.339)	1.707 (0.323)	8.595, p<0.001 *Drink X Test X Minute* F (16,736) = 0.545, p=0.923

Table 2.14: Summary table for Reaction Times on the RIPT between baseline and 60 minutes (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	0g	514.200 (28.343)	540.350 (25.229)	568.575 (32.735)	555.575 (33.421)	547.750 (35.472)	***Drink*** F (1,184) = 1.711, p=0.149
	10g	506.706 (30.742)	515.559 (27.364)	538.529 (35.506)	584.382 (36.250)	564.735 (38.475)	
	30g	532.282 (28.704)	544.179(25.550)	581.744 (33.152)	596.410 (33.847)	548.872 (35.924)	***Session*** F (1,184) = 0.960, p=0.328
	50g	487.743 (30.300)	503.457 (26.971)	466.486 (34.995)	486.286 (35.279)	563.286 (37.921)	***Drink X Session*** F (4,184) = 1292, p=0.275
	70g	469.780 (27.995)	570.317 (24.919)	518.366 (32.333)	552.146 (33.011)	588.024 (35.037)	
RT 2	0g	487.300 (24.721)	559.525 (25.125)	551.025 (27.559)	552.200 (28.067)	552.075 (27.970)	***Minute*** F (4,736) = 4.693, p=0.001
	10g	483.588 (26.814)	503.176 (27.282)	495.235 (29.892)	474.676 (30.443)	553.559 (30.337)	***Drink X Minute*** F (16,736) = 0.865, p=0.610
	30g	552.359 (25.036)	525.923 (25.473)	559.231 (27.910)	542.103 (28.425)	532.000 (28.326)	***Test X Minute*** F (4,736) = 0.541, p=0.706
	50g	485.829 (26.428)	520.457 (26.889)	551.743 (29.462)	502.029 (30.005)	549.171 (29.901)	*Drink X Test X Minute* F (16,736) = 0.620, p=0.870
	70g	508.049 (24.418)	538.659 (24.844)	539.927 (27.221)	558.220 (27.723)	558.610 (27.627)	

Table 2.15: Summary table for Correct responses on the RIPT between 60 and 120 minutes (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Correct 3	0g -0g	3.889 (0.486)	3.500 (0.420)	3.056 (0.448)	2.722 (0.431)	3.222 (0.459)	***Drink*** F (4,184) = 1.602,
	0g -20g	4.381 (0.450)	4.381 (0.389)	3.905 (0.415)	4.000 (0.399)	3.333 (0.425)	p=0.176 ***Top***
	10g -0g	4.562 (0.516)	4.063 (0.445)	4.000 (0.476)	4.188 (0.457)	3.375 (0.486)	F (1,184) = 0.185, p=0.668
	10g -20g	4.833 (0.486)	4.444 (0.420)	3.667 (0.448)	4.389 (0.431)	3.222 (0.459)	***Drink X Top*** F (4,184) = 2.153,
	30g -10g	4.762 (0.450)	3.667 (0.389)	3.524 (0.415)	3.476 (0.399)	3.286 (0.425)	p=0.076
	30g -20g	5.000 (0.461)	4.200 (0.398)	3.500 (0.426)	3.650 (0.409)	2.950 (0.435)	***Minute*** F (4,736) =
	50g -0g	5.706 (0.500)	5.529 (0.432)	4.294 (0.462)	4.588 (0.443)	4.647 (0.472)	21.632, p<0.01 ***Drink X Minute***
	50g -20g	4.286 (0.450)	3.905 (0.389)	3.762 (0.415)	3.857 (0.399)	3.190 (0.425)	F (16,736) = 0.727, p=0.768
	70g -0g	4.250 (0.461)	4.350 (0.398)	4.050 (0.426)	3.700 (0.409)	3.000 (0.435)	***Top X Minute*** F (4,736) = 0.509,
	70g -20g	4.318 (0.440)	3.682 (0.380)	3.455 (0.406)	3.409 (0.390)	3.455 (0.415)	p=0.729 *Drink X Top X Minute* F (16,736) = 0.937 p=0.526

Table 2.16: Summary table for Wrong responses on the RIPT between 60 and 120 minutes (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrong 3	0g -0g	2.667 (0.588)	2.222 (0.503)	1.833 (0.442)	1.944 (0.471)	1.889 (0.644)	***Drink*** F (4,184) = 1.062,
	0g -20g	1.143 (0.545)	1.143 (0.466)	1.143 (0.409)	1.333 (0.436)	2.524 (0.596)	p=0.377 ***Top***
	10g -0g	3.438 (0.624)	1.687 (0.534)	1.500 (0.469)	1.750 (0.500)	1.625 (0.683)	F (1,184) = 0.006, p=0.938
	10g -20g	1.667 0.588)	1.167 (0.503)	1.056 (0.442)	2.056 (0.471)	1.722 (0.644)	***Drink X Top*** F (4,184) = 0.848,
	30g -10g	1.429 (0.545)	1.190 (0.466)	0.667 (0.409)	1.190 (0.436)	1.048 (0.596)	p=0.496
	30g -20g	1.850 (0.558)	1.550 (0.477)	1.500 (0.419)	1.850 (0.447)	2.400 (0.611)	***Minute*** F (4,736) = 4.425,
	50g -0g	0.882 (0.605)	0.882 (0.518)	0.824 (0.455)	0.822 (0.485)	0.941 (0.663)	p<0.01 ***Drink X Minute***
	50g -20g	1.238 (0.545)	0.714 (0.466)	1.238 (0.409)	0.952 (0.436)	1.714 (0.596)	F (16,736) = 1.144, p=0.309
	70g -0g	1.850 (0.558)	1.500 (0.477)	1.450 (0.419)	1.900 (0.447)	1.800 (0.611)	***Top X Minute*** F (4,736) = 5.232,
	70g -20g	1.227 (0.532)	1.500 (0.455)	1.818 (0.400)	2.000 (0.426)	1.955 (0.582)	p<0.001 *Drink X Top X Minute* F (16,736) = 0.786 p=0.703

Table 2.17: Summary table for Reaction Times on the RIPT between 60 and 120 minutes (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 3	0g-0g	477.722 (36.128)	494.000 (35.855)	494.889 (36.442)	489.611 (37.870)	517.444 (45.159)	***Drink*** F (4,184) = 0.420, p=0.794 ***Top*** F (1,184) = 0.368, p=0.545 ***Drink X Top*** F (4,184) = 1.133, p=0.342 ***Minute*** F (4,736) = 5.253, p<0.001 ***Drink X Minute*** F (16,736) = 0.712, p=0.783 ***Top X Minute*** F (4,736) = 0.738, p=0.566 *Drink X Top X Minute* F (16,736) = 1.216 p=0.249
	0-20g	443.238 (33.448)	563.238 (33.196)	525.429 (33.739)	513.190 (35.060)	550.143 (41.809)	
	10g-0g	501.250 (38.319)	473.188 (38.030)	475.313 (38.653)	500.125 (40.167)	513.875 (47.898)	
	10g -20g	447.722 (36.128)	464.889 (35.855)	509.833 (36.442)	477.056 (37.870)	472.333 (45.159)	
	30g -10g	495.000 (33.448)	493.286 (33.196)	561.381 (33.739)	566.524 (35.060)	488.667 (41.809)	
	30g -20g	439.000 (34.274)	463.200 (34.015)	584.900 (34.572)	441.450 (35.926)	529.000 (42.841)	
	50g -0g	425.824 (37.175)	489.118 (36.895)	516.353 (37.499)	544.647 (38.968)	514.588 (46.468)	
	50g -20g	506.905 (33.448)	514.810 (33.196)	581.905 (33.739)	494.286 (35.060)	473.048 (41.809)	
	70g -0g	416.100 (34.274)	499.900 (34.015)	517.800 (34.572)	443.650 (35.926)	473.300 (42.841)	
	70g -20g	469.136 (32.679)	500.727 (32.432)	526.273 (32.963)	538.364 (34.254)	561.455 (40.848)	

Chapter 3: The Interaction between Carbohydrate and Fibre

3.1 INTRODUCTION

Previous research on the effects of fibre in the diet has focused primarily on its effects on hunger and satiety. High doses of fibre (20-30g) have been found to suppress subsequent food intake and hunger ratings, when compared to low fibre or light breakfasts (0-4g), or preloads consumed before a test meal (Stevens et al., 1987; Burley et al., 1993; Delargy et al., 1995; 1997).

Studies have used fibre supplementation, wheat bran or psyllium gum added to test meals (Stevens et al., 1987; Delargy et al., 1997) and also foods naturally high in fibre (for example, 20g of fibre within breakfast cereals). However, this has resulted in large breakfast meals being consumed to reach the required fibre intake. Holt et al., (1999) used 74g of All Bran (total weight consumed) compared to Levine et al., (1989) who used 57g of Fibre One (total weight) in studying the effects of fibre supplementation.

Following the successful suppression of appetite and food intake with foods high in fibre, it seemed logical to ask if doses more typical of normal meals have a similar action.

Fibre has been shown to reduce the glycaemic and insulinaemic responses to foods in both normal and diabetic participants (Wolever et al., 1991; Jenkins et al., 1978). In particular psyllium (Rigaud et al., (1998), and other soluble dietary fibres, such as oat and guar gums (Wood et al., 1994; Braaten et al., 1991), have been found to flatten blood glucose levels to a greater extent than insoluble fibres, such as wheat bran and sugar beet fibre. However, both soluble and insoluble fibre act primarily by absorbing water and adding more bulk to the stool, which encourages movement to the bowel, slowing the rate of gastric emptying into the small intestine and thus over time reducing the rate of absorption of blood glucose and other nutrients (Blackwood et al., 2000). Ou et al., (2001) found that diffusion of glucose was hindered by the increased viscosity of dietary fibres, which also bind to and dilute the available glucose.

Recently, Kaplan et al., (2000) demonstrated that consumption of foods with low GI, for example barley, failed to induce large changes in blood glucose levels over time, and were associated with increased cognitive performance in a healthy, elderly population. It is possible that varying the amount of carbohydrate and fibre consumed as a breakfast meal may influence subsequent cognitive performance. Furthermore, choosing to analyse realistic quantities of foods containing naturally occurring fibre is more ecologically valid. The large amounts of the breakfast cereals (57-74g) used in previous studies are rarely, if ever, consumed.

3.1.1 AIM

The present study aimed to investigate the effects of varied amounts of fibre and carbohydrate on mood, hunger and cognitive performance over a two-hour test period. The levels of fibre and carbohydrate were chosen to reflect values typical of the normal range of intake.

3.2 METHOD

3.2.1 PARTICIPANTS

189 female undergraduate students, mean age 20.41 years (SD 1.99), acted as participants. All were recruited through advertisements within the University of Wales, Swansea.

Groups of participants were compared under nine conditions:

1. Control Condition – No Food (N=16; mean 21.56yrs, SD 4.15)
2. Low-Carbohydrate Low-Fibre (N=18; mean 20.33yrs, SD 1.50)
3. Low-Carbohydrate Medium-Fibre (N=20, mean 20.15yrs, SD 1.42)
4. Medium-Carbohydrate Low-Fibre (N=18, mean 20.33yrs; SD 1.33)
5. Medium-Carbohydrate Medium-Fibre (N=20; mean 20.15yrs, SD 1.14)
6. Medium-Carbohydrate High-Fibre (N=17; mean 20.29yrs, SD 1.26)
7. High-Carbohydrate Low-Fibre (N=17; mean 20.24yrs, SD1.09)
8. High-Carbohydrate Medium-Fibre (N=21, mean 20.62yrs, SD 2.96)
9. High-Carbohydrate High-Fibre (N=20, mean 20.15yrs, SD 1.09)

Table 3.1 illustrates the make-up of the breakfast meals. All participants fasted overnight and once in the laboratory consumed their allocated breakfast meal. All participants gave written consent and the local Ethics Committee approved the procedure. Due to the nature of food sources, i.e. breakfast cereals, it was impossible to create a LCHF breakfast.

Table 3.1: The amounts of Cornflakes (CF), All Bran (AB) and Skimmed Milk (millilitres) consumed as the active breakfasts

	LOW CARBOHYDRATE 15g	MEDIUM CARBOHYDRATE 30g	HIGH CARBOHYDRATE 50g
	Amount Carb Fib	Amount Carb Fib	Amount Carb Fib
LOW FIBRE approx = to 1.5g	100ml 5.00 - 10g CF 8.30 0.30 4g AB 1.80 1.16 TOTAL 15.10g 1.46g	200ml 10.00 - 23g CF 19.09 0.69 3g AB 1.35 0.87 TOTAL 30.44g 1.56g	200ml 10.00 - 48g CF 39.84 1.44 TOTAL 49.84g 1.44g
MEDIUM FIBRE approx = to 6g	100ml 5.00 - 21g AB 9.45 6.09 TOTAL 14.45g 6.09g	200ml 10.00 - 13g CF 10.79 0.39 20g AB 9.00 5.80 TOTAL 29.79g 6.19g	200ml 10.00 - 40g CF 33.20 1.20 17g AB 7.65 4.93 TOTAL 50.85g 6.13g
HIGH FIBRE approx = to 13g		200ml 10.00 - 45g AB 20.25 13.05 TOTAL 30.25g 13.05g	200ml 10.00 - 25g CF 20.75 0.75 42g AB 18.90 12.18 TOTAL 49.65g 12.93g

3.2.2 BREAKFAST

In addition to each participant receiving the allocated breakfast (Table 3.1), a choice of beverages were offered. Decaffeinated Tea (Typhoo) or Decaffeinated Coffee (Nescafe), and sweetener (Hermesetas) if required, with skimmed milk (up to 35ml), or Sugar Free Orange Squash (Robinson's R). Participants also had access to unlimited water throughout the experiment. Table 3.2 illustrates the mean nutritional values of the breakfasts consumed.

Table 3.2: Mean Nutritional values for the test breakfast and habitual breakfasts consumed by the participants

Meal	Carb (g)	Fibre (g)	Fat (g)	Protein (g)	Energy (Kcal)
LCLF	15.10	1.46	0.34	4.62	81.80
LCMF	14.45	6.09	0.94	6.03	90.70
MCLF	30.44	1.56	0.59	8.83	161.20
MCMF	29.79	6.19	1.10	10.24	170.10
MCHF	30.25	14.05	2.00	12.45	189.50
HCLF	49.84	1.44	0.58	10.44	245.60
HCMF	50.85	6.13	1.20	12.01	261.90
HCHF	49.65	12.93	2.08	14.06	274.90
Habitual	56.03	4.46	11.43	11.53	347.20

3.2.3 WORD LISTS

Two lists of 30 words, each having five letters, were chosen to be high in frequency and imagery (Quinlan, 1992) (Appendix 1). The list was presented aurally, at a rate of one word per two seconds using a tape recorder. All responses were written and the time taken was noted.

3.2.4 MOOD

The six basic dimensions of mood, Total mood and hunger were assessed (section 2.2.4).

3.2.5 COGNITIVE TESTS

The Rapid Information Processing Task (RIPT) and Hick Paradigm (Reaction Times) were used to assess changes in cognitive functioning in response to the breakfasts consumed (section 2.2.5, 2.2.6).

3.2.6 BLOOD GLUCOSE

Blood glucose determinations were made with the use of an ExacTech sensor, made by Medisense Britain Limited. The sensor uses an enzymic method coupled with microelectronic measurement that has been shown to give valid measures (Matthews et al., 1987).

3.2.7 PROCEDURE

Table 3.3 illustrates the procedure. Blood glucose levels were determined on entering the laboratory. Informed consent was given and Mood questionnaires were completed. Subjects were allocated to one of nine conditions, receiving one of the test breakfasts. The subjects sat for 20 minutes to allow digestion of the food to begin. Blood glucose levels and Mood were measured for a second time. The first word list was then presented aurally, and immediate recall (1) assessed. Subjects then completed the RIPT (1), Hick Paradigm (1) and the RIPT (2) on the computers. On completion of the tests the third blood glucose reading was taken, and Mood and delayed recall assessed (1). Participants then sat quietly for 20 minutes.

Following the rest period, blood glucose levels and mood were measured for the fourth time. The second word list was then presented aurally and immediate recall (2) was assessed. Participants then completed the Hick Paradigm (2) and the RIPT (3). On completion of the tests the final measure of blood glucose and Mood was taken and the participants were debriefed.

Table 3.3: Profile of the testing procedure for Chapter 3.

10:00	*BGL 1 / MOOD / CONSENT*	0 minutes
10:10	BREAKFAST (Table 3.1) 20 MINUTES WAIT	10 minutes
10:30	*BGL2 / MOOD*	30 minutes
10:40	**TEST SESSION 1** IMMEDIATE RECALL 1 RIPT 1 HICK 1 RIPT 2 DELAYED RECALL 1	40 minutes
11:00	*BGL3 / MOOD*	60 minutes
11:10	REST	70 minutes
11:30	*BGL4 / MOOD*	90 minutes
11:40	**TEST SESSION 2** IMMEDIATE RECALL 2 HICK 2 RIPT 3 DELAYED RECALL 2	100 minutes
12:00	*BGL5 / MOOD / DEBRIEFING*	120 minutes

3.3 STATISTICAL ANALYSIS

3.3.1 EFFECT OF BREAKFAST

Due to the nature of the design of the breakfasts tested, the statistical analysis had to be performed in three ways:

1. Breakfast (9 groups, see section 3.2.1)
2. Carbohydrate (medium, high) X Fibre (low, medium, high)
3. Carbohydrate (low, medium, high) X Fibre (low, medium).

3.3.1.1 Breakfast

- Measures of Blood Glucose were analysed using a two-way ANOVA: Breakfast (fast/breakfast) X Time (0, 30, 60, 90, 120 minutes) (repeated measure).
- Difference scores were firstly calculated for the measures of Mood (Composed/Agreeable/Elated/Confident/Energetic/Clearheaded) and Hunger using the following calculation:

  Mood at 30, 60, 90 & 120 minutes – baseline

  These measures were then analysed using two-way ANOVAs:

  Breakfast (fast/breakfast) X Time (30, 60, 90, 120 minutes) (repeated measure).
- Measures of Word recall and Recall times were analysed using either three-way ANOVAs:

  Breakfast (fast/breakfast) X Session (1, 2) (repeated measure) X Recall (immediate/delayed) (repeated measure).

- Measures of Reaction Times (Decision Time, Movement Time) were analysed using three-way ANOVAs:

  Breakfast (fast/breakfast) X Session (1, 2) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVAs:

  Breakfast (fast/breakfast) X Session (1, 2) (repeated measure).

- Measures of Correct responses, Wrong responses and Reaction Times on the RIPT were analysed using three-way ANOVAs:

  Breakfast (fast/breakfast) X Session (1, 2) (repeated measure) X Minute of testing (1, 2, 3, 4, 5) (repeated measure).

- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

3.3.1.2 Carbohydrate X Fibre

- Measures of Blood Glucose were also analysed using three-way ANOVAs:

  Carbohydrate X Fibre X Time (0, 30, 60, 90, 120 minutes) (repeated measure).

- Difference scores were calculated as in 3.3.1.1

  These measures were then analysed using three-way ANOVAs:

  Carbohydrate X Fibre X Time (30, 60, 90, 120 minutes) (repeated measure).

- Measures of Word recall and Recall times were analysed using four-way ANOVA's:

Carbohydrate X Fibre X Session (1, 2) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

- Measures of Reaction Times (Decision Time, Movement Time) were analysed using four-way ANOVAs:

  Carbohydrate X Fibre X Session (1, 2) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

- Measures of Slope, Intra-Individual Variability and Intercept were analysed using three-way ANOVAs:

  Carbohydrate X Fibre X Session (1, 2) (repeated measure).

- Measures of Correct responses, Wrong responses and Reaction Times on the RIPT were analysed using four-way ANOVAs:

  Carbohydrate X Fibre X Session (1, 2) (repeated measure) X Minute of testing (1, 2, 3, 4, 5) (repeated measure).

- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

3.3.2 EFFECT OF MACRONUTRIENTS

Stepwise Linear Regressions were performed, with Carbohydrate, Fat, Protein, Fibre and Kcal as the Independent variables. The following dependent variables were used:

- Mood at each time point (difference score).
- All aspects of Memory (Immediate and Delayed) for each session.
- Total Decision times for each session.

- Intercept and Intra-Individual Variability at each time point.
- Total Correct, Wrong responses and Reaction times for each session.

3.3.3 EFFECT OF BLOOD GLUCOSE LEVELS AND CHANGE

Stepwise Linear Regressions, with blood glucose levels (0, 30, 60, 90, 120 minutes) and changes in blood glucose levels as the Independent variables, were performed on the data set. Changes in blood glucose levels were calculated using the following equations:

- Change 1 = BG 30 – BG 0
- Change 2 = BG 60 – BG 30
- Change 3 = BG 90 – BG 60
- Change 4 = BG 120 – BG 90

The regressions were performed on the data separately for each breakfast condition. The following Dependent variables were used:

- Mood at each time point (Difference score).
- All aspects of Memory (Immediate and Delayed) for each session.
- Total Decision times for each session.
- Intercept and Intra-Individual Variability at each time point.
- Total Correct, Wrong responses and Reaction times for each session.

3.3.4 EFFECT OF HABITUAL BREAKFAST CONSUMPTION

- Measures of Total Mood and Hunger were analysed using three-way ANOVA's:

Breakfast (fast/breakfast) X Habitual breakfast consumption (Yes/No) X Difference (30, 60, 90, 120) (repeated measure).

- Measures of Word Recall were analysed using four-way ANOVA's: Breakfast (fast/breakfast) X Habitual breakfast consumption (Yes/No) X Recall (Immediate/Delayed) X Session (1, 2,) (repeated measure).

3.4 RESULTS

For clarity only significant results involving macronutrients or condition will be reported. It may be assumed that main effects and higher order interactions that are not reported were non-significant.

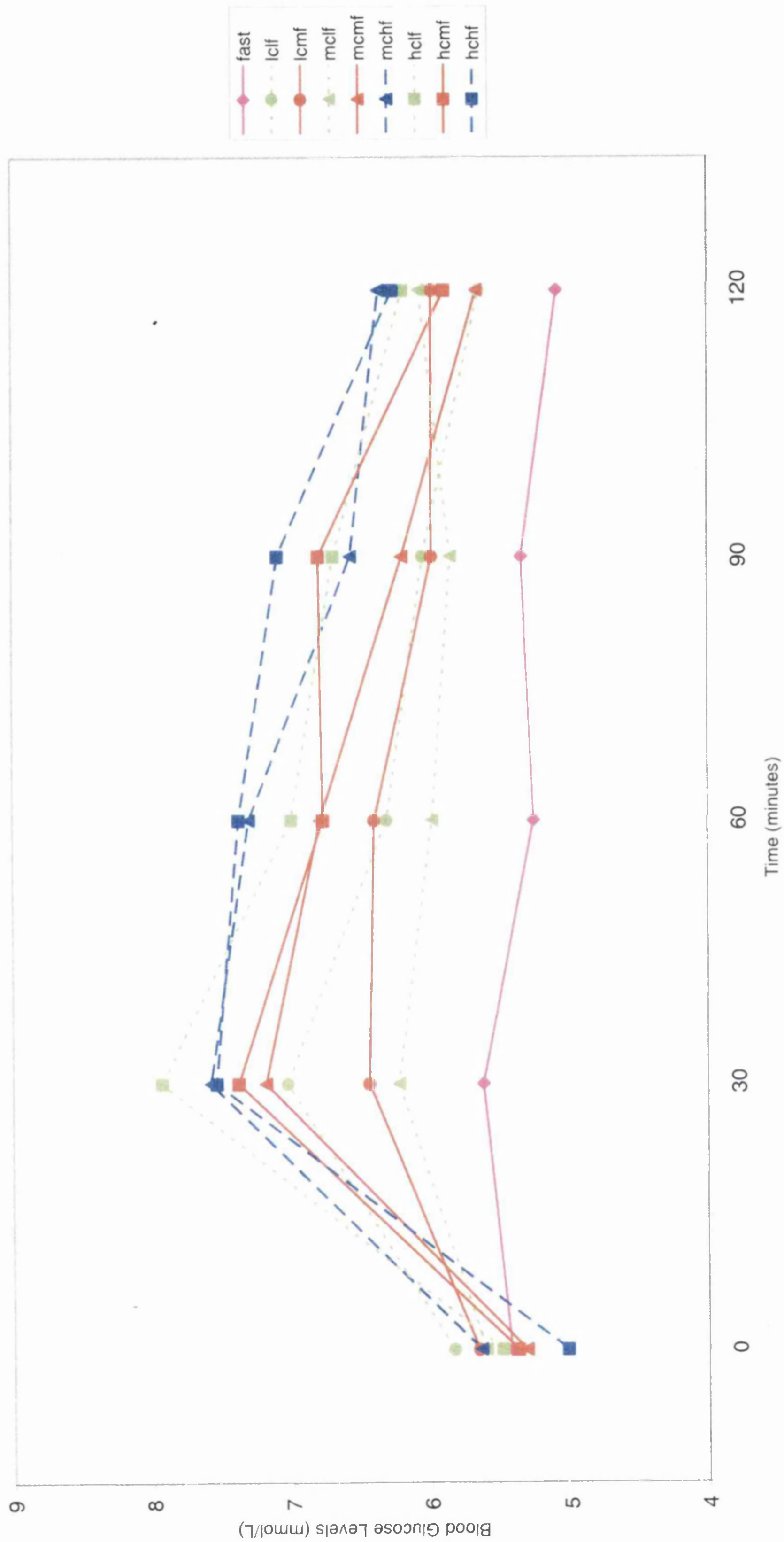
22 participants were removed from the data set due to baseline blood glucose levels over 7.4mmol/L. It was assumed that either participants had eaten before arriving at the laboratory, or had a metabolic problem.

3.4.1 EFFECT OF BREAKFAST

Breakfast and Blood Glucose Levels

The interaction Breakfast x Time reached significance [$F(32,632) = 2.53$, $p<0.001$]. Figure 3.1 displays the pattern of blood glucose levels over time. Simple Main Effects (SME's) show that there were no significant changes in blood glucose levels over time for

Figure 3.1: Profile of Blood Glucose Levels over Time



the fasting [F (4,632) = 0.60, p=0.663], LCMF [F (4,632) = 2.04, p=0.087] and MCLF conditions [F (4,632) = 0.95, p=0.437]. There were no significant differences in blood glucose levels at baseline [F (8,158) = 1.19, p=n.s.].

Table 3.4: Summary table for the significant differences between the conditions with respect to Blood Glucose Levels at the five time points

Time	F-ratio, Sig.	Significant Differences
0 minutes	F (8,158) = 1.19, p=n.s.	No significant differences
30 minutes	F (8,158) = 5.64, p<0.001	- Fast significantly differed from all breakfasts except LCMF and MCLF - LCMF and MCLF significantly differed from HCLF
60 minutes	F (8,158) = 4.46, p<0.001	- Fast significantly differed from MCMF; MCHF; HCLF; HCMF; HCHF - MCLF significantly differed from HCLF
90 minutes	F (8,158) = 3.28, p<0.01	- Fast significantly differed from HCMF and HCHF
120 minutes	F (8,158) = 2.06, p<0.05	- Fast significantly differed from MCHF

The three-way interaction Carbohydrate X Fibre X Time reached significance [F (8,432) = 2.09, p<0.05]. In addition to the results in Table 3.4, Simple Simple Main Effects (SSME's) demonstrated that the MCMF condition, compared to the MCLF condition had significantly higher blood glucose levels at 30 minutes [F (1,110) = 4.60, p<0.05]. Furthermore, consumption of the high carbohydrate (50g), compared to both low

(15g) and medium (30g) breakfasts, resulted in significantly higher blood glucose levels at 30 minutes for both low (1.5g) [F (2,109) = 8.10, p=0.001] and medium (6g) fibre conditions [F (2,109) = 3.17, p<0.05].

Breakfast and Mood

The interaction Carbohydrate X Time was significant for both analyses with respect to Total Mood {(1) [F (3,321) = 2.87, p<0.05]; (2) [F (6,324) = 2.19, p<0.05]}. Figure 3.2 illustrates Total Mood. SME's demonstrated that participants who consumed 15g of carbohydrate, compared to 30g, reported significantly poorer mood at 120 minutes [F (2,108) = 3.11, p<0.05], significant changes over time were observed for all three conditions.

The interaction Carbohydrate X Time reached significance with respect to ratings of Confidence [F (3,321) = 3.04, p<0.05]. Figure 3.3 and SME's performed on the data found no significant differences between the conditions at any time point. Significant changes over time were demonstrated following consumption of 30g of carbohydrate [F (3,333) = 8.47, p<0.001].

The interaction Carbohydrate X Time reached significance for ratings of Clearheadedness [F (3,321) = 3.45, p<0.05]. SME's demonstrated significant changes over time for both 30g [F (3,333) = 6.08, p<0.001] and 50g [F (3,333) = 8.51, p<0.001] carbohydrate, however, no significant differences were observed between the groups at any time point.

Figure 3.2: Profile of Total Mood over Time for Carbohydrate groupings (means +/- s.e.m)

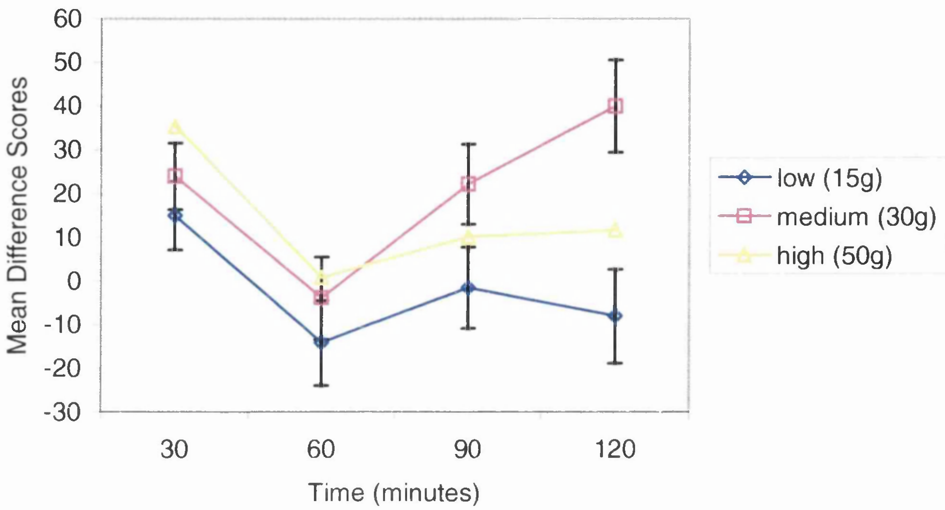


Figure 3.3: Profile of Confidence ratings over Time for Carbohydrate groupings (means +/- s.e.m)

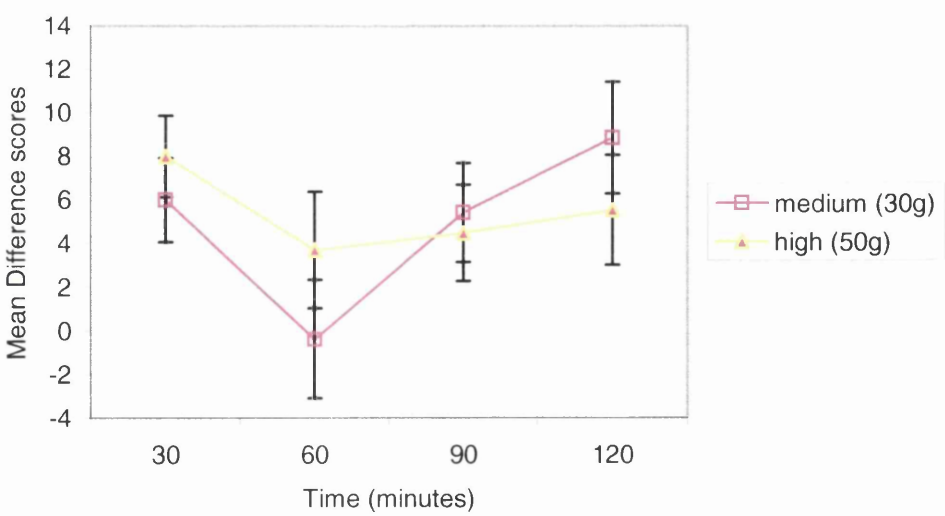


Figure 3.4: Profile of Total Mood over Time for Fibre groupings (means +/- s.e.m)

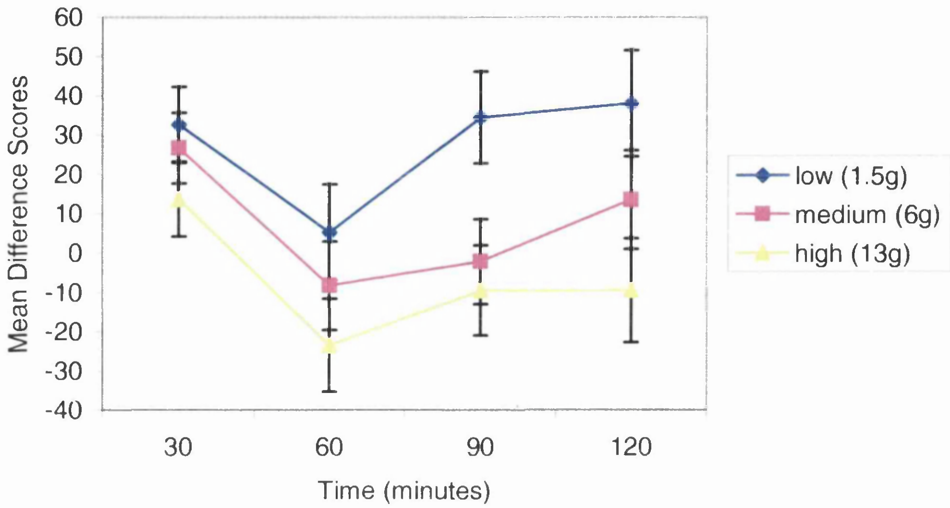
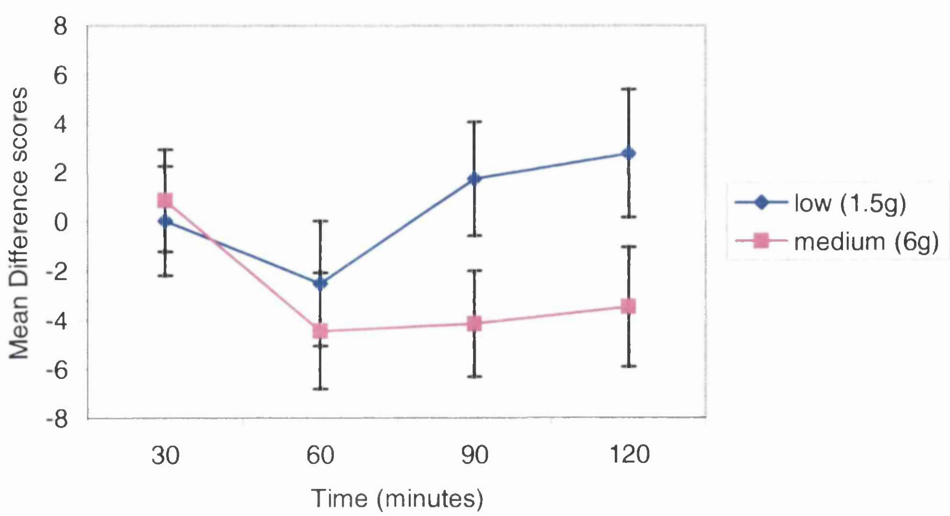


Figure 3.5: Profile of Agreeability ratings over time for Fibre groupings (means +/- s.e.m)



In addition to the effect of carbohydrate, there was a main effect of Fibre with respect to Total mood [$F(2,107) = 3.07$, $p=0.05$]. Figure 3.4 and post-hoc tests illustrated that high fibre (13g) breakfasts were significantly detrimental to mood compared to low fibre (1.5g) breakfasts at 90 [$F(2,107) = 4.15$, $p<0.05$] and 120 minutes [$F(2,107) = 4.16$ $p<0.05$].

The interaction Fibre X Time reached significance with respect to Agreeability [$F(3,324) = 2.74$, $p<0.05$]. SME's and Figure 3.5 showed that there were significant changes over time following consumption of the medium fibre (6g) meals [$F(3,336) = 3.21$, $p<0.05$]. Also there was a trend for low fibre (1.5g) conditions to be significantly more agreeable than the medium fibre (6g) conditions at 90 [$F(1,108) = 3.45$, $p=0.07$] and 120 minutes [$F(1,108) = 3.06$, $p=0.08$].

A high fibre (13g) breakfast significantly decreased energy compared to low fibre breakfasts over the morning [$F(2,107) = 3.51$, $p<0.05$]. The effect was most significant at 90 minutes ($p<0.05$).

Breakfast and Hunger

Ratings of Hunger were influenced by the test meal consumed [$F(8,158) = 6.96$, $p<0.001$]. Figure 3.6 and Table 3.5 illustrate the differences between the breakfast conditions over time.

Figure 3.6: Profile of Hunger ratings over Time

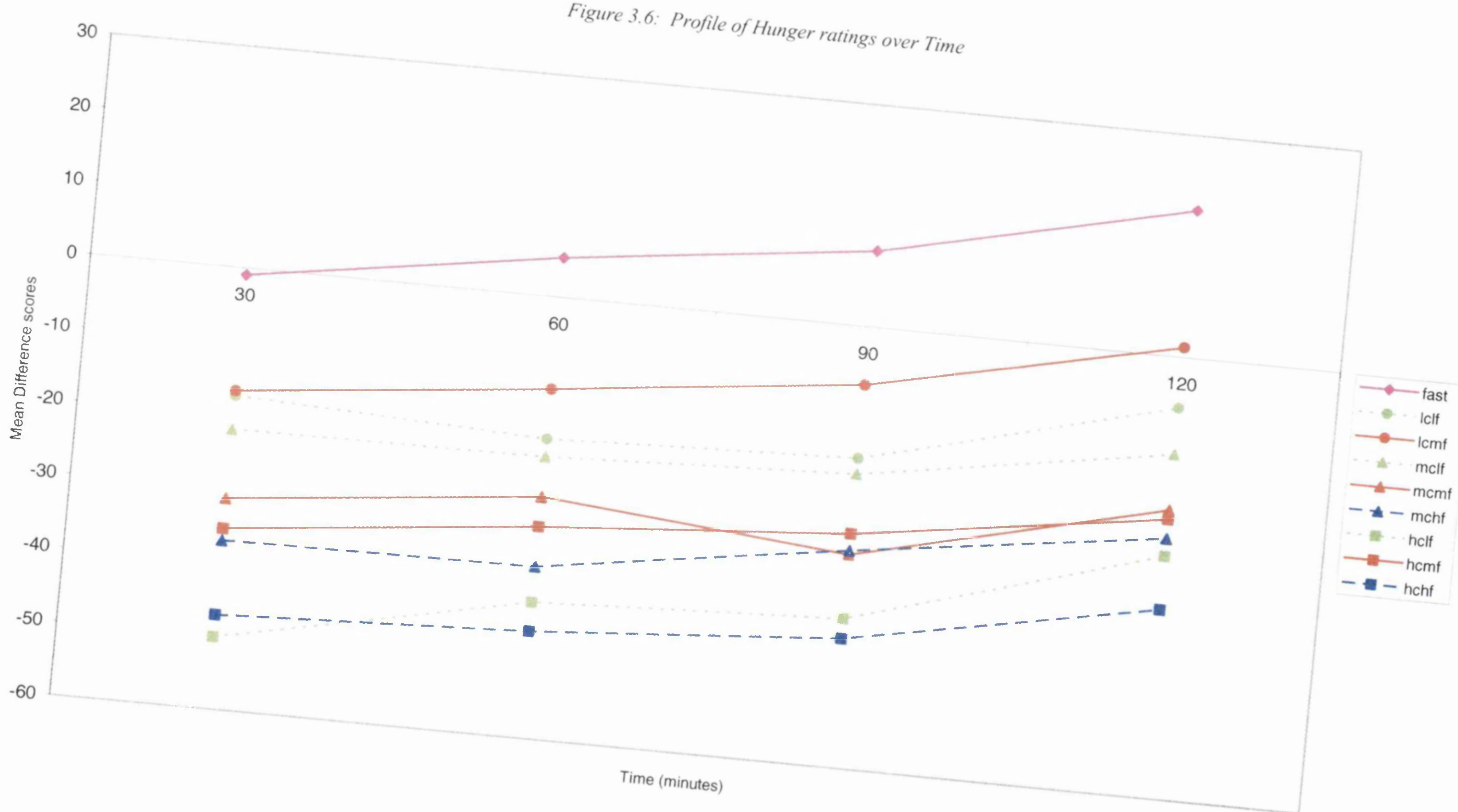


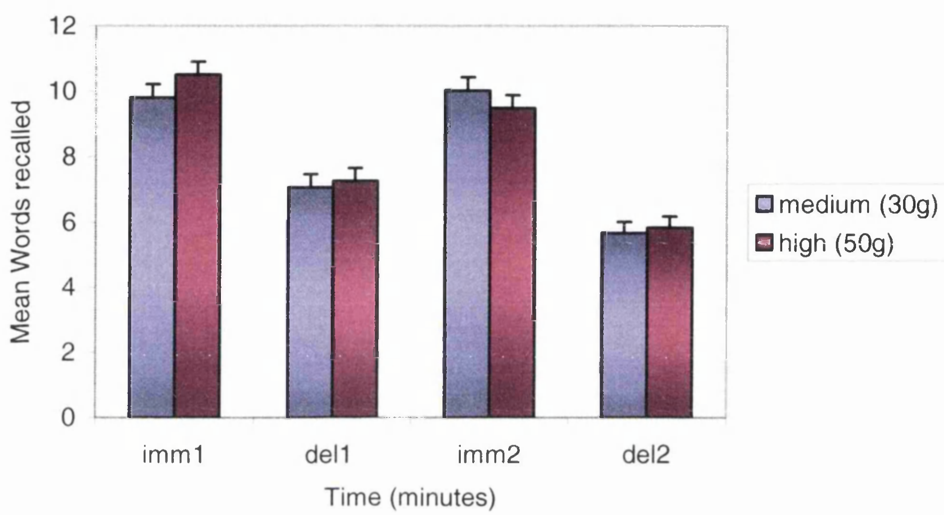
Table 3.5: Summary table for the significant differences between the conditions with respect to Hunger

Time	F-ratio, Sig.	Differences
30 minutes	F (8,158) = 7.73, p<0.001	- Fast significantly differed from MCMF; MCHF; HCLF; HCMF; HCHF - LCLF, LCMF & MCLF significantly differed from HCLF; HCHF
60 minutes	F (8,158) = 5.96, p<0.001	- Fast significantly differed from MCMF; MCHF; HCLF; HCMF; HCHF - LCMF significantly differed from HCLF; HCHF
90 minutes	F (8,158) = 5.70, p<0.001	- Fast significantly differed from MCMF; MCHF; HCLF; HCMF; HCHF - LCMF significantly differed from HCLF; HCHF
150 minutes	F (8,158) = 4.75, p<0.001	- Fast significantly differed from MCMF; MCHF; HCLF; HCMF; HCHF - LCMF significantly differed from HCHF

Breakfast Meal and Memory

The interaction Carbohydrate X Session X Recall reached significance, with respect to the number of words recalled from the word lists [$F(1,107) = 6.82$, $p=0.01$] (Figure 3.7). SSME's failed to demonstrate any significant differences between the carbohydrate groupings at either recall (immediate/delayed) or session (1,2). However, significant changes in the number of words recalled from 40 to 100 minutes were observed for each carbohydrate grouping and at both immediate and delayed recall. Furthermore, significant differences were observed between the number of words recalled at immediate and delayed recall for medium carbohydrate (30g) at 40 minutes [F (1,111) = 12.23, p=0.001], and high carbohydrate (30g) at 40 minutes [F (1,111) = 7.73, p<0.001] and 100 minutes [F (1,123) = 14.50, p< 0.001].

Figure 3.7: Profile of Words recalled over Time for each Carbohydrate grouping (means +/- s.e.m)



Fibre failed to influence the number of words recalled {(1) [F (2,107) = 0.241, p=n.s.]; (2) [F (1,108) = 1.99, p=n.s.].

When the time taken to recall the word lists was analysed, the interaction Fibre X Session reached significance {(1) [F (2,107) = 3.25, p<0.05]; (2) [F (1,108) = 6.90, p=0.01]. SME's preformed on the data showed these findings to reflect significant decreases in the time taken to recall the word lists over the two sessions.

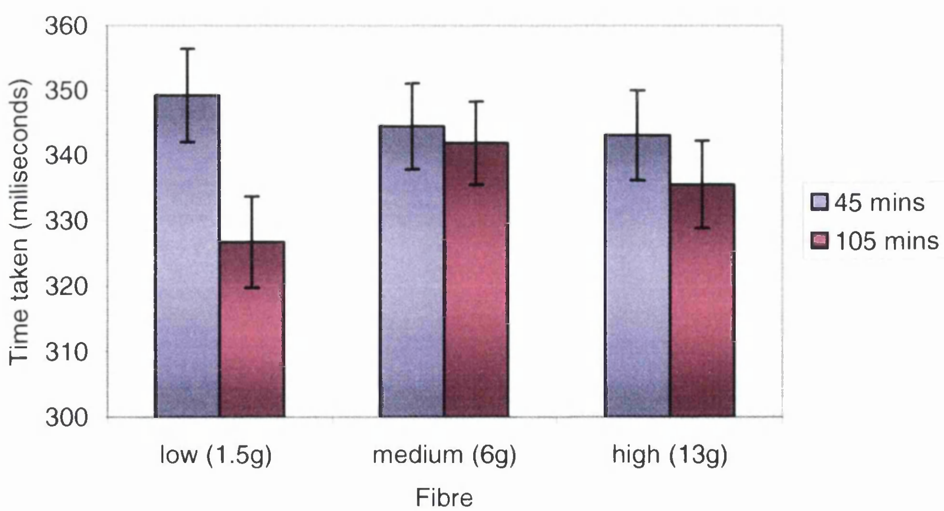
The interaction Carbohydrate X Recall also reached significance [F (2,108) = 4.36, p<0.05]. SME's revealed that there was a significant difference between the carbohydrate conditions at delayed recall [F (2,108) = 3.94, p<0.05], with the low carbohydrate (15g) condition taking the longest time.

Breakfast and the Hick Paradigm

12 participants were removed from the analysis due to incomplete data, or negative slopes.

The interaction Fibre X Session reached significance with respect to Decision times {(1) [F (2,102) = 4.67, p<0.05]; (2) [F (1,100) = 7.16, p<0.01]}. Figure 3.8 and SME's show that the low fibre (1.5g), compared to higher fibre conditions, perform the second session significantly quicker than the first {(1) [F (1,105) = 21.31, p<0.001]; (2) [F (1,104) = 20.15, p<0.001].

Figure 3.8: The effect of Fibre on Decision Times over Time (means +/- s.e.m)



The interaction Carbohydrate X Fibre X Session reached significance with respect to Movement times {(1) [F (1,102) = 5.92, p<0.01]; (2) [F (2,100) = 4.85, p=0.01]}. This reflected a significant increase in movement times from the first to the second session for those in the hcmf condition.

When Slope values were considered, the interaction Carbohydrate X Fibre X Session reached significance {(1) [F (2,102) = 3.47, p<0.05]; (2) [F (2,100) = 5.07, p<0.01]}. Figure 3.9 and SSME's demonstrate that:

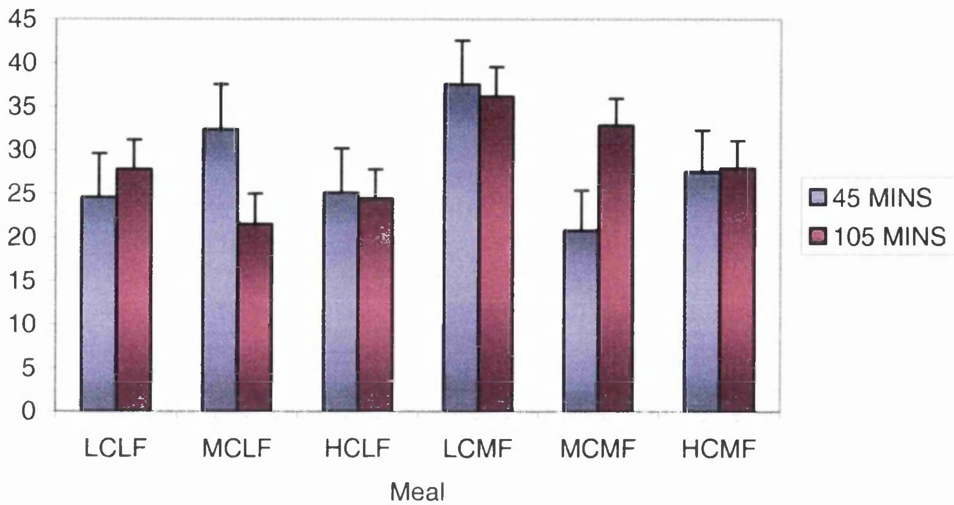
(1) the mclf condition was significantly better on the second session than the mcmf condition [F (1,(102) = 5.60, p<0.05]

(2) the mclf condition performed significantly better in the second session than the first {(1) [F (1,102) = 4.66, p<0.05]; (2) [F (1,100) = 5.15, p<0.05]}

(3) the mcmf condition performed significantly worse in the second session than the first {(1) [F (1,102) = 7.21, p<0.01]; (2) [F (1,100) = 7.96, p<0.01]

Neither carbohydrate {(1) [F (1,102) = 0.10, p=0.75]; (2) [F (2,100) = 1.33, p=0.27]}, nor fibre {(1) [F (1,102) = 0.23, p=0.80]; (2) [F (1,100) = 0.35, p=0.55] affected Intercept values. In addition Intra-Individual Variability also failed to be affected by carbohydrate {(1) [F 1,102) = 0.10, p=0.76]; (2) [F (2,100) = 0.20, p=0.82]} or fibre {(1) [F (2,102) = 0.22, p=0.80]; (2) [F (1,100) = 0.79, p=0.38].

Figure 3.9: The effect of Carbohydrate and Fibre on Slope values over Time (means +/- s.e.m)



Breakfast Meal and the Rapid Information Processing Task

30 Participants were removed from the RIPT, due to incomplete data or incorrect performance on the task (>20 wrong responses per minute).

Neither Carbohydrate nor Fibre affected correct responses {(1) [F (1,92) = 0.82, p=0.37]; (2) [F (2,92) = 0.87, p=0.42]} or wrong responses {(1) [F (1,92) = 0.50, p = 0.48]; (2) [F (2,92) = 0.51, p=0.60]}.

When reaction times were analysed the interaction Carbohydrate x Fibre reached significance {(1) [F (2,92) = 4.94, p<0.05]; (2) [F (2,89) = 4.29, p<0.05]}. SME's demonstrated that the mcmf condition had significantly quicker reaction times than the hcmf condition [F (1,94) = 4.17, p<0.05]. In addition the hclf condition was significantly quicker than the hcmf condition {(1) [F (2,93) = 4.01, p<0.05]; (2) [F (1,91) = 6.79, p=0.01].

The interaction Carbohydrate X Session also reached significance [F (4,178) = 4.50, p<0.01]. SME's showed that there was a significant decrease in the reaction times over the three sessions for the medium carbohydrate (30g) conditions.

3.4.2 EFFECT OF MACRONUTRIENTS

Breakfasts low in fibre were associated with increased Energy between 60 and 90, increased total mood at 90 minutes and Composure at 120 minutes. Breakfasts low in Kilocalories, the LCLF and LCMF conditions, were associated with increased Hunger over the morning.

Breakfasts high in Protein were associated with quicker delayed recall times.
No consistent patterns were observed with macronutrients and measures of the Hick Paradigm.

Low caloric intake was associated with increased wrong responses on the third test (110 minutes).

3.4.3 EFFECT OF BLOOD GLUCOSE LEVELS AND CHANGE

Stepwise linear regressions were performed on the data, with the blood glucose levels, and changes in blood glucose levels as independent variables, and measures of Mood, Hunger, and measures of cognition as dependent variables. Patterns observed within the breakfast conditions are reported.

LCLF

Slowly rising and low blood glucose levels over the first 30 minutes were associated with lower intercepts (40, 100mins), quicker decision times and less variability on the Hick Paradigm (100mins). Falling blood glucose levels between 60 and 90 minutes were associated with increased mood between 60 and 120 minutes, and increased wrong responses on the RIPT (40, 55, 100mins). Affected measures were Composure (60mins), Confidence (60 & 120mins), Energy (90 minutes) and Clearheadedness (120mins). Rapidly falling levels between 90 and 120 minutes were associated with less variability on the Hick paradigm (100mins), and taking more time to recall the second word list (100mins).

LCMF

Slowly rising and low blood glucose levels over the first 30 minutes were associated with increased correct responses on the RIPT (40, 55mins), increased word recall (100mins) and longer time taken to recall the word lists (40, 100mins). Slowly falling levels between 60 and 90 minutes were associated with increased wrong responses on the third RIPT test (100minutes). Slow falling and stable blood glucose levels between 90 and 120 minutes were associated with increased hunger over the morning, and less time taken to recall the word lists (100mins)

MCLF

Low blood glucose levels at 60 minutes were associated with increased correct responses on the RIPT (40mins) and lower intercept values on the Hick (40mins). Falling blood glucose levels between 60 and 90 minutes were associated with increased Confidence (90mins), Composure and Total mood (120mins), and increased wrong responses on the RIPT (40mins). Slow falling and stable levels between 90 and 120 minutes were associated with increased Confidence over the morning, total mood (120mins), increased word recall (100mins), increased correct responses and quicker reaction times on the RIPT (100mins), but longer reaction times at 40 minutes.

MCMF

High blood glucose levels at 30 minutes were associated with increased wrong responses on the RIPT (55mins), however slowly falling and stable blood glucose levels between 30 an 60 minutes were associated with less variability on the Hick Paradigm (100mins). Rapidly falling levels between 60 and 90 minutes were associated with increased correct responses on the RIPT (55mins) and low levels at 90 minutes with increased word recall (100mins) and longer time taken to recall the word lists (40mins). Slowly falling and stable blood glucose levels from 90 to 120 minutes were associated with increased Composure (30, 90mins), Agreeability and Total mood (30mins), however, rapidly falling levels were associated with quicker reaction times on the RIPT (55mins).

MCHF

Rapidly rising blood glucose levels between 0 and 30 minutes were associated with increased Composure (30mins) and Confidence after 60 minutes. Slow falling and stable levels between 30 and 60 minutes with increased Elation between (60, 90mins). High blood glucose levels at 30 were associated with longer reaction times on the RIPT (40mins). Falling blood glucose levels between 60 and 90 minutes were associated with increased Elation and Energy (90mins) and Total mood (60, 90mins). Falling levels between 90 and 120 minutes were associated with lower intercepts on the Hick (40mins) and less time taken to recall the first word list (40mins). However rising and high levels at 120 minutes were associated with quicker reaction times on the RIPT (100mins) and less variability on the Hick (100mins).

HCLF

Low blood glucose levels over the first hour were associated with increased correct responses on the RIPT (40, 55, 110mins). Falling levels between 30 and 60 minutes were associated with quicker recall times (40mins), less wrong responses on the RIPT (100mins) and increased hunger at 120 minutes. High blood glucose levels at 90 minutes were associated with increased Elation and Clearheadedness (60mins) and Total mood (30, 60mins). Falling levels from 90 to 120 minutes were associated with increased Composure over the morning and increased wrong responses on the RIPT (55mins).

HCMF

High baseline and slowly rising blood glucose levels over the first 30 minutes were associated with increased Composure (90, 120mins) and Hunger (60, 120mins). Low levels at 30 minutes were associated with increased Clearheadedness, Energy and Total mood (60mins), quicker decision times (40mins) and lower intercepts (40, 100mins). Falling blood glucose levels from 30 to 60 minutes were associated with increased word recall (40mins), however, with increased variability on the Hick Paradigm (40mins). Slow falling and stable levels between 90 and 120 minutes were associated with quicker decision times (100mins), lower intercept and flatter slope values (40mins) on the Hick Paradigm.

HCHF

Low baseline blood glucose levels were associated with increased Hunger over the morning. Rapidly falling blood glucose levels from 90 to 120 minutes were associated with quicker decision times and less variability on the Hick Paradigm (40, 100mins), however, slowly falling and stable levels were associated with quicker reaction times on the RIPT (100mins) and increased word recall (40mins).

3.4.4 EFFECT OF HABITUAL BREAKFAST CONSUMPTION

When the number of words recalled from the word list was analysed, the interaction Habitual X Fibre failed to reach significance [$F(2,102) = 0.266, p=0.08$]. SME's could not be performed on the data due to the ANOVA calculating modified population marginal means, as there were no non-habitual breakfast consumers in the MCLF condition.

However, non-breakfast consumers, who consumed a medium fibre (6g) breakfast, recalled more words than those who consumed a high fibre breakfast (13g).

The interaction Habitual breakfast consumption X Fibre trended towards significance with respect to Total mood [$F(2,102) = 2.86$, $p=0.06$]. Again, due to the missing data for MCLF condition, adjusted means were used which in turn produced large standard errors. In those non-breakfast consumers, consumption of a high fibre (13g) breakfast increased total mood, whereas in breakfast consumers, a low fibre (1.5g) breakfast increased total mood.

The interaction Habitual breakfast consumption X Carbohydrate also approached significance with respect to Total mood [$F(2,103) = 2.92$, $p=0.06$]. Again, adjusted means were used due to the missing data for the MCLF condition, which in turn produced large standard errors. In non-breakfast consumers, a high carbohydrate (50g) breakfast increased Total mood, whereas in breakfast consumers, a medium carbohydrate (30g) breakfast increased Total mood.

There was a main effect of carbohydrate with respect to hunger ratings [$F(2,103) = 5.56$, $p<0.01$]. Participants who consumed the high carbohydrate breakfast were the least hungry over the morning test session.

3.5 SUMMARY

Breakfast and Blood Glucose Levels

- Consumption of the low-carbohydrate/medium fibre and medium-carbohydrate/low fibre meals failed to induce significant changes in blood glucose levels over time.
- Consumption of higher carbohydrate breakfasts (30g, 50g) resulted in significantly higher blood glucose levels at 30 minutes compared to lower doses (10g).

Breakfast, Mood and Hunger

- Consumption of 30g of carbohydrate, compared to 15g of carbohydrate, resulted in better mood at the end of the study (120 minutes), and better mood throughout the morning.
- Consumption of low fibre meals (1.5g) were beneficial to mood throughout the morning.
- Both higher doses of carbohydrate (50g) and fibre (13g) significantly reduced hunger over the morning, with those who fasted or consumed the low-carbohydrate/low-fibre meal reporting the most hunger; the larger the meal in size, the greater the reduction in hunger.

Breakfast and Memory

- Participants who consumed the medium carbohydrate (30g) meals showed no deterioration in the number of words recalled from immediate to delayed recall at

40 minutes, however, no differences were observed between the carbohydrate conditions.

- Fibre failed to influence the number of words recalled.
- Participants who consumed the low carbohydrate (15g) meals took longer to recall the word lists than higher doses (30g or 50g).

Breakfast and Cognition

- Participants who consumed low quantities of Fibre (1.5g) had significantly quicker Decision times, and more consistent results over the Lamps (Slope values) than the other groups.
- Neither Carbohydrate nor fibre influenced the number of correct or wrong responses on the RIPT.
- Participants who consumed the medium carbohydrate (30g) breakfasts had the greatest improvement in reaction times over time, with participants who consumed the high-carbohydrate/medium-fibre meal performing the slowest.

- **LCLF & LCMF** - in both of these conditions, slowly rising levels blood glucose levels over the first 30 minutes, and falling levels from 60 to 120 minutes, were associated with enhanced performance on the Memory tests, Hick Paradigm, RIPT and increased mood.
- **MCLF, MCMF & MCHF** – Low and falling blood glucose levels from 60 to 90 minutes, and slow falling and stable levels between 90 and 120 minutes, were

associated with enhanced performance on the Memory tests, Hick Paradigm, RIPT and increased mood.

- **HCLF, HCMF & HCHF** – Groups need to be looked at individually with respect to blood glucose levels.

3.6 DISCUSSION

The present study aimed to examine the effects of varied amounts of fibre and carbohydrate consumed as a breakfast meal. As expected, the larger the meal in size, carbohydrate and fibre content, the greater the response in blood glucose levels (Figure 3.1), and the decrease in hunger (Figure 3.6).

Consumption of low fibre breakfasts (1.5g) resulted in increased mood (Figure 3.4, 3.5), quicker decision times and flatter slope values at 105 minutes (Figure 3.8, 3.9), reflecting consistent performance on the Hick Paradigm. Consumption of medium carbohydrate breakfasts (30g) helped recovery of mood following the first test battery and decreased the decline in word recall from the first to the second word list (Figure 3.2).

The relationship between blood glucose levels and performance on the measures tested, reflected the ability to effectively utilise the macronutrients ingested, especially with respect to the low and medium carbohydrate breakfasts. In these conditions the different amounts of fibre (1.5, 6, 13g) had a negligible effect. Patterns were observed across the carbohydrate conditions (15, 30, 50g) rather than the fibre groupings. In both the low (15g) and medium carbohydrate (30g) conditions, falling blood glucose levels over the last 60 minutes, indicating utilisation of glucose, was associated with enhanced cognitive performance.

In the high carbohydrate (50g) condition, it was possible that the nutritional content of the meal had a greater effect on blood glucose levels and performance. Carbohydrate content remained constant, however, fibre, fat, protein and energy content increased linearly from the low to high fibre meals. It is possible that the greater metabolic changes in the GIR (Glucose to Insulin Ratio), as a function of the greater carbohydrate load, may have influenced the different effects observed between the three meals.

The present study replicated the finding that high-fibre, high-carbohydrate breakfast meals decreased subsequent hunger over the morning (Holt et al., 1999; Delargy et al., 1997, 1995; Levine et al., 1989). In this study, participants who consumed the placebo meal were significantly hungrier over the morning than those who consumed the MCMF, MCHF, HCLF, HCMF and HCHF meals. Additionally those who consumed the LCMF were significantly hungrier than those who consumed HCLF and HCHF meals up to 100 minutes, and only the HCHF at 150 minutes. Thus participants who consumed the largest meal were the least hungry at the end of the study. Meal size was further emphasised as being an important predictor of subsequent hunger through regression equations, in which caloric intake were negatively associated with hunger.

The fact that the highest dose of fibre used in this study (13g from 45g All Bran) is much lower than that used by Holt et al., (1999; 19.1g from 74g of All Bran), further suggests that meal size, rather than composition, is a predictor of satiety. The HCHF meal consisted of 67g cereal (42g All Bran; 25g Cornflakes) with 200ml skimmed milk. Holt et al., (1999) gave 74g All Bran and found subsequent reductions in hunger, however, this may be as a function of eating a big meal, or a meal which participants would not normally choose. Using unrealistic portion sizes and meal compositions may account for the effects observed in previous studies (Holt et al., 1999; Delargy et al., 1997, 1995; Levine et al., 1989; Stevens et al., 1987).

The effects observed may reflect a change from the habitual breakfast consumed by the participants (Holt et al., 1999). However, using a naturally occurring high fibre food (45g/100g carbohydrate; 29g / 100g fibre), and realistic portion sizes, allows the results to be applicable to real life diets. However, due to the nature of food sources, it was impossible to create a LCHF condition. This had implications for the analysis of the study, and helps to explain why marginal findings appear/disappear depending on the combination of fibre and carbohydrate.

The type of fibre may also have had an effect on the results. In the present study insoluble wheat bran was investigated through the consumption of breakfast cereals, however, previous studies have reported a variable influence on satiety (Stevens et al., 1987, Delargy et al., 1997; Jenkins et al., 1978). It is possible that the consumption of soluble fibres, such as inulin and psyllium gum, may have a differential effect on satiety, blood glucose levels and cognitive performance.

Previous research with fibre has focused primarily on hunger and satiety, and not cognitive performance. However results from this study fail to give any support to fibre enhancing measures of Memory or Attention. Low fibre (1.5g) was found enhance Reaction times and aspects of Mood, whilst medium carbohydrate (30g) influenced memory. However, the ability to effectively utilise the carbohydrate load, demonstrated through changes in blood glucose levels over time, was associated with enhanced performance on the Memory and Cognitive tests, and increased Mood.

3.6.1 CONCLUSION

The present findings suggest that low quantities of Fibre (approximately 1.5g) and medium quantities of Carbohydrate (30g) consumed within a breakfast meal enhanced aspects of Mood, Memory and Cognitive performance over the course of two hours.

Once again, the results are consistent with the suggestion that individual differences in the ability to effectively utilise the carbohydrate load is an important factor influencing mood and cognitive functioning. This concept will be investigated in more depth in subsequent chapters.

Table 3.6: Summary table with respect to measures of Mood (+/- s.e.m)

MOOD	MEAL	30mins – base	60mins – base	90mins – base	120mins – base	RESULT
Composure	Fast	0.688 (4.111)	-2.438 (5.169)	-2.312 (4.662)	-5.625 (5.349)	Meal F (8,158) = 1.389, p=0.205
	LCLF	-2.333 (3.876)	-5.833 (4.874)	0.500 (4.395)	-1.833 (5.043)	
	LCMF	-0.500 (3.677)	-3.200 (4.623)	-2.150 (4.169)	-0.450 (4.784)	Time F (3,474) = 3.839, p=0.01
	MCLF	2.056 (3.876)	0.278 (4.874)	4.944 (4.395)	8.833 (5.043)	Meal X Time F (24,474) = 0.862, p=0.655
	MCMF	8.900 (3.677)	3.250 (4.623)	7.500 (4.169)	10.100 (4.784)	
	MCHF	1.706 (3.989)	0.471 (5.015)	4.471 (4.522)	1.118 (5.189)	
	HCLF	10.000 (3.989)	5.412 (5.015)	8.824 (4.522)	12.471 (5.189)	
	HCMF	3.667 (3.589)	-3.571 (4.512)	-1.810 (4.069)	-3.429 (4.669)	
	HCHF	-0.300 (3.677)	-4.700 (4.623)	-1.700 (4.169)	-7.050 (4.784)	
Agreeability	Fast	1.187 (3.886)	-2.125 (4.330)	-4.875 (4.198)	0.562 (4.518)	Meal F (8,158) = 0.794, p=0.608
	LCLF	0.444 (3.664)	-1.611 (4.082)	1.167 (3.958)	0.944 (4.260)	
	LCMF	2.600 (3.476)	-4.250 (3.873)	-3.000 (3.755)	-2.600 (4.041)	Time F (3,474) = 4.898, p<0.01
	MCLF	-1.667 (3.664)	-3.111 (4.082)	1.833 (3.958)	6.167 (4.260)	Meal X Time F (24,474) = 0.884, p=0.624
	MCMF	3.850 (3.664)	-1.400 (4.082)	-0.400 (3.958)	3.350 (4.260)	
	MCHF	-2.118 (3.770)	-5.824 (4.201)	-4.706 (4.073)	-1.294 (4.383)	
	HCLF	1.353 (3.770)	-2.824 (4.201)	2.235 (4.073)	1.235 (4.383)	
	HCMF	-3.857 (3.392)	-7.667 (3.779)	-9.048 (3.664)	11.143 (3.944)	
	HCHF	0.450 (3.664)	-5.050 (4.082)	-2.100 (3.958)	-3.250 (4.260)	

Elation	Fast	2.188 (2.871)	0.375 (4.017)	0.812 (3.429)	0.500 (3.570)	Meal F (8,158) = 0.532, p=0.831 Time F (3,474) = 5.453, p=0.001 Meal X Time F (24,474) = 0.857, p=0.662
	LCLF	-1.611 (2.707)	-6.944 (3.787)	-2.111 (3.233)	-0.944 (3.366)	
	LCMF	1.750 (2.568)	-2.850 (3.593)	1.550 (3.067)	-3.100 (3.193)	
	MCLF	-0.500 (2.707)	1.778 (3.787)	4.778 (3.233)	6.167 (3.366)	
	MCMF	-0.450 (2.568)	-1.800 (3.593)	2.000 (3.067)	4.550 (3.193)	
	MCHF	0.824 (2.786)	-2.412 (3.897)	-0.824 (3.326)	1.882 (3.463)	
	HCLF	-1.176 (2.786)	-2.647 (3.897)	1.353 (3.326)	1.059 (3.463)	
	HCMF	2.476 (2.506)	-2.190 (3.506)	-2.571 (2.993)	1.333 (3.116)	
	HCHF	-0.700 (2.568)	-7.700 (3.593)	-2.300 (3.067)	-2.250 (3.193)	
Confidence	Fast	6.375 (3.683)	3.313 (4.669)	4.063 (4.197)	6.588 (4.695)	Meal F (8,158) = 0.480, p=0.869 Time F (3,474) = 10.554, p<0.001 Meal X Time F (24,474) = 1.212, p=0.224
	LCLF	1.944 (3.473)	-0.111 (4.402)	3.500 (3.957)	4.167 (4.426)	
	LCMF	7.100 (3.295)	-0.150 (4.176)	1.850 (3.754)	4.750 (4.199)	
	MCLF	6.500 (3.473)	-1.167 (4.402)	9.000 (3.957)	13.611 (4.426)	
	MCMF	1.000 (3.295)	-3.500 (4.176)	1.150 (3.754)	4.950 (4.199)	
	MCHF	10.471 (3.573)	3.529 (4.530)	6.118 (4.071)	8.000 (4.555)	
	HCLF	11.235 (3.573)	4.529 (4.530)	9.588 (4.071)	8.588 (4.555)	
	HCMF	6.333 (3.215)	4.857 (4.076)	1.476 (3.663)	6.619 (4.098)	
	HCHF	6.400 (3.295)	1.750 (4.176)	2.400 (3.754)	1.400 (4.199)	

Energy	Fast	4.188 (5.581)	1.562 (6.363)	-1.812 (6.263)	-3.375 (6.693)	Meal F (8,158) = 1.222, p=0.289
	LCLF	2.944 (5.262)	0.222 (5.999)	-6.222 (5.905)	-9.167 (6.310)	
	LCMF	6.350 (4.992)	-4.100 (5.691)	-4.950 (5.602)	-8.950 (5.987)	Time F (3,474) = 13.777, p<0.001
	MCLF	6.333 (5.262)	-1.222 (5.999)	3.500 (5.905)	4.278 (6.310)	Meal X Time F (24,474) = 0.760, p=0.787
	MCMF	11.100 (4.992)	4.800 (5.691)	3.450 (5.602)	4.300 (5.987)	
	MCHF	-0.176 (5.415)	-9.412 (6.173)	-11.412 (6.076)	-10.765 (6.493)	
	HCLF	13.118 (5.415)	8.176 (6.173)	11.882 (6.076)	6.412 (6.493)	
	HCMF	7.333 (4.872)	-6.048 (5.554)	-5.810 (5.467)	-1.381 (5.842)	
	HCHF	-0.650 (4.992)	-9.500 (5.691)	-8.450 (5.602)	-5.650 (5.987)	
Clearheaded	Fast	-0.062 (4.079)	-3.375 (4.903)	-1.125 (4.883)	-1.437 (5.420)	Meal F (8,158) = 0.588, p=0.787
	LCLF	5.444 (3.845)	-1.333 (4.623)	0.500 (4.603)	-0.833 (5.110)	
	LCMF	5.800 (3.648)	1.850 (4.386)	6.350 (4.367)	1.900 (4.848)	Time F (3,474) = 11.209, p<0.001
	MCLF	5.222 (3.845)	-3.278 (4.623)	1.944 (4.603)	5.667 (5.110)	Meal X Time F (24,474) = 0.987, p=0.482
	MCMF	5.550 (3.648)	-2.400 (4.386)	4.600 (4.367)	8.000 (4.848)	
	MCHF	1.294 (3.957)	-7.118 (4.757)	-3.059 (4.737)	-2.294 (5.258)	
	HCLF	12.765 (3.957)	4.588 (4.757)	9.059 (4.737)	1.706 (5.258)	
	HCMF	7.571 (3.560)	-0.905 (4.280)	-4.810 (4.262)	-0.095 (4.731)	
	HCHF	10.350 (3.648)	-0.900 (4.386)	2.650 (4.367)	1.350 (4.848)	

Total Mood	Fast	14.562 (14.447)	-2.688 (17.991)	-5.250 (17.424)	-3.688 (20.329)	Meal F (8,158) = 1.164, p=0.324
	LCLF	6.883 (13.261)	-15.611 (16.962)	-2.667 (16.427)	-7.667 (19.166)	
	LCMF	23.100 (12.922)	-12.700 (16.092)	-0.350 (15.584)	-8.450 (18.183)	Time F (3,474) = 15.325, p<0.001
	MCLF	17.944 (13.261)	-6.722 (16.962)	26.000 (16.427)	44.722 (19.166)	Meal X Time F (24,474) = 1.143, p=0.291
	MCMF	29.950 (12.922)	-1.050 (16.092)	18.300 (15.584)	35.250 (18.183)	
	MCHF	12.000 (14.016)	-20.765 (17.454)	-9.412 (16.903)	47.294 (19.722)	
	HCLF	47.294 (14.016)	17.235 (17.454)	42.941 (16.903)	31.471 (19.722)	
	HCMF	23.524 (12.610)	-15.524 (15.704)	-22.571 (15.209)	-8.095 (17.745)	
	HCHF	15.550 (12.922)	-26.100 (16.092)	-9.500 (15.584)	-15.584 (18.183)	
Hunger	Fast	-0.938 (5.971)	5.375 (6.755)	10.312 (7.230)	19.937 (8.070)	Meal F (8,158) = 6.963, p<0.001
	LCLF	-17.444 (5.629)	-19.333 (6.369)	-17.944 (6.817)	-6.944 (7.608)	
	LCMF	-16.800 (5.341)	-12.500 (6.042)	-7.950 (6.467)	1.350 (7.218)	Time F (3,474) = 33.525, p<0.001
	MCLF	-22.000 (5.629)	-21.778 (6.369)	-20.111 (6.817)	-13.278 (7.608)	Meal X Time F (24,474) = 0.595, p=0.937
	MCMF	-31.450 (5.341)	-27.250 (6.042)	-31.100 (6.467)	-20.850 (7.218)	
	MCHF	-37.176 (5.793)	-36.765 (6.554)	-30.529 (7.014)	-24.765 (7.829)	
	HCLF	-50.176 (5.793)	-41.588 (6.554)	-39.824 (7.014)	-27.176 (7.829)	
	HCMF	-35.571 (5.212)	-31.333 (5.896)	-28.286 (6.311)	-22.143 (7.044)	
	HCHF	-47.200 (5.341)	-45.500 (6.042)	-42.500 (6.467)	-34.450 (7.218)	

Table 3.7: Summary table with respect to the total number of words recalled on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	RESULT
Fast	10.187 (0.801)	7.188 (0.722)	10.437 (0.796)	6.750 (0.746)	Meal F (8,158) = 0.177, p=0.994 Session F (1,158) = 17.565, p<0.001 Meal X Session F (8,158) = 0.630, p=0.752 Recall F (1,1158) = 690.429, p<0.001 Meal X Recall F (8,158) = 0.800, p=0.603 Session X Recall F (1,158) = 24.915, p<0.001 Meal X Session X Recall F (8,158) = 1.422, p=0.191
LCLF	10.333 (0.755)	8.000 (0.728)	9.778 (0.751)	6.333 (0.703)	
LCMF	9.850 (0.717)	7.300 (0.690)	9.850 (0.712)	5.850 (0.667)	
MCLF	9.667 (0.755)	6.944 (0.728)	10.222 (0.751)	5.278 (0.703)	
MCMF	10.150 (0.717)	6.750 (0.690)	9.900 (0.712)	5.850 (0.667)	
MCHF	9.588 (0.777)	7.529 (0.749)	9.941 (0.772)	5.882 (0.724)	
HCLF	10.353 (0.777)	7.000 (0.749)	9.412 (0.772)	6.294 (0.724)	
HCMF	9.905 (0.699)	7.095 (0.674)	9.238 (0.695)	5.571 (0.651)	
HCHF	11.250 (0.717)	7.700 (0.690)	9.800 (0.712)	5.650 (0.667)	

Table 3.8: Summary table with respect to the time taken to recall the word lists on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	RESULT
Fast	43.000 (3.949)	30.250 (2.706)	42.687 (3.345)	28.438 (2.311)	Meal F (8,158) = 0.943, p=0.483 Session F (1,158) = 56.743, p<0.001 Meal X Session F (8,158) = 2.321, p<0.05 Recall F (1,1158) = 454.480, p<0.001 Meal X Recall F (8,158) = 1.972, p=0.053 Session X Recall F (1,158) = 0.586, p=0.445 Meal X Session X Recall F (8,158) = 0.889, p=0.527
LCLF	46.889 (3.723)	37.000 (2.552)	44.056 (3.153)	29.944 (2.179)	
LCMF	46.550 (3.532)	35.400 (2.421)	38.600 (2.992)	28.500 (2.067)	
MCLF	46.667 (3.723)	33.611 (2.552)	45.611 (3.153)	26.778 (2.179)	
MCMF	43.100 (3.532)	28.750 (2.421)	38.750 (2.992)	23.250 (2.067)	
MCHF	47.000 (3.831)	31.529 (2.626)	41.000 (3.245)	25.941 (2.242)	
HCLF	42.941 (3.831)	25.941 (2.626)	38.824 (3.245)	26.118 (2.242)	
HCMF	56.046 (3.447)	35.095 (2.632)	43.619 (2.919)	23.571 (2.018)	
HCHF	44.900 (3.532)	31.300 (2.421)	39.500 (2.992)	24.750 (2.067)	

Table 3.9: Summary table for Decision Times on the Hick Paradigm (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	323.438 (10.187)	338.156 (9.984)	378.031 (11.361)	412.625 (18.514)	Meal F (8,149) = 1.215,
	LCLF	317.265 (9.883)	332.029 (9.686)	350.382 (11.022)	393.118 (17.961)	p=0.294
	LCMF	313.382 (9.883)	340.735 (9.686)	370.294 (11.022)	426.765 (17.691)	Session F (1,149) = 20.757,
	MCLF	308.250 (10.187)	320.312 (9.984)	356.438 (11.361)	404.188 (18.514)	p<0.001 Meal X Session
	MCMF	306.000 (9.111)	323.225 (8.930)	337.675 (10.161)	370.400 (16.559)	F (8,149) = 1.576, p=0.136
	MCHF	311.813 (10.187)	334.406 (9.984)	363.469 (11.361)	399.844 (18.514)	Lamps F (3,447) = 375.442,
	HCLF	318.794 (9.883)	333.824 (9.686)	357.088 (11.022)	394.794 (17.961)	p<0.001 Meal X Lamps
	HCMF	317.263 (9.348)	339.053 (9.162)	359.789 (10.425)	402.500 (16.990)	F (24,447) = 0.897, p=0.606
	HCHF	298.450 (9.111)	314.550 (8.930)	339.250 (10.161)	383.000 (16.559)	Session X Lamps F (3,447) = 2.484,
Sess 2	Fast	307.469 (10.471)	337.594 (10.925)	370.500 (11.744)	400.844 (15.196)	p=0.060 Meal X Session X
	LCLF	293.559 (10.158)	330.794 (10.598)	359.529 (11.394)	376.706 (14.743)	Lamps F (24,447) = 1.214,
	LCMF	303.500 (10.158)	342.324 (10.598)	376.853 (11.394)	411.059 (14.743)	p=0.224
	MCLF	300.594 (10.471)	307.000 (10.925)	334.187 (11.744)	363.312 (15.196)	
	MCMF	286.950 (9.365)	314.500 (9.771)	336.725 (10.504)	389.000 (13.592)	
	MCHF	302.469 (10.471)	327.687 (10.925)	356.969 (11.744)	375.906 (15.196)	
	HCLF	293.382 (10.158)	312.029 (10.598)	336.853 (11.394)	366.618 (14.743)	
	HCMF	317.500 (9.608)	330.63 (10.025)	358.816 (10.777)	401.184 (13.945)	
	HCHF	285.825 (9.365)	314.550 (9.771)	340.775 (10.504)	380.175 (13.592)	

Table 3.10: Summary table for Movement Times on the Hick Paradigm (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	190.937 (11.452)	192.281 (12.879)	199.688 (12.785)	208.906 (12.833)	Meal F (8,149) = 0.876,
	LCLF	195.353 (11.110)	194.176 (12.494)	208.559 (12.403)	213.059 (12.450)	p=0.539
	LCMF	175.588 (11.110)	179.206 (12.494)	187.029 (12.403)	196.618 (12.450)	Session F (1,149) = 0.051,
	MCLF	177.375 (11.452)	191.906 (12.879)	192.250 (12.785)	198.031 (12.833)	p= 0.822 Meal X Session
	MCMF	184.800 (10.243)	179.375 (11.519)	191.350 (11.435)	200.225 (11.478)	F (8,149) = 2.294, p<0.05
	MCHF	188.687 (11.452)	188.156 (12.879)	195.500 (12.785)	205.125 (12.833)	Lamps F (3,447) = 47.025,
	HCLF	174.529 (11.110)	171.618 (12.494)	193.912 (12.403)	193.912 (12.450)	p<0.001 Meal X Lamps
	HCMF	187.711 (10.509)	192.026 (11.818)	210.316 (11.732)	209.947 (11.776)	F (24,447) = 0.691, p=0.862
	HCHF	187.700 (10.243)	189.500 (11.519)	197.325 (11.435)	202.300 (11.478)	Session X Lamps F (3,447) = 2.609,
Sess 2	Fast	199.156 (12.001)	192.031 (13.234)	203.937 (12.711)	202.500 (11.712)	p=0.051 Meal X Session X
	LCLF	195.794 (11.643)	194.176 (12.839)	204.294 (12.331)	215.176 (11.363)	Lamps F (24,447) = 0.677,
	LCMF	176.353 (11.643)	181.441 (12.839)	176.941 (12.331)	196.206 (11.363)	p=0.875
	MCLF	175.166 (12.001)	185.625 (13.234)	189.344 (12.711)	199.281 (11.712)	
	MCMF	176.175 (10.734)	180.300 (11.837)	174.650 (11.369)	189.600 (10.476)	
	MCHF	190.906 (12.001)	189.031 (13.234)	194.687 (12.711)	206.062 (11.712)	
	HCLF	168.500 (11.643)	170.853 (12.839)	174.882 (12.331)	182.647 (11.363)	
	HCMF	212.368 (11.013)	215.342 (12.144)	222.421 (11.664)	233.184 (10.748)	
	HCHF	183.400 (10.734)	183.575 (11.837)	193.325 (11.369)	199.300 (10.476)	

Table 3.11: Summary table for Intercept and Slope on the Hick Paradigm (+/- s.e.m)

	MEAL	Session 1	Session 2	RESULT
Intercept	Fast	316.950 (10.514)	307.150 (10.054)	Meal F (8,149) = 1.075, p=0.384
	LCLF	311.318 (10.200)	298.429 (9.753)	
	LCMF	308.476 (10.200)	308.476 (9.753)	Session F (1,149) = 18.653, p<0.001
	MCLF	298.713 (10.514)	293.975 (10.054)	Meal X Session F (8,149) = 0.988, p=0.448
	MCMF	303.165 (9.404)	282.540 (8.992)	
	MCHF	313.675 (10.514)	303.319 (10.054)	
	HCLF	313.441 (10.200)	290.553 (9.753)	
	HCMF	319.521 (9.648)	310.200 (9.226)	
	HCHF	292.055 (9.404)	283.955 (8.992)	
Slope	Fast	30.744 (4.994)	31.300 (3.514)	Meal F (8,149) = 1.060, p=0.394
	LCLF	24.576 (4.844)	27.812 (3.409)	
	LCMF	37.571 (4.844)	36.176 (3.409)	Session F (1,149) = 0.001, p=0.971
	MCLF	32.381 (4.994)	21.531 (3.514)	Meal X Session F (8,149) = 1.942, p=0.058
	MCMF	20.770 (4.466)	32.840 (3.143)	
	MCHF	30.894 (4.994)	24.963 (3.514)	
	HCLF	25.135 (4.844)	24.453 (3.409)	
	HCMF	27.489 (4.582)	27.905 (3.225)	
	HCHF	27.845 (4.466)	30.935 (3.143)	

Table 3.12: Summary table for Intra-Individual Variability on the Hick Paradigm (+/- s.e.m)

	MEAL	Session 1	Session 2	RESULT
Intra-Individual Variability	Fast	242.265 (25.039)	183.377 (24.787)	Meal $F(8,149) = 0.767$, $p=0.632$
	LCLF	177.346 (24.292)	151.720 (24.027)	
	LCMF	197.223 (24.292)	181.095 (24.047)	Session $F(1,149) = 3.689$, $p=0.057$
	MCLF	194.718 (25.039)	138.399 (24.787)	Meal X Session
	MCMF	165.692 (22.396)	181.155 (22.170)	$F(8,149) = 0.942$, $p=0.484$
	MCHF	171.837 (25.039)	155.261 (24.787)	
	HCLF	174.471 (24.292)	145.402 (24.047)	
	HCMF	165.803 (22.978)	173.911 (22.746)	
	HCHF	181.263 (22.396)	194.829 (22.170)	

Table 3.13: Summary table for Correct responses on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Corr 1	Fast	4.500 (0.479)	3.429 (0.508)	3.500 (0.469)	3.643 (0.481)	2.929 (0.383)	Meal F (8,132) = 0.708, p=0.684 Session F (2,264) = 7.202, p=0.001 Meal X Session F (16,264) = 0.640, p=0.850 Minute F (4,528) = 92.006, p<0.001 Meal X Minute F (32,528) = 0.897, p=0.633 Session X Minute F (8,1056) = 1.026, p=0.414 Meal X Session X Minute F (64,1056) = 0.966, p=0.554
	LCLF	4.933 (0.463)	4.333 (0.490)	3.467 (0.453)	4.400 (0.465)	2.133 (0.370)	
	LCMF	4.143 (0.479)	4.071 (0.508)	3.929 (0.469)	3.286 (0.481)	2.714 (0.383)	
	MCLF	4.625 (0.448)	3.750 (0.475)	3.000 (0.439)	3.250 (0.450)	2.250 (0.358)	
	MCMF	5.111 (0.423)	4.667 (0.448)	3.889 (0.414)	4.056 (0.424)	3.389 (0.337)	
	MCHF	4.929 (0.479)	4.714 (0.508)	3.714 (0.469)	3.929 (0.481)	2.500 (0.383)	
	HCLF	4.933 (0.463)	4.267 (0.490)	3.867 (0.453)	4.400 (0.465)	2.733 (0.370)	
	HCMF	4.412 (0.435)	4.000 (0.461)	3.235 (0.426)	4.235 (0.436)	2.706 (0.347)	
	HCHF	4.778 (0.423)	4.111 (0.448)	3.056 (0.414)	3.611 (0.424)	1.889 (0.337)	
Corr 2	Fast	4.571 (0.532)	3.571 (0.455)	4.071 (0.497)	3.643 (0.497)	3.000 (0.428)	
	LCLF	4.133 (0.514)	4.400 (0.440)	3.667 (0.481)	4.533 (0.480)	2.867 (0.414)	
	LCMF	4.857 (0.532)	4.714 (0.455)	3.857 (0.497)	3.929 (0.497)	2.786 (0.428)	
	MCLF	5.000 (0.498)	4.125 (0.426)	3.313 (0.465)	3.625 (0.465)	2.437 (0.401)	
	MCMF	5.556 (0.469)	4.778 (0.401)	4.222 (0.439)	5.056 (0.439)	2.833 (0.378)	
	MCHF	4.929 (0.532)	4.929 (0.455)	4.286 (0.497)	4.571 (0.497)	3.071 (0.428)	
	HCLF	4.533 (0.514)	4.600 (0.440)	3.067 (0.481)	4.200 (0.480)	2.600 (0.414)	
	HCMF	4.765 (0.483)	4.412 (0.413)	3.235 (0.451)	4.882 (0.451)	3.176 (0.389)	
	HCHF	3.833 (0.469)	4.222 (0.401)	4.111 (0.439)	4.056 (0.439)	2.722 (0.378)	

Corr 3	Fast	4.500 (0.543)	4.214 (0.499)	4.214 (0.501)	4.429 (0.533)	3.286 (0.433)	
	LCLF	5.200 (0.525)	3.867 (0.482)	3.700 (0.484)	4.533 (0.515)	3.533 (0.419)	
	LCMF	4.143 (0.543)	4.214 (0.499)	3.571 (0.501)	3.714 (0.533)	2.857 (0.433)	
	MCLF	4.813 (0.508)	3.750 (0.467)	3.750 (0.468)	4.875 (0.499)	2.500 (0.405)	
	MCMF	5.111 (0.479)	4.722 (0.440)	4.167 (0.442)	4.889 (0.470)	2.889 (0.382)	
	MCHF	5.500 (0.543)	4.929 (0.499)	4.286 (0.501)	4.786 (0.533)	3.500 (0.433)	
	HCLF	4.800 (0.525)	4.333 (0.482)	3.600 (0.484)	3.933 (0.515)	3.333 (0.419)	
	HCMF	5.235 (0.493)	4.471 (0.453)	4.000 (0.454)	4.765 (0.484)	3.000 (0.393)	
	HCHF	4.667 (0.479)	4.389 (0.440)	3.500 (0.470)	3.889 (0.470)	2.611 (0.382)	

Table 3.14: Summary table for Wrong responses on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrg 1	Fast	3.357 (0.969)	2.929 (0.786)	3.429 (0.960)	3.000 (0.847)	2.786 (0.797)	Meal F (8,132) = 0.508, p=0.849 Session F (2,264) = 15.333, p<0.001 Meal X Session F (16,264) = 0.455, p=0.965 Minute F (4,528) = 1.023, p=0.395 Meal X Minute F (32,528) = 0.685, p=0.905 Session X Minute F (8,1056) = 2.274, p<0.05 Meal X Session X Minute F (64,1056) = 0.954, p=0.581
	LCLF	2.400 (0.936)	2.467 (0.759)	2.933 (0.927)	2.800 (0.818)	2.200 (0.770)	
	LCMF	3.429 (0.969)	2.429 (0.786)	2.929 (0.960)	2.429 (0.847)	2.357 (0.797)	
	MCLF	2.500 (0.907)	2.625 (0.735)	2.188 (0.898)	3.188 (0.792)	1.875 (0.745)	
	MCMF	2.556 (0.855)	2.444 (0.693)	2.056 (0.847)	2.000 (0.747)	2.222 (0.703)	
	MCHF	2.857 (0.969)	1.214 (0.786)	2.286 (0.960)	1.929 (0.847)	2.000 (0.797)	
	HCLF	1.933 (0.936)	1.667 (0.759)	1.467 (0.927)	1.933 (0.818)	1.333 (0.770)	
	HCMF	3.176 (0.880)	3.118 (0.713)	2.765 (0.871)	2.647 (0.769)	2.765 (0.723)	
	HCHF	3.333 (0.855)	2.222 (0.693)	1.389 (0.847)	1.722 (0.747)	1.278 (0.703)	
Wrg 2	Fast	2.214 (0.723)	1.643 (0.662)	1.929 (0.743)	2.286 (0.820)	2.429 (0.811)	
	LCLF	1.400 (0.698)	2.533 (0.640)	1.933 (0.717)	2.733 (0.792)	2.000 (0.783)	
	LCMF	1.786 (0.723)	2.857 (0.662)	2.071 (0.743)	2.643 (0.820)	2.5741 (0.811)	
	MCLF	1.812 (0.676)	2.375 (0.619)	1.750 (0.695)	1.937 (0.767)	1.437 (0.758)	
	MCMF	1.444 (0.637)	1.500 (0.584)	2.000 (0.655)	2.222 (0.723)	1.722 (0.715)	
	MCHF	2.286 (0.723)	1.071 (0.662)	1.429 (0.743)	1.571 (0.820)	2.643 (0.811)	
	HCLF	0.733 (0.698)	1.333 (0.640)	1.133 (0.717)	1.533 (0.792)	0.733 (0.783)	
	HCMF	1.882 (0.656)	2.294 (0.601)	2.059 (0.674)	1.647 (0.744)	2.235 (0.736)	
	HCHF	1.556 (0.637)	0.889 (0.584)	1.222 (0.655)	1.167 (0.723)	0.944 (0.715)	

Wrg 3	Fast	1.571 (0.776)	1.500 (0.617)	1.929 (0.804)	2.429 (0.742)	3.071 (0.830)	
	LCLF	2.133 (0.750)	1.733 (0.596)	2.000 (0.776)	2.333 (0.716)	1.867 (0.802)	
	LCMF	1.214 (0.776)	2.214 (0.617)	1.786 (0.804)	1.929 (0.742)	1.857 (0.830)	
	MCLF	2.438 (0.726)	1.000 (0.577)	3.000 (0.752)	1.937 (0.694)	2.500 (0.776)	
	MCMF	2.444 (0.685)	1.389 (0.544)	1.722 (0.709)	1.611 (0.654)	1.944 (0.732)	
	MCHF	1.500 (0.776)	1.071 (0.617)	0.929 (0.804)	1.571 (0.742)	1.286 (0.830)	
	HCLF	0.733 (0.750)	0.467 (0.596)	0.400 (0.776)	1.267 (0.716)	0.733 (0.802)	
	HCMF	1.647 (0.704)	1.471 (0.559)	2.588 (0.729)	2.176 (0.673)	1.059 (0.753)	
	HCHF	1.222 (0.685)	1.444 (0.544)	1.333 (0.709)	1.500 (0.654)	1.500 (0.732)	

Table 3.15: Summary table for Reaction Times on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	Fast	640.357 (53.758)	549.357 (40.149)	541.500 (49.953)	525.643 (51.531)	577.714 (57.407)	Meal F (8,132) = 1.732, p=0.097 Session F (2,264) = 8.010, p<0.001 Meal X Session F (16,264) = 1.515, p=0.094 Minute F (4,528) = 3.230, p<0.05 Meal X Minute F (32,528) = 1.028, p=0.427 Session X Minute F (8,1056) = 1.246, p=0.269 Meal X Session X Minute F (64,1056) = 0.874, p=0.748
	LCLF	523.067 (51.935)	475.533 (38.787)	532.067 (48.259)	525.600 (49.784)	424.267 (55.561)	
	LCMF	564.643 (53.758)	497.143 (40.149)	545.500 (49.953)	495.714 (51.531)	553.286 (57.407)	
	MCLF	553.563 (50.286)	548.500 (37.556)	515.750 (46.727)	577.563 (48.203)	625.125 (53.700)	
	MCMF	586.611 (47.410)	562.444 (35.408)	556.944 (44.054)	605.056 (45.446)	550.556 (50.628)	
	MCHF	510.857 (53.758)	530.071 (40.149)	559.571 (49.953)	553.357 (51.531)	603.143 (57.407)	
	HCLF	547.933 (51.935)	507.467 (38.787)	570.667 (48.259)	445.600 (49.784)	496.533 (55.461)	
	HCMF	484.294 (48.784)	567.765 (36.434)	583.000 (45.332)	611.824 (46.764)	647.588 (52.096)	
	HCHF	561.667 (47.410)	504.167 (35.408)	540.611 (44.054)	663.944 (45.446)	585.333 (50.628)	
RT 2	Fast	591.643 (10.244)	540.500 (32.905)	532.786 (43.800)	637.357 (43.115)	641.500 (53.572)	
	LCLF	535.400 (38.879)	542.000 (31.789)	535.200 (42.315)	549.800 (41.653)	488.933 (51.755)	
	LCMF	507.000 (40.244)	537.571 (32.905)	572.071 (43.800)	577.071 (43.115)	590.286 (53.572)	
	MCLF	563.813 (37.645)	521.313 (30.780)	498.687 (40.971)	564.750 (40.330)	584.125 (50.112)	
	MCMF	503.000 (35.492)	511.167 (29.019)	500.889 (38.628)	511.056 (38.024)	426.833 (47.246)	
	MCHF	514.143 (40.244)	517.357 (32.905)	554.000 (43.800)	562.429 (43.115)	466.357 (53.572)	
	HCLF	480.133 (38.879)	491.733 (31.789)	525.067 (42.315)	486.533 (41.653)	532.133 (51.755)	
	HCMF	545.118 (36.521)	528.235 (29.861)	553.588 (39.748)	567.118 (39.126)	601.235 (48.616)	
	HCHF	482.722 (35.492)	461.222 (29.019)	528.944 (38.628)	571.556 (38.024)	593.556 (47.246)	

RT 3	Fast	505.786 (41.357)	525.000 (37.861)	544.714 (45.384)	606.357 (48.077)	561.000 (48.589)	
	LCLF	479.867 (39.955)	487.133 (36.577)	564.600 (43.845)	585.200 (46.446)	568.333 (46.941)	
	LCMF	531.286 (41.357)	560.786 (37.861)	554.143 (45.384)	602.071 (48.077)	504.143 (48.589)	
	MCLF	514.625 (38.686)	521.875 (35.416)	558.188 (42.453)	514.813 (44.971)	412.625 (45.450)	
	MCMF	478.056 (36.474)	511.556 (33.390)	504.000 (40.025)	514.722 (42.400)	407.167 (42.851)	
	MCHF	444.000 (41.357)	472.214 (37.861)	488.071 (45.384)	469.929 (48.077)	479.071 (48.589)	
	HCLF	414.400 (39.955)	463.400 (36.577)	460.400 (43.845)	549.400 (46.446)	488.800 (46.941)	
	HCMF	473.235 (37.531)	538.118 (34.359)	595.588 (41.185)	503.353 (43.629)	577.118 (44.093)	
	HCHF	471.056 (36.474)	476.056 (33.390)	522.222 (40.025)	528.278 (42.400)	492.111 (42.851)	

Chapter 4: The Interaction between Carbohydrate, Fat and Protein

4.1 INTRODUCTION

The previous chapters have demonstrated that consumption of 30g of carbohydrate, with up to 1.5g of fibre, significantly enhanced measures of mood, hunger and cognition over the course of the morning.

Following these findings, it was asked what effect meals containing variable amounts of carbohydrate, fat and protein would have on measures of mood, hunger and cognition. It has been previously demonstrated that the manipulation of pure macronutrient meals can significantly influence measures of cognition (section 1.8.2) and mood (section 1.8.3). Furthermore, it has been demonstrated that the changes in blood glucose levels are substantially different depending on the nutritional content of the food that is consumed (section 1.6.2), and on the individual's glucose tolerance (section 1.3.6).

4.1.1 AIM

This chapter aimed to test the hypothesis that breakfast meals differing in carbohydrate, fat and protein content would influence blood glucose levels, mood, hunger and cognitive functioning differentially. It was expected that meals with different macronutrients would release at different rates into the blood.

4.2 METHOD

4.2.1 PARTICIPANTS

225 female undergraduate students, mean age 20.36 years (SD 3.48), acted as participants. All were recruited through advertisements within the University of Wales, Swansea.

Groups of participants were compared under seven conditions:

1. Control Condition - No food (N=25; mean 19.64; SD 1.89)
2. Low Carbohydrate Low Fat Low Protein - (N=25; mean 19.72yrs; SD 1.59)
3. High Carbohydrate Low Fat Low Protein - (N=25; mean 21.00yrs, SD 4.66)
4. Low Carbohydrate High Fat Low Protein - (N=25; mean 20.44yrs, SD 3.61)
5. High Carbohydrate High Fat Low Protein - (N=25; mean 20.76yrs; SD 3.82)
6. Low Carbohydrate Low Fat High Protein - (N=25; mean 20.08yrs; SD 2.27)
7. High Carbohydrate Low Fat High Protein - (N=25; mean 20.96yrs; SD 4.84)
8. Low Carbohydrate High Fat High Protein - (N=25; mean 21.08yrs; SD 4.88)
9. High Carbohydrate High Fat High Protein - (N=25; mean 19.56yrs; SD 1.42)

Table 4.1: Breakfast meals consumed as the active breakfasts

Breakfast	Constituents
Low Carbohydrate Low Fat Low Protein	2 Original Ryvita Crispbreads (18g) 18g Strawberry Jam (Tesco) 1g slightly salted Butter (Tesco) Placebo Orange Drink
High Carbohydrate Low Fat Low Protein	2 Original Ryvita Crispbreads (18g) 18g Strawberry Jam (Tesco) 1g slightly salted Butter (Tesco) 35g Orange Glucose Drink
Low Carbohydrate High Fat Low Protein	2 Original Ryvita Crispbreads (18g) 20g Slightly salted Butter (Tesco) 13g Orange Glucose Drink
High Carbohydrate High Fat Low Protein	2 Original Ryvita Crispbreads (18g) 20g Slightly salted Butter (Tesco) 48g Orange Glucose Drink
Low Carbohydrate Low Fat High Protein	2 Original Ryvita Crispbreads (18g) 20g Low Fat Cottage Cheese (Tesco) 24g Turkey Breast (Bernard Matthews) 12g Orange Glucose Drink
High Carbohydrate Low Fat High Protein	2 Original Ryvita Crispbreads (18g) 20g Low Fat Cottage Cheese (Tesco) 24g Turkey Breast (Bernard Matthews) 47g Orange Glucose Drink
Low Carbohydrate High Fat High Protein	2 Original Ryvita Crispbreads (18g) 20g Slightly salted Butter (Tesco) 20g Low Fat Cottage Cheese (Tesco) 24g Turkey Breast (Bernard Matthews) 12g Orange Glucose Drink
High Carbohydrate High Fat High Protein	2 Original Ryvita Crispbreads (18g) 20g Slightly salted Butter (Tesco) 20g Low Fat Cottage Cheese (Tesco) 24g Turkey Breast (Bernard Matthews) 47g Orange Glucose Drink

Table 4.1 illustrated the make-up of the breakfast meals. All participants fasted overnight and once in the laboratory consumed their allocated breakfast meal. All participants gave written consent and the local Ethics Committee approved the procedure.

4.2.2 BREAKFAST

Table 4.2 illustrates the breakfasts consumed by the participants. Participants also had access to unlimited water throughout the experiment. Table 4.2 illustrates the mean nutritional values of the meals consumed.

Table 4.2: Mean Nutritional values for the test breakfasts and habitual breakfast consumed by the participants

Meal	Energy (Kcal)	Carbohydrate (g)	Fat (g)	Protein (g)	Fibre (g)
LCLFLP	114.34	24.41	1.09	1.67	3.32
HCLFLP	241.74	59.41	1.09	1.67	3.32
LCHFLP	248.12	24.56	16.48	1.70	3.20
HCHFLP	375.52	59.56	16.48	1.70	3.20
LCLFHP	140.40	24.22	1.02	9.81	3.20
HCLFHP	267.80	59.22	1.02	9.81	3.20
LCHFHP	279.86	24.37	16.42	9.91	3.20
HCHFHP	407.26	59.37	16.42	9.81	3.20
Habitual	347.20	56.03	11.43	11.53	4.46

4.2.3 GLUCOSE DRINKS

The active drink contained 48g Glucose powder (Unichem Ltd.) dissolved in a mixture of water, sugar free orange squash (35ml) and lemon juice (15ml) to make up a volume of 250ml in each drink. In addition to this, the active drink had 3 Hermestas Sweetener tablets added (1 tablet equivalent to 1 teaspoon of sugar), a low calorie artificial sweetener that contains aspartame and saccharin (Crooks Health Care Ltd.), to give a similar taste. The placebo drinks contained sugar free orange squash (150ml), lemon juice (10ml) and 10 tablets of artificial sweetener mixed with water to make up a volume of 250ml.

- The 12g Drink contained 63ml of the active solution and 187ml placebo.
- The 13g Drink contained 68ml of the active solution and 182ml placebo.
- The 35g Drink contained 182ml of the active solution and 68ml placebo.
- The 47g Drink contained 245ml of the active solution and 5ml placebo.

4.2.4 WORD LISTS

Three lists of 30 words, each having five letters, were chosen to be high in frequency and imagery (Quinlan, 1992). Each list had 15 abstract words and 15 concrete words (Appendix 1). The list was presented aurally, at a rate of one word per two seconds using a tape recorder. All responses were written and the time taken was noted.

4.2.5 MOOD

The six basic dimensions of mood, Total mood and hunger were assessed (section 2.2.4).

4.2.6 COGNITIVE TESTS

The Rapid Information Processing Task (RIPT) and Hick Paradigm (Reaction Times) were used to assess changes in cognitive functioning in response to the breakfasts consumed (section 2.2.5, 2.2.6).

4.2.7 ADULT EPQ-R AND DISCRIMINATION TASK

The Adult EPQ-R (Eysenck & Eysenck, 1991) and Discrimination task completed by each individual were used as cognitive tasks to increase mental fatigue. The Discrimination task required participants to circle as many 'E's as possible on each page in three minutes. The performance on these measures was not assessed.

4.2.8 BLOOD GLUCOSE

Blood glucose determinations were made with the use of an ExacTech sensor, made by Medisense Britain Limited. The sensor uses an enzymic method coupled with microelectronic measurement that has been shown to give valid measures (Matthews et al., 1987).

4.2.9 PROCEDURE

Table 4.3 illustrates the procedure. Blood glucose levels were determined on entering the laboratory. Informed consent was given and Mood questionnaires were completed. Subjects were allocated to one of seven conditions, receiving one of the test breakfasts. The subjects sat for 20 minutes to allow digestion of the food to begin. Blood glucose levels and Mood were measured for a second time. The word list was then presented aurally, and immediate recall assessed (1). Subjects then completed the Hick Paradigm and the RIPT (1) on the computers. On completion of the tests the third blood glucose reading was taken, and Mood and delayed recall assessed (1).

Participants then completed the Adult EPQ-R (Eysenck & Eysenck, 1991) and then sat for 20 minutes. Following this the second word list was then presented aurally and immediate recall (2) was assessed. Participants then completed the Hick Paradigm and the RIPT (2). On completion of the tests the fourth blood glucose reading was taken, and Mood and delayed recall (2) assessed. Participants then completed a Discrimination task, which took approximately 5 minutes and sat quietly for the remainder of the 20 minutes break.

The third test session followed this, with immediate recall (3), Hick (3), RIPT (3) and delayed recall (3). The final measure of blood glucose and Mood was taken and the participants were debriefed.

Table 4.3: Profile of the testing procedure for Chapter 4

10:00	*BGL 1 / MOOD / CONSENT*	0 minutes
10:10	BREAKFAST (Table 4.1) 20 MINUTES WAIT	10 minutes
10:30	*BGL2 / MOOD*	30 minutes
10:40	**TEST SESSION 1** IMMEDIATE RECALL HICK VIGILANCE DELAYED RECALL	40 minutes
11:00	*BGL3 / MOOD* 20 MINUTES WAIT (complete EPQ)	60 minutes
11:25	**TEST SESSION 2**	85 minutes
11:45	*BGL4 / MOOD* 20 MINUTES WAIT (complete Discrimination Task)	105 minutes
12:10	**TEST SESSION 3**	130 minutes
12:30	*BGL5 / MOOD / DEBRIEFING*	150 minutes

4.3 STATISTICAL ANALYSIS

4.3.1 EFFECT OF BREAKFAST

- Measures of Blood Glucose were analysed using a two-way ANOVA:

  Breakfast (fast/breakfast) X Time (0, 30, 60, 105, 150 minutes) (repeated measure)

  And using a four-way ANOVA:

  Carbohydrate X Fat X Protein X Time (0, 30, 60, 105, 150 minutes) (repeated measure).

- Difference scores were firstly calculated for the measures of Mood (Composed/Agreeable/Elated/Confident/Energetic/Clearheaded) and Hunger using the following calculation:

  Mood at 30, 60, 105, & 150 minutes – baseline.

  These measures were then analysed using two-way ANOVA's:

  Breakfast (fast/breakfast) X Time (30, 60, 105, 150 minutes) (repeated measure)

  And using three-way ANOVA's:

  Carbohydrate X Fat X Protein X Time (30, 60, 105, 150 minutes) (repeated measure).

- Measures of Word Recall, Total, Concrete and Abstract, and Recall Times were analysed using three-way ANOVA's:

  Breakfast (fast/active) X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure)

  And using five-way ANOVA's:

Carbohydrate X Fat X Protein X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

- Measures of Decision times on the Hick Paradigm were analysed using three-way ANOVA's:

  Breakfast (fast/active) X Session (1, 2, 3) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure)

  And using five-way ANOVA's:

  Carbohydrate X Fat X Protein X Session (1, 2, 3) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVA's:

  Breakfast (fast/active) X Session (1, 2, 3) (repeated measure)

  And four-way ANOVA's:

  Carbohydrate X Fat X Protein X Session (1, 2, 3) (repeated measure).

- Measures of Correct responses, Wrong responses and Reaction times on the Vigilance test were analysed using three-way ANOVA's:

  Breakfast (fast/active) X Minutes (1, 2, 3, 4, 5) X Session (1, 2, 3) (repeated measure)

  And five-way ANOVA's:

  Carbohydrate X Fat X Protein X Session (1, 2, 3) (repeated measure) X Minutes (1, 2, 3, 4, 5) (repeated measure).

- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

4.3.2 EFFECT OF MACRONUTRIENTS

Stepwise Linear Regressions were calculated as in section 3.3.2.

4.3.3 EFFECT OF BLOOD GLUCOSE LEVELS

Stepwise Linear Regressions, with blood glucose levels (0, 30, 60, 105, 150 minutes) and changes in blood glucose levels as the independent variables, were performed on the data set. Changes in blood glucose levels were calculated using the following equations:

- Change 1 = BG 30 – BG 0
- Change 2 = BG 60 – BG 30
- Change 3 = BG 105 – BG 60
- Change 4 = BG 150 – BG 105

The regressions were performed for each active breakfast condition. The following Dependent variables were used:

- Each difference score for Mood
- All aspects of Memory (Immediate and Delayed) for each session
- Total Decision times for each session
- Intercept and Intra-Individual Variability at each time point
- Total Correct, Wrong responses and Reaction times for each session

4.3.4 EFFECT OF HABITUAL BREAKFAST CONSUMPTION

- Measures of Total Mood and Hunger were analysed using three-way ANOVA's: Breakfast (fast/active) X Habitual breakfast consumption (Yes/No) X Difference (30, 60, 105, 150 minutes) (repeated measure).

- Measures of Word Recall were analysed using four-way ANOVA's:

  Breakfast (fast/active) X Habitual breakfast consumption (Yes/No) X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

4.4 RESULTS

For clarity only significant results involving macronutrients or condition will be reported. It may be assumed that main effects and higher order interactions that are not reported were non-significant and are documented in Appendix 2.

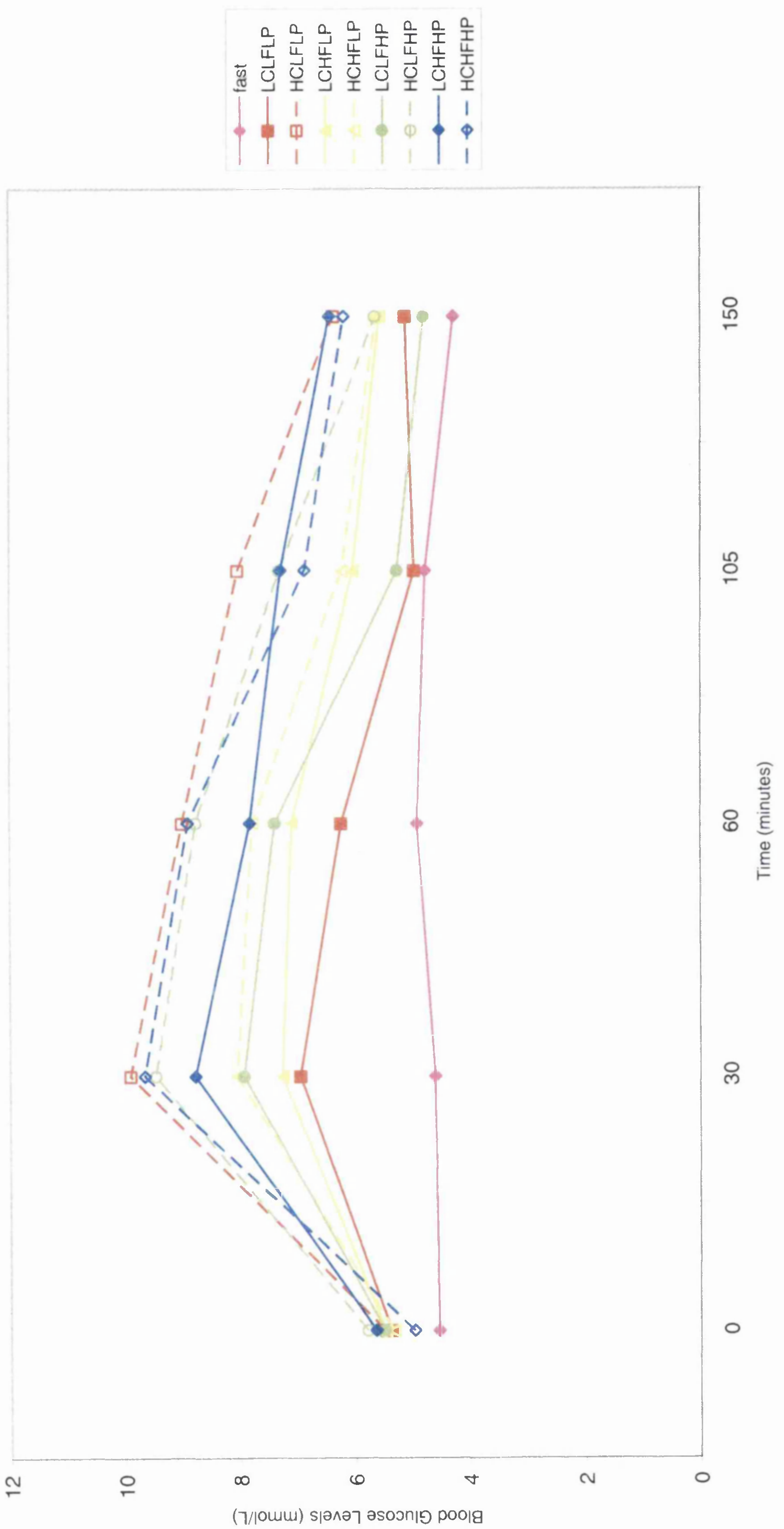
11 participants were removed from the data set due baseline blood glucose levels over 7.4mmol/L. It was assumed that either participants had eaten before arriving at the laboratory, or had a metabolic problem.

4.4.1 EFFECT OF BREAKFAST

Breakfast and Blood Glucose Levels

The interaction Breakfast X Time reached significance [$F(32,820) = 7.11$, $p<0.001$]. Figure 4.1 and SME's demonstrate significant differences between the breakfast conditions at all five time points. Table 4.4 illustrates the significant differences between the breakfast conditions.

Figure 4.1: Profile of Blood Glucose Levels over Time



Additionally there were significant differences in blood glucose levels over the morning for all groups except the fasting condition [F (4,820) = 1.00, p=n.s.].

Table 4.4: Summary table for the significant differences between the meals with respect to Blood Glucose Levels at the five time points

Time	F-ratio, Sig.	Differences
0 minutes	F (8,205) = 2.83, p<0.01	- Fast significantly differed from HCLFHP & LCHFHP
30 minutes	F (8,205) = 30.63, p<0.001	- Fast significantly differed from all meals - LCLFLP & LCHFLP significantly differed from HCLFLP; HCLFHP; LCHFHP; HCHFHP - LCLFHP & HCHFLP significantly differed from HCLFLP; HCLFHP; HCHFHP
60 minutes	F (8,205) = 11.55, p<0.001	- Fast significantly differed from all meals except LCLFLP - LCLFLP significantly differed from HCLFLP; HCLFHP; HCHFHP - LCHFLP significantly differed from HCLFLP; HCHFHP
105 minutes	F (8,205) = 11.37, p<0.001	- Fast, LCLFLP & LCLFHP significantly differed from HCLFLP; HCLFHP; LCHFHP; HCHFHP - LCHFLP & HCHFLP significantly differed from HCLFLP
150 minutes	F (8,205) = 5.35, p<0.001	- Fast & LCLFHP significantly differed from HCLFLP; LCHFHP; HCHFHP

The interaction Carbohydrate X Fat X Time reached significance [F (4,724) = 4.52, p=0.01]. All SSME's reported below were significant. HCLF, compared to LCLF, had higher blood glucose levels at 30, 60, 105 and 150 minutes; HCHF, compared to LCHF, had higher blood glucose levels at 30 and 60 minutes; HCLF, compared to HCHF, had higher blood glucose levels at 0, 30, and 105 minutes; LCHF, compared to LCLF, had higher blood glucose levels at 105 minutes. In summary, high carbohydrate meals resulted in higher blood glucose levels over time, and high fat intake slowed the release of glucose, demonstrated by lower blood glucose levels.

The interaction Fat X Protein X Time also reached significance [$F(4,724) = 3.70$, $p<0.01$]. SSME's demonstrated that LFLP, compared to HFLP, had higher blood glucose levels at 30 minutes; HFHP, compared to LFHP, had higher blood glucose levels at 30, 60, 105 and 150 minutes. Again high fat intake slowed the release of glucose into the blood, however, the presence of a large amount of protein resulted in higher blood glucose levels, and greater liberation of glucose.

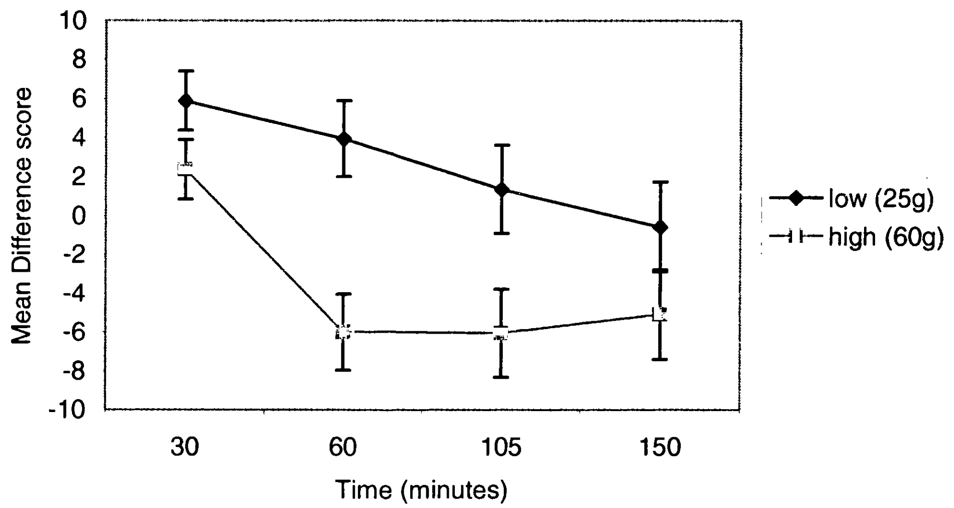
Breakfast and Mood

The three-way interaction Carbohydrate X Fat X Protein reached significance with respect to Composure [$F(1,181) = 4.21$, $p<0.05$], SSME's demonstrated that LCLFHP, compared LCHFHP, was significantly more composed over the morning [$F(1,184) = 4.30$, $p<0.05$].

The interaction Carbohydrate X Fat X Protein just missed significance with respect to Clearheadedness [$F(1,181) = 3.03$, $p=0.07$], SME's demonstrated that LCLFHP, compared to LCLFLP, was significantly more Clearheaded over the morning [$F(1,184) = 3.88$, $p=0.05$].

Furthermore, the interaction Carbohydrate X Fat X Protein just missed significance with respect to ratings of Energy [F (1,181) = 2.85, p=0.09]. SME's showed that HCLFLP, compared to LCLFLP [F (1,184) = 4.65, p<0.05], and compared to HCHFLP [F (1,184) = 3.98, p<0.04], had significantly more energy over the morning.

Figure 4.2: Profile of Agreeability ratings over Time for Carbohydrate groupings (means +/- s.e.m)



The interaction Carbohydrate X Time reached significance with respect to Agreeability [F (3,543) = 2.72, p<0.05]. Figure 4.2 and SME's demonstrate that there are significant decreases in mood over the morning, and that the decreases are more extensive in the high carbohydrate [F (3,561) = 10.62, p<0.001], compared to the low carbohydrate conditions [F (3,561) = 5.18, p<0.01]. Additionally, the low Carbohydrate breakfasts reported significantly better mood, compared to high carbohydrate, at 60 minutes [F (1,181) = 13.01, p<0.001] and 100 minutes [F (1,181) = 5.35, p<0.05].

The interaction Carbohydrate X Time also reached significance for ratings of Energy [$F (3,543) = 2.76, p<0.05$] and just missed significance with respect to Clearheadedness [$F (3,543) = 2.55, p=0.06$]. SME's demonstrated that for both measures, significant decreases in mood over time were observed for both high and low carbohydrate.

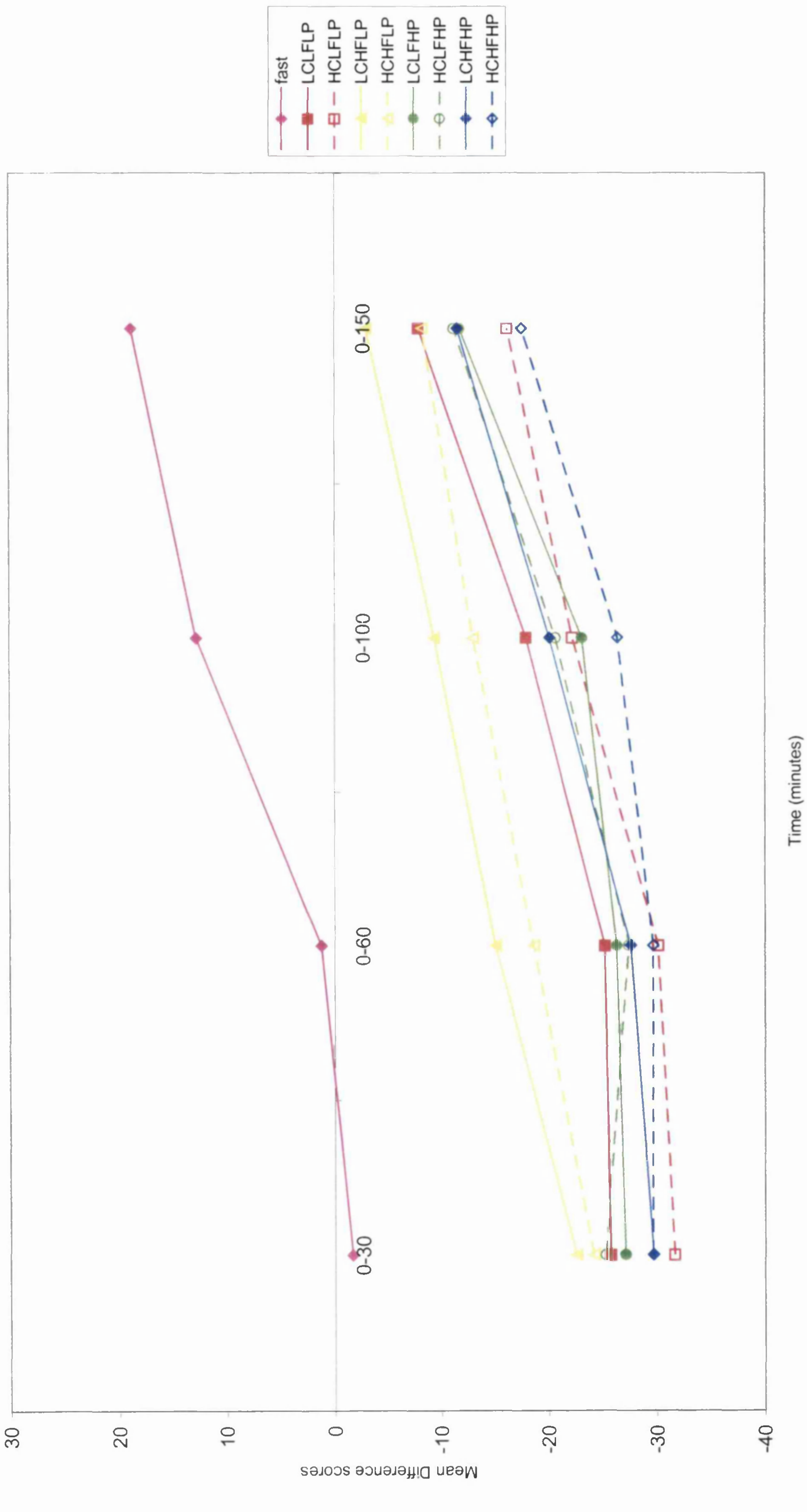
The interaction Carbohydrate X Protein reached significance with respect to ratings of Agreeability [$F (1,181) = 4.35, p<0.05$]. SME's showed that LCHP, compared to LCLP [$F (1,186) = 10.53, p<0.001$] and HCHP conditions [$F (1,186) = 10.83, p<0.001$], had significantly better mood over the morning.

When the fasting condition was included in the analysis, there was a main effect of Agreeability [$F (8,205) = 2.78, p<0.01$], with those who fasted reporting poorer mood. However, low-carbohydrate and high protein meals were still associated with enhanced Agreeability over time.

Breakfast and Hunger

The fasting condition was significantly hungrier than the 8 fed conditions over the first 30 minutes of the morning ($p<0.05$). After the first 30 minutes, the fasting condition was significantly hungrier than all fed conditions except LCHFLP ($p<0.05$). Figure 4.3 illustrates these findings.

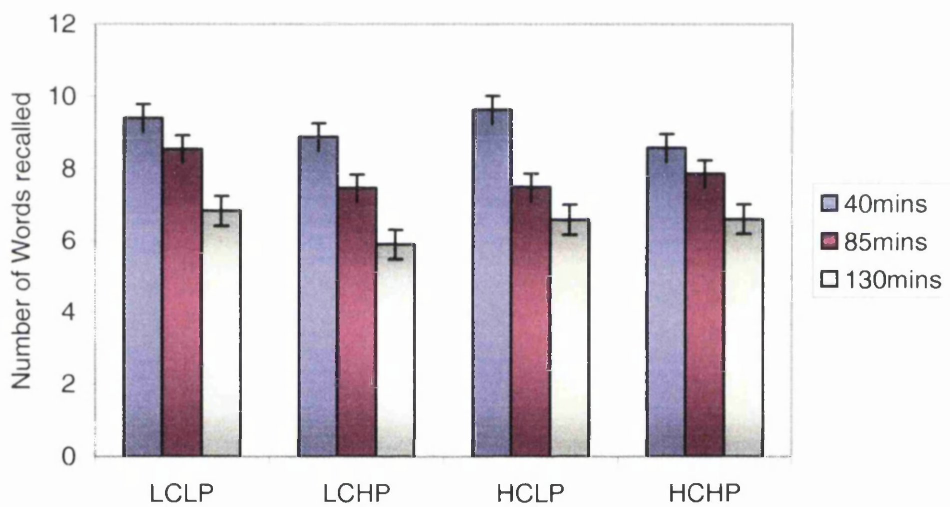
Carbohydrate [$F (1,181) = 0.98, p=0.32$], Fat [$F (1,181) = 0.81, p=0.37$] and Protein [$F (1,181) = 2.332, p=0.13$] failed to influence ratings of hunger over the morning.


fast
LCLFLP
HCLFLP
LCHFLP
HCHFLP
LCLFHP
HCLFHP
LCHFHP
HCHFHP
30
20
10
0
-10
-20
-30
-40
Mean Difference scores
0-30
0-60
0-100
0-150
Time (minutes)

Breakfast and Memory

The interaction Carbohydrate X Protein X Session reached significance [F (2,362) = 3.88, p<0.05]. The number of words recalled significantly decreased in each condition over time. In addition the LCLP conditions recalled significantly more words than the LCHP at 85 minutes, irrespective of fat [F (1,186) = 4.00, p<0.05] (Figure 4.4).

Figure 4.4: The effect of Carbohydrate and Protein over Time on Word List recall (means +/- s.e.m)



The interaction Carbohydrate X Protein X Session again reached significance when concrete words were analysed [F (2,362) = 3.66, p<0.05]. Again the number of words recalled significantly decreased over time. In addition the HCLP conditions recalled significantly more words than the HCHP conditions in 40 minutes, irrespective of fat [F (1,186) = 5.48, p<0.05].

When abstract words were analysed, the interaction Carbohydrate X Fat reached significance [F (1,181) = 4.04, p<0.05]. SME's revealed that the LCLF conditions recalled significantly more abstract words than the LCHF [F (1,186) = 9.98, p<0.01] and HCLF conditions irrespective of protein [F (1,186) = 4.41, p<0.05].

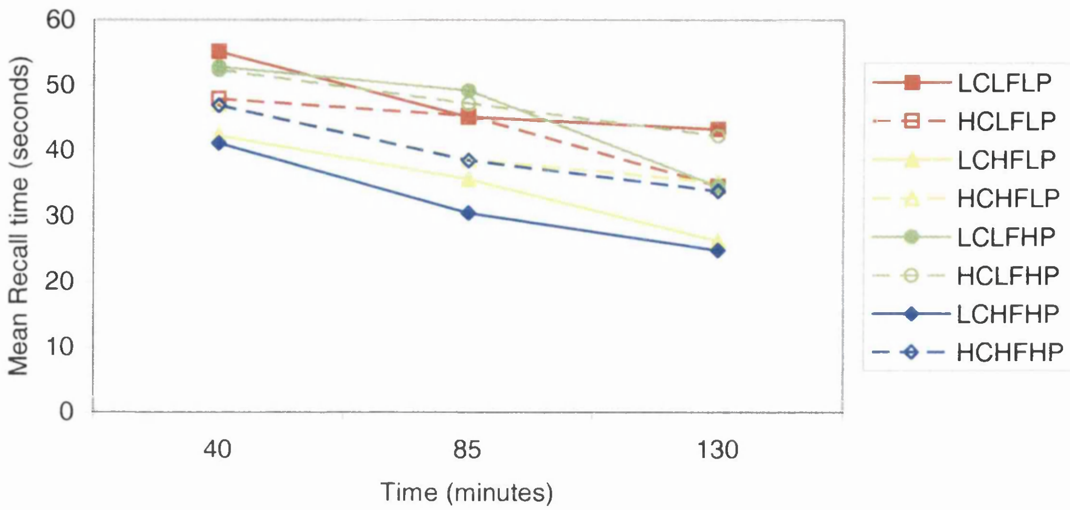
When the time taken to recall the words was analysed, the four-way interaction Carbohydrate X Fat X Protein X Session reached significance [F (2,362) = 6.49, p<0.01]. Figure 4.5 and SSME's demonstrate the following differences:

(1) CARBOHYDRATE – At 130 minutes LCLFLP, compared to HCLFLP consumers, took significantly longer to recall the word list. However, LCLFHP, LCHFLP and LCHFHP consumers took significantly less time to recall the list at 130 minutes compared to their respective HC conditions.

(2) FAT – LCLFLP and LCLFHP consumers, compared to LCHFLP and LCHFHP consumers, took significantly longer to recall the word lists at each session. Additionally at 85 and 130 minutes, HCLFHP consumers took significantly longer than HCHFHP consumers.

(3) PROTEIN – those who consumed the LCLFLP, compared to LCLFHP, took significantly longer to recall word list at 130 minutes.

Figure 4.5: Profile of the time taken to recall the word lists for Carbohydrate, Fat and Protein



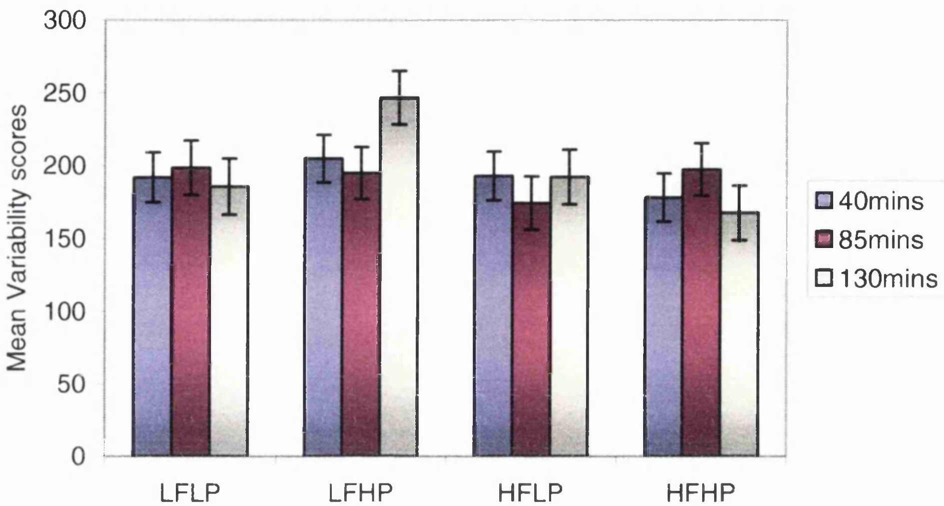
Breakfast and the Hick Paradigm

17 participants were removed from the data due to missing results and negative slope values.

Neither Carbohydrate [F (1,165) = 0.81, p=n.s.], Fat [F (1,165) = 0.08, p=n.s.] nor Protein [F (1,165) = 0.42, p=n.s.] influenced Decision Times on the Hick Paradigm. Additionally neither Intercept nor Slope values were influenced.

The interaction Carbohydrate X Fat X Protein X Session reached significance with respect to Movement times [F (2,330) = 3.17, $p<0.05$], however, this finding appeared to be due to chance.

Figure 4.6: Profile of Intra-Individual Variability over Time for Fat and Protein conditions (means +/- s.e.m)



The interaction Fat X Protein X Session reached significance with respect to Intra-Individual Variability [F (2,330) = 4.43, p<0.05]. Figure 4.6 and SSME's show that at 130 minutes, those who consumed LFHP meals demonstrated significantly greater variability in their decision times than either LFLP [F (1,170) = 4.98, p<0.05] or HFHP meals [F (1,170) = 8.71, p<0.01].

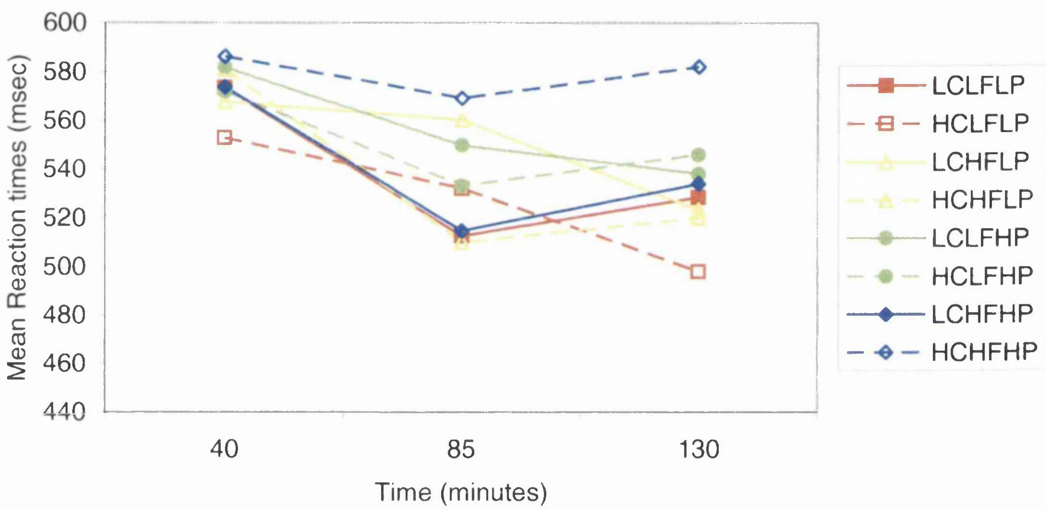
Breakfast and the RIPT

2 participants were removed form the data set due to incomplete data or incorrect performance on the task (>20 wrong responses per minute).

Carbohydrate [F (1,179) = 0.25, p=n.s.], Fat [F (1,179) = 1.46, p=n.s.] and Protein [F (1,179) = 0.22, p=n.s.] all failed to influence correct responses on the RIPT.

When wrong responses were analysed, the four-way interaction Carbohydrate X Fat X Protein X Session reached significance [F (2,358) = 3.43, p<0.05]. SSME's demonstrated significant decreases in wrong responses over the three test sessions for the LCHFHP [F (2,358) = 3.23, p<0.05] and HCHFLP conditions [F (2,358) = 12.72 p<0.001].

Figure 4.7: The effect of Carbohydrate, Fat and Protein on total Reaction times on the RIPT over time



The four-way interaction Carbohydrate X Fat X Protein X Session just missed significance with respect to response times [F (2,358) = 2.85, p=0.06]. Figure 4.7 and SSME's show that there are significant decreases in reactions times over the three sessions for the LCHFHP [F (2,358) = 3.04, p<0.05], HCHFLP [F (2,358) = 4.96, p<0.01] and LCLFLP conditions [F (2,358) = 3.20, p<0.05]. In addition, LCHFHP [F (1,182) = 4.07, p<0.05] and HCHFLP [F (1,182) = 4.78, p<0.05] were significantly quicker than the HCHFHP at 85 minutes. HCHFLP was also quicker than HCHFHP at 130 minutes [F (1,182) = 5.05, p<0.05].

In summary, quicker reaction times were associated with less wrong responses over time for LCHFHP and HCHFLP.

4.4.2 EFFECT OF MACRONUTRIENTS

Stepwise Linear Regressions demonstrated that breakfasts high in protein were associated with increased Agreeability over the first 105 minutes, and increased Elation and Total Mood at 105 minutes. Participants who consumed low carbohydrate breakfasts were significantly more Agreeable at 60 minutes. High carbohydrate was associated with increased reported Energy at 60 minutes.

Breakasts low in calories were significantly associated with increased reports of hunger over the first 30 minutes. Over the rest of the morning low levels of Carbohydrate and Protein predicted increased hunger.

Breakfasts low in protein were associated with increased delayed word recall at 40 minutes. High fat breakfasts were associated with less time being taken to recall all the word lists.

Carbohydrate, Fat and Protein failed to predict performance on any aspect of the Hick Paradigm.

Low Protein breakfasts were significantly associated with quicker reaction times at 130 minutes.

4.4.3 EFFECT OF BLOOD GLUCOSE LEVELS AND CHANGE

Stepwise linear regressions were performed on the data, with the blood glucose levels, and the four periods between as independent variables, and measures of Mood, Hunger, and measure of cognition as dependent variables. Patterns observed within the breakfast conditions are reported.

LCLFLP

- High blood glucose levels over the first 30 minutes predicted increased Agreeability and Energy over the morning, and decreased ratings of hunger. Rapidly falling blood glucose levels 100-150 minutes were associated with increased Composure over the first hour.
- Low and slow rising blood glucose levels over the first 30 minutes predicted increased word recall and time taken to recall the word lists.
- No consistent patterns emerged for the Hick paradigm or the RIPT.

HCLFLP

- Rapidly falling blood glucose levels between 30 and 60 minutes were associated with increase Clearheadedness over the first 30 minutes and between 60 and 100 minutes.
- No consistent patterns emerged with respect to Memory, the Hick Paradigm or the RIPT.

LCHFLP

- High blood glucose levels at 30 minutes predicted better Composure over the morning and Total mood over the last 90 minutes. Rapidly falling blood glucose levels 105-150 minutes were associated with increased Elation and increased Hunger over the last 90 minutes.
- Rapidly falling blood glucose levels between 30 and 60 minutes predicted increased word recall and time taken to recall the word lists at 85 minutes.
- Slow falling blood glucose levels between 60 and 105 minutes were associated with less variability at 85 minutes.
- High blood glucose levels at 105 minutes predicted increased wrong responses on the RIPT over the morning.

HCHFLP

- High blood glucose levels at 30 minutes predicted increased Elation between 30 and 100 minutes. Rising blood glucose levels between 30 and 60 minutes were associated with increased Total mood over the first 30 minutes.
- Low blood glucose levels at 30 minutes and slowly falling levels between 60 and 100 minutes predicted increased word recall and time taken to recall the word lists over the morning.
- Rapidly falling blood glucose levels between 30 and 60 minutes, and high levels at 100 minutes were associated with quicker Decision times and steadier performance at 40 minutes.

- Rapidly rising and high blood glucose levels over the first 30 minutes predicted increased correct responses at 85 and 130 minutes with respect to the RIPT.

LCLFHP

- Slow falling blood glucose levels between 30 and 60 minutes predicted better Total mood over the first 30 minutes. High blood glucose levels at 150 minutes predicted increased Energy over the last 90 minutes. High blood glucose levels at baseline and at 150 minutes were associated with increased hunger over the first hour.
- Rapidly falling blood glucose levels between 60 and 100 minutes predicted increased word recall and time taken to recall the word lists at 40 minutes.
- High blood glucose levels at 30 minutes predict flatter slopes at 40 and 130 minutes, and quicker decision times and less intra-individual variability at 130 minutes with respect to the Hick Paradigm.
- High blood glucose levels at 30 minute predicted increased correct responses at 85 and 130 minutes on the RIPT. However rapidly rising blood glucose levels between 0 and 30 minutes predicted increased wrong responses at 130 minutes.

HCLFHP

- Rapidly falling blood glucose levels between 30 and 60 minutes predicted increased Elation over the first 100 minutes and increased Confidence over the last 90 minutes. Slow falling blood glucose levels between 100 and 150 minutes predicted increased Agreeability and Elation over the last 90 minutes, and Total mood between 60 and 100 minutes. Low blood glucose levels at baseline predicted increased reports of hunger over the morning.

- No consistent patterns emerge with respect to Memory, however, falling blood glucose levels between 60 and 100 minutes predicted increased delayed word recall at 85 and 130 minutes.
- Rapidly falling and low blood glucose levels between 100-and 150 minutes predicted enhanced performance on the Hick at 130 minutes.
- Slow falling blood glucose levels between 30 and 60 minute predicted increased wrong responses on the RIPT at 40 and 130 minutes, with high blood glucose levels at 60 minutes being associated with increased wrong responses at 85 minutes.

LCHFHP

- Slow rising blood glucose levels over the first 30 minutes predicted increased Composure over the morning. Low blood glucose levels at 100 minutes were associated with increased Confidence after the first 30 minutes.
- Slow rising blood glucose levels over the first 30 minutes was associated with more time taken to recall the word lists at 40 and 85 minutes.
- High blood glucose levels at 30 were associated with quicker decision times and lower intercept values at 40 minutes.
- No patterns emerged with respect to RIPT.

HCHFHP

- Low baseline blood glucose levels predicted increase Elation, Energy, Clearheadedness and Total mood between 60 and 100 minutes.
- Falling blood glucose levels between 30 and 60 minutes predicted increased word recall at 85 and 130 minutes.
- Falling blood glucose levels between 30 and 60 minutes predicted increased correct responses on the RIPT at 40 minutes, and less Intra-Individual Variability at 130 minutes on the Hick.

4.4.4 EFFECT OF HABITUAL BREAKFAST CONSUMPTION

Table 4.2 illustrates the nutrient values for the test breakfasts and for the average habitual breakfast as specified by the participants.

The interaction Breakfast X Habitual breakfast consumption X Recall reached significance with respect to Word list recall [$F(8,196) = 2.11$, $p<0.05$], however, SME's performed on the data appear to reflect chance findings.

The interaction Habitual breakfast consumption X Time reached significance with respect to Total mood [$F(3,588) = 3.03$, $p<0.05$]. However SME's found this reflected significant changes in mood over the morning; no significant differences were observed between habitual and non-habitual breakfast consumers at any time point.

The interaction Breakfast X Habitual breakfast consumption X Time was significant for hunger [$F (24, 588) = 1.55$, $p<0.05$], however, further analysis demonstrated that this was a consequence of using difference scores; when actual mood scores were analysed there was no significant result.

4.5 SUMMARY

Breakfast and Blood Glucose Levels

- High carbohydrate (60g) meals resulted in significantly higher blood glucose levels over time, compared to low carbohydrate meals (25g). Furthermore, high fat intake (16g), compared to low fat (1g), resulted in lower blood glucose levels irrespective of the amount of carbohydrate consumed.

Breakfast, Mood and Hunger

- Low carbohydrate/high protein breakfasts were associated with enhanced mood over the morning.
- High carbohydrate breakfasts resulted in poorer mood towards the end of the morning.
- HCLFLP resulted in more Energy over the morning than either LCLFLP or HCHFLP breakfasts.

- High quantities of carbohydrate and protein were associated with decreased hunger over the morning. Participants who fasted or consumed LCHFLP reported the greatest hunger over the morning.

Breakfast and Memory

- Low protein (2g), compared to high protein (10g) breakfasts, were associated with more words recalled.
- LCLF was associated with increased abstract word recall compared to either LCHF or HCLF.
- LCLFLP, compared to HCLFLP, took significantly longer to recall the word list at 130 minutes, however, the high carbohydrate (60g) conditions of the remaining breakfasts took significantly longer than the low carbohydrate breakfasts to recall the same list.
- Low fat intake (1g) was associated with an increase in the time taken to recall the word lists over the morning compared to high fat intake (16g).
- LCLFLP, compared to LCLFHP, took significantly less time to recall the word list at 130 minutes.

Breakfast and other Cognitive tests

- LFHP conditions were significantly more variable in their responses on the Hick Paradigm than the LFLP and HFHP conditions.

- Quicker reaction times and fewer wrong responses were recorded following consumption of LCHFHP and HCHFLP breakfasts, this was associated with enhanced performance on the RIPT.

Breakfast and Blood Glucose Levels

- In the low carbohydrate (25g) meals, high blood glucose levels between 30-60, and falling levels 60-150 minutes, were associated with enhanced mood over the morning. This pattern was not observed for LCHFHP, that demonstrated slow rising blood glucose levels 0-30 minutes and low levels at 105 minutes were associated with enhanced Composure and Clearheadedness.
- With the high carbohydrate (60g) meals, falling blood glucose levels from 30-60 minutes were associated with enhanced mood over the morning. However, this pattern was not observed for HCHFLP, where rising blood glucose levels from 30-60 minutes were associated with enhanced mood. Furthermore, in those who consumed HCLFLP and HCLFHP breakfast, slowly falling blood glucose levels from 105-150 minutes were associated with enhanced mood from 0-100 minutes.
- Low and falling blood glucose levels following the consumption of breakfast were predictive of enhanced memory throughout the morning for all conditions.
- No patterns were observed with respect to carbohydrate, fat and protein for the Hick Paradigm or the RIPT, only patterns within meal conditions.

4.6 DISCUSSION

The present study aimed to examine the effects of meals differing in carbohydrate, fat and protein content consumed as a breakfast meal.

Low carbohydrate (25g) high protein (10g) breakfasts significantly enhanced mood over the morning. High carbohydrate (60g) breakfasts were associated with poorer mood later on in the morning. Benton et al., (2001) has previously demonstrated that high carbohydrate intake (51g) was associated with increased mood in the short-term, but then significantly declined over a period of two hours. High increases in blood glucose levels following a high carbohydrate load elicit the release of high levels of insulin to speed the glucose away to the required areas. The poorer mood associated with the high carbohydrate intake may reflect the quicker fall in blood glucose levels following the larger insulin release.

It has been previously claimed that high carbohydrate/low protein meals are consumed for their positive psychopharmacological effects (Wurtman and Wurtman, 1995). The finding that a high protein meal enhanced reported mood contradicts the Wurtman hypothesis (1995). One could suggest that the protein consumed may help to maintain more stable blood glucose levels, after the glucose from the carbohydrate is utilised. Furthermore, Hunger was significantly reduced following consumption of a high-carbohydrate (60g)/high protein (10g) meals. One could also suggest that the consumption of a high protein meal may influence mood through decreased hunger over the morning.

Enhanced memory performance over the morning was associated with low fat intake (1g) in general, but other combinations of carbohydrate, fat and protein had observable effects. A more important factor with respect to memory was that low blood glucose levels over the first 30 minutes, and falling blood glucose levels between 30-100 minutes were associated with enhanced memory performance. Once again this can be said to reflect the ability to effectively utilise the carbohydrate load ingested, suggesting those with better glucose tolerance perform better on memory tests.

A major criticism of many of the previous studies examining this area was that often the meals given were unrealistic in an everyday setting. Many of the test meals were offered as a milkshake (Kaplan et al., 2001; Cunliffe et al., 1997), or spoonable creams (Fischer et al., 2002; 2001), however this study presented real food. It could be said that the meals resembled a continental style breakfast.

In addition to real food being used, the design of the study allowed the macronutrient content to be varied in a controlled way, whilst giving a range of energy intakes. The energy intakes of the meals offered ranged from 114.34 to 407.26 Kcal. The high carbohydrate (60g) high fat (16g) high protein (10g) breakfast was the closest meal in nutritional content to what participants reported as a habitual breakfast. It was found that the larger meals, even though eliciting greater satiety, were not beneficial with respect to mood or cognitive function. In fact, it was demonstrated that the small meals, for example low carbohydrate and low fat meals, that failed to produce great changes in blood glucose levels were more beneficial.

One can suggest, therefore, that consumption of the smaller meals, may be beneficial for mood and enhanced cognitive functioning, and may contribute to an overall 'better' breakfast. These ideas will be discussed further in Chapter 10.

The relative effects of carbohydrate, fat and protein will be discussed in greater detail (Chapters 8 and 9) following the meta-analysis of all breakfast studies (Chapter 7).

4.6.1 CONCLUSION

The present findings suggest again that the ability to effectively utilise the carbohydrate load ingested is an important factor influencing mood and cognitive functioning. High carbohydrate was found to be detrimental especially with respect to Mood. In addition it was implied that meal size may also be an important factor. It was suggested that low carbohydrate and low fat meals may be beneficial. These concepts will be investigated in more depth in subsequent chapters.

The tables below do not contain the ANOVA results due to the extent of the Main effects and Interactions. Please refer to Appendix 2.

Table 4.5: Summary table with respect to measures of Mood

MOOD	MEAL	30mins – base	60mins – base	90mins – base	120mins – base
Composure	Fast	8.120 (3.859)	4.480 (4.956)	-1.640 (5.265)	0.320 (5.055)
	LCLFLP	8.217 (4.024)	2.435 (5.167)	8.130 (5.489)	9.652 (5.271)
	HCLCLP	6.348 (4.024)	2.957 (5.167)	3.826 (5.489)	3.304 (5.271)
	LCHFLP	12.958 (3.939)	7.417 (5.058)	11.042 (5.373)	14.500 (5.160)
	HCHFLP	90.783 (4.024)	-5.130 (5.167)	-3.043 (5.489)	0.826 (5.271)
	LCLFHP	16.840 (3.859)	12.240 (4.956)	14.230 (5.265)	11.640 (5.055)
	HCLFHP	7.870 (4.024)	1.435 (5.167)	5.652 (5.489)	4.435 (5.271)
	LCHFHP	7.391 (4.024)	2.913 (5.167)	-1.696 (5.489)	-2.565 (5.271)
	HCHFHP	14.800 (3.859)	10.040 (4.956)	6.080 (5.265)	6.440 (5.055)
Agreeability	Fast	-3.080 (3.160)	-7.080 (3.879)	-12.280 (4.386)	-8.160 (4.434)
	LCLFLP	0.696 (3.294)	0.130 (4.044)	-6.913 (4.573)	-4.435 (4.623)
	HCLCLP	-1.087 (3.294)	-7.130 (4.044)	-7.304 (4.573)	-7.826 (4.623)
	LCHFLP	-1.542 (3.225)	-4.083 (3.959)	-3.833 (4.477)	-3.583 (4.526)
	HCHFLP	5.261 (3.294)	-5.609 (4.044)	-6.217 (4.573)	-3.739 (4.623)
	LCLFHP	10.480 (3.160)	7.560 (3.879)	6.520 (4.386)	3.280 (4.434)
	HCLFHP	2.130 (3.294)	-8.609 (4.044)	-5.478 (4.573)	-5.696 (4.623)
	LCHFHP	13.609 (3.294)	12.217 (4.044)	9.739 (4.573)	2.522 (4.623)
	HCHFHP	3.240 (3.160)-	-2.640 (3.879)	-5.200 (4.386)	-3.040 (4.434)

Elation	Fast	3.840 (2.885)	0.800 (3.322)	-3.120 (3.197)	0.440 (3.398)
	LCLFLP	2.000 (3.008)	-0.478 (3.463)	-5.043 (3.334)	-5.174 (3.542)
	HCLCLP	6.4778 (3.008)	6.000 (3.463)	2.565 (3.334)	3.957 (3.542)
	LCHFLP	-2.083 (2.945)	-2.708 (3.390)	-4.833 (3.263)	-5.625 (3.468)
	HCHFLP	4.826 (3.008)	-0.739 (3.463)	-1.304 (3.334)	-2.304 (3.542)
	LCLFHP	0.480 (2.885)	1.960 (3.322)	-0.560 (3.197)	-3.640 (3.398)
	HCLFHP	5.435 (3.008)	5.522 (3.463)	4.478 (3.334)	1.957 (3.542)
	LCHFHP	9.217 (3.008)	4.609 (3.463)	3.957 (3.334)	5.913 (3.542)
	HCHFHP	4.960 (2.885)	-0.080 (3.322)	0.440 (3.197)	2.640 (3.398)
Confidence	Fast	13.120 (3.462)	8.080 (4.373)	6.240 (4.554)	11.800 (4.576)
	LCLFLP	6.174 (3.609)	9.652 (4.559)	10.739 (4.748)	13.870 (4.771)
	HCLCLP	6.783 (3.609)	6.522 (4.559)	4.609 (4.748)	6.348 (4.771)
	LCHFLP	12.417 3.533()	3.667 (4.463)	5.625 (4.648)	11.333 (4.670)
	HCHFLP	12.130 (3.609)	6.435 (4.559)	8.261 (4.748)	9.478 (4.771)
	LCLFHP	12.840 (3.462)	10.800 (4.373)	12.880 (4.554)	13.200 (4.576)
	HCLFHP	7.826 (3.609)	4.913 (4.559)	7.565 (4.748)	9.000 (4. 771)
	LCHFHP	3.391 (3.609)	0.783 (4.559)	2.348 (4.748)	5.174 (4.771)
	HCHFHP	7.400 (3.462)	8.720 (4.373)	8.240 (4.554)	4.440 (4.576)

Energy	Fast	6.640 (3.501)	2.960 (4.384)	-6.400 (4.216)	-7.000 (4.609)
	LCLFLP	4.391 (3.650)	0.435 (4.571)	2.391 (4.395)	-1.087 (4.805)
	HCLCLP	18.304 (3.650)	20.565 (4.571)	8.435 (4.395)	3.783 (4.805)
	LCHFLP	10.958 (3.575)	3.750 (4.475)	-1.875 (4.303)	-7.708 (4.704)
	HCHFLP	12.826 (3.650)	2.957 (4.571)	-0.391 (4.395)	-5.957 (4.805)
	LCLFHP	16.800 (3.501)	13.560 (4.384)	7.960 (4.216)	5.760 (4.609)
	HCLFHP	11.348 (3.650)	12.957 (4.571)	5.000 (4.395)	-6.957 (4.805)
	LCHFHP	11.261 (3.501)	5.565 (4.384)	0.130 (4.216)	2.217 (4.609)
	HCHFHP	12.480 (3.501)	10.200 (4.384)	3.160 (4.216)	0.320 (4.609)
Clearheaded	Fast	5.320 (3.613)	-1.640 (4.067)	-5.960 (4.702)	-4.720 (4.533)
	LCLFLP	-1.304 (3.766)	-2.826 (4.241)	-6.696 (4.902)	-3.913 (4.727)
	HCLCLP	6.913 (3.766)	4.870 (4.241)	-4.304 (4.902)	-3.696 (4.727)
	LCHFLP	8.667 (3.687)	-0.375 (4.151)	2.125 (4.799)	0.917 (4.627)
	HCHFLP	5.348 (3.766)	-1.739 (4.241)	-4.391 (4.902)	-4.913 (4.727)
	LCLFHP	11.120 (3.613)	3.040 (4.067)	7.320 (4.702)	4.200 (4.533)
	HCLFHP	4.870 (3.766)	-3.565 (4.241)	-4.870 (4.902)	-9.609 (4.727)
	LCHFHP	6.348 (3.766)	-1.217 (4.241)	-1.217 (4.902)	-0.826 (4.727)
	HCHFHP	6.160 (3.613)	2.320 (4.067)	0.640 (4.702)	-4.200 (4.533)

Total Mood	Fast	33.960 (11.833)	7.600 (15.986)	-23.160 (17.366)	-7.320 (17.563)
	LCLFLP	20.174 (12.337)	9.348 (16.667)	2.609 (18.105)	8.913 (18.311)
	HCLCLP	43.739 (12.337)	33.783 (16.667)	7.826 (18.105)	5.870 (18.311)
	LCHFLP	41.375 (12.077)	7.667 (16.316)	8.250 (17.724)	9.833 (17.925)
	HCHFLP	50.174 (12.337)	-3.826 (16.667)	-7.087 (18.105)	-6.609 (18.311)
	LCLFHP	68.920 (11.833)	49.160 (15.986)	48.440 (17.366)	34.440 (17.563)
	HCLFHP	39.478 (12.337)	12.652 (16.667)	12.348 (18.105)	-6.870 (18.311)
	LCHFHP	51.217 (12.337)	24.870 (16.667)	13.261 (18.105)	12.435 (18.311)
	HCHFHP	49.040 (11.833)	28.560 (15.986)	13.360 (17.366)	6.600 (17.563)
Hunger	Fast	-1.640 (4.186)	1.240 (4.407)	12.840 (5.187)	18.880 (5.305)
	LCLFLP	-25.739 (4.364)	-25.217 (4.595)	-17.913 (5.408)	-7.826 (5.531)
	HCLCLP	-31.652 (4.364)	-30.130 (4.595)	-22.217 (5.408)	-16.130 (5.531)
	LCHFLP	-22.625 (4.273)	-15.042 (4.498)	-9.333 (5.294)	-2.875 (5.414)
	HCHFLP	-24.217 (4.364)	-18.609 (4.595)	-12.957 (5.408)	-8.174 (5.531)
	LCLFHP	-27.120 (4.186)	-26.320 (4.407)	-23.120 (5.187)	-11.720 (5.305)
	HCLFHP	-25.304 (4.364)	-27.435 (4.595)	-20.652 (5.408)	-11.174 (5.531)
	LCHFHP	-29.696 (4.364)	-27.609 (4.595)	-20.087 (5.408)	-11.478 (5.531)
	HCHFHP	-29.640 (4.186)	-29.680 (4.407)	-26.400 (5.187)	-17.520 (5.305)

Table 4.6: Summary table with respect to the total number of words recalled on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3
Fast	10.880 (0.569)	7.800 (0.555)	10.160 (0.556)	5.000 (0.555)	10.050 (0.618)	3.880 (0.636)
LCLFLP	11.348 (0.594)	8.478 (0.579)	11.478 (0.579)	7.217 (0.578)	10.435 (0.644)	5.565 (0.663)
HCLFLP	11.565 (0.594)	8.522 (0.579)	10.000 (0.579)	5.435 (0.578)	8.652 (0.644)	4.261 (0.663)
LCHFLP	10.042 (0.581)	7.750 (0.567)	9.792 (0.567)	5.708 (0.566)	8.292 (0.631)	3.042 (0.649)
HCHFLP	10.522 (0.594)	7.913 (0.579)	9.174 (0.579)	5.348 (0.578)	8.696 (0.644)	4.739 (0.663)
LCLFHP	10.560 (0.569)	7.880 (0.555)	9.800 (0.556)	5.440 (0.555)	8.840 (0.618)	3.880 (0.636)
HCLFHP	9.870 (0.594)	6.565 (0.579)	9.870 (0.579)	5.391 (0.578)	8.913 (0.644)	3.870 (0.663)
LCHFHP	10.130 (0.594)	6.957 (0.579)	9.217 (0.579)	5.391 (0.578)	7.739 (0.644)	3.087 (0.663)
HCHFHP	10.240 (0.569)	7.640 (0.555)	10.360 (0.556)	5.840 (0.555)	9.200 (0.618)	4.400 (0.636)

Table 4.7: Summary table with respect to the number of Concrete words recalled on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3
Fast	6.800 (0.382)	5.160 (0.392)	6.120 (0.381)	3.520 (0.388)	5.600 (0.409)	2.520 (0.392)
LCLFLP	6.435 (0.399)	5.478 (0.408)	6.565 (0.397)	4.565 (0.404)	5.304 (0.426)	3.087 (0.409)
HCLFLP	7.130 (0.399)	5.870 (0.408)	5.739 (0.397)	3.652 (0.404)	4.739 (0.426)	2.435 (0.409)
LCHFLP	5.917 (0.390)	5.000 (0.400)	6.000 (0.389)	3.917 (0.396)	4.625 (0.417)	1.958 (0.400)
HCHFLP	6.652 (0.399)	5.609 (0.408)	5.565 (0.397)	3.565 (0.404)	4.826 (0.426)	2.739 (0.409)
LCLFHP	5.920 (0.382)	4.960 (0.392)	5.720 (0.381)	3.440 (0.388)	4.640 (0.409)	2.120 (0.392)
HCLFHP	6.000 (0.399)	4.478 (0.408)	5.957 (0.397)	3.522 (0.404)	4.304 (0.426)	2.087 (0.409)
LCHFHP	6.000 (0.399)	4.609 (0.408)	5.696 (0.397)	3.696 (0.404)	4.000 (0.426)	1.652 (0.409)
HCHFHP	6.240 (0.399)	5.120 (0.408)	6.200 (0.397)	3.920 (0.404)	5.080 (0.426)	2.720 (0.409)

Table 4.8: Summary table with respect to the number of Abstract words recalled on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3
Fast	4.080 (0.346)	2.640 (0.301)	4.040 (0.304)	1.520 (0.263)	4.480 (0.350)	1.320 (0.328)
LCLFLP	4.913 (0.361)	3.000 (0.314)	4.913 (0.317)	2.652 (0.275)	5.130 (0.365)	2.478 (0.342)
HCLFLP	4.348 (0.361)	2.652 (0.314)	4.261 (0.317)	1.783 (0.275)	3.913 (0.365)	1.826 (0.342)
LCHFLP	4.125 (0.354)	2.708 (0.307)	3.792 (0.310)	1.792 (0.269)	3.667 (0.358)	1.083 (0.335)
HCHFLP	3.870 (0.361)	2.304 (0.314)	3.609 (0.317)	1.783 (0.275)	3.870 (0.365)	2.000 (0.342)
LCLFHP	4.464 (0.346)	2.920 (0.301)	4.120 (0.304)	1.960 (0.263)	4.200 (0.350)	1.760 (0.328)
HCLFHP	3.870 (0.361)	2.087 (0.314)	3.913 (0.317)	1.826 (0.275)	4.609 (0.365)	1.783 (0.342)
LCHFHP	4.130 (0.361)	2.348 (0.314)	3.522 (0.317)	1.696 (0.275)	3.739 (0.365)	1.435 (0.342)
HCHFHP	4.000 (0.346)	2.520 (0.301)	4.160 (0.304)	1.960 (0.263)	4.120 (0.350)	1.720 (0.328)

Table 4.9: Summary table with respect to the time taken to recall the word lists on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3
Fast	54.360 (3.708)	34.120 (2.587)	43.760 (3.166)	30.960 (3.165)	43.800 (3.218)	27.280 (2.432)
LCLFLP	62.000 (3.866)	48.304 (2.697)	52.174 (3.300)	38.174 (3.300)	53.913 (3.355)	32.652 (2.535)
HCLFLP	58.348 (3.866)	37.565 (2.697)	54.348 (3.300)	37.391 (3.300)	42.913 (3.355)	26.391 (2.535)
LCHFLP	51.458 (3.785)	33.250 (2.640)	41.875 (3.231)	29.500 (3.231)	34.208 (3.284)	18.375 (2.482)
HCHFLP	55.478 (3.866)	38.565 (2.697)	45.565 (3.300)	31.870 (3.300)	43.261 (3.355)	27.217 (2.535)
LCLFHP	63.360 (3.708)	42.240 (2.587)	55.840 (3.166)	42.520 (3.165)	42.040 (3.218)	27.160 (2.432)
HCLFHP	61.783 (3.866)	42.913 (2.697)	56.130 (3.300)	38.348 (3.300)	53.087 (3.355)	31.478 (2.535)
LCHFHP	53.826 (3.866)	28.478 (2.697)	36.652 (3.300)	24.391 (3.300)	29.565 (3.355)	20.174 (2.535)
HCHFHP	54.360 (3.708)	34.120 (2.587)	43.760 (3.166)	30.960 (3.165)	43.800 (3.218)	27.280 (2.432)

Table 4.10: Summary table for Decision Times on the Hick Paradigm (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8
Sess 1	Fast	313.375 (7.267)	337.854 (8.198)	362.646 (9.756)	416.792 (15.354)
	LCLFLP	305.614 (7.950)	329.182 (8.563)	357.023 (10.189)	419.523 (16.036)
	HCLCLP	292.000 (8.168)	316.816 (9.214)	342.000 (10.964)	380.079 (17.256)
	LCHFLP	315.762 (7.769)	329.357 (8.765)	254.667 (10.429)	396.310 (16.414)
	HCHFLP	298.841 (7.590)	323.295 (8.563)	352.341 (10.189)	394.091 (16.036)
	LCLFHP	302.580 (7.120)	329.620 (8.033)	354.820 (9.558)	398.040 (15.043)
	HCLFHP	298.325 (7.961)	328.150 (8.981)	358.850 (10.687)	434.850 (16.819)
	LCHFHP	296.405 (7.769)	327.500 (8.765)	357.024 (10.429)	383.857 (16.414)
	HCHFHP	304.761 (7.424)	327.022 (8.375)	357.000 (9.965)	405.935 (15.684)
Sess 2	Fast	319.750 (8.689)	339.708 (9.012)	373.417 (10.058)	409.854 (14.947)
	LCLFLP	293.295 (9.075)	317.000 (9.412)	349.182 (10.506)	401.841 (15.612)
	HCLCLP	288.974 (9.766)	314.105 (10.128)	334.289 (11.305)	382.289 (16.799)
	LCHFLP	303.024 (9.289)	331.905 (9.634)	356.190 (10.753)	396.738 (15.979)
	HCHFLP	296.886(9.0 75)	321.977 (9.412)	339.023 (10.506)	384.705 (15.612)
	LCLFHP	299.080 (8.513)	325.780 (8.830)	532.721 (9.855)	408.400 (14.645)
	HCLFHP	308.050 (9.518)	340.800 (9.872)	366.925 (11.018)	421.175 (16.374)
	LCHFHP	303.262 (9.289)	321.167 (9.634)	355.048 (10.753)	408.238 (15.979)
	HCHFHP	295.804 (8.876)	313.609 (9.206)	348.565 (10.650)	387.304 (15.26)

Sess 3	Fast	312.437 (8.275)	329.479 (8.140)	358.687 (10.426)	404.146 (15.548)
	LCLFLP	302.318 (8.643)	330.227 (8.502)	359.955 (10.889)	406.591 (16.240)
	HCLCLP	290.579 (9.301)	319.579 (9.149)	339.289 (11.717)	374.553 (17.475)
	LCHFLP	309.857 (8.847)	341.119 (8.702)	361.571 (11.146)	405.500 (16.622)
	HCHFLP	293.750 (8.643)	318.727 (8.502)	347.909 (10.889)	394.432 (16.240)
	LCLFHP	298.460 (8.108)	320.860 (7.976)	353.340 (10.215)	406.540 (15.234)
	HCLFHP	293.500 (9.065)	330.650 (8.917)	364.300 (11.421)	407.100 (17.032)
	LCHFHP	299.714 (8.847)	323.310 (8.702)	354.167 (11.146)	384.810 (16.622)
	HCHFHP	288.130 (8.453)	314.609 (8.315)	348.239 (10.650)	393.565 (15.882)

Table 4.11: Summary table for Movement Times on the Hick Paradigm (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8
Sess 1	Fast	190.187 (9.102)	191.562 (9.278)	208.229 (9.595)	204.958 (10.368)
	LCLFLP	182.932 (9.507)	183.023 (9.690)	192.068 (10.021)	199.523 (10.829)
	HCLCLP	171.105 (10.230)	175.053 (10.427)	173.395 (10.784)	175.421 (11.652)
	LCHFLP	187.452 (9.731)	198.833 (9.918)	202.476 (10.257)	222.429 (11.084)
	HCHFLP	177.614 (9.507)	178.886 (9.690)	197.909 (10.021)	214.955 (10.829)
	LCLFHP	179.200 (8.918)	183.980 (9.090)	187.780 (9.401)	200.220 (10.158)
	HCLFHP	180.800 (9.971)	187.800 (10.163)	202.100 (10.511)	202.925 (11.357)
	LCHFHP	184.881 (9.731)	182.500 (9.918)	183.119 (10.257)	196.000 (11.084)
	HCHFHP	178.435 (9.298)	180.609 (9.477)	190.130 (9.801)	204.739 (10.591)
Sess 2	Fast	194.708 (10.085)	201.417 (9.908)	207.500 (9.381)	216.437 (10.783)
	LCLFLP	166.091 (10.534)	175..955 (10.348)	182.682 (10.268)	202.886 (11.262)
	HCLCLP	179.079 (11.135)	179.026 (11.135)	181.868 (11.049)	184.421 (12.119)
	LCHFLP	192.476 (10.781)	197.167 (10.592)	208.619 (10.510)	234.762 (11.527)
	HCHFLP	178.886 (10.534)	192.477 (10.348)	195.136 (10.268)	206.909 (11.262)
	LCLFHP	194.100 (9.881)	200.300 (9.707)	201.060 (9.632)	215.720 (10.565)
	HCLFHP	179.975 (10.048)	178.000 (10.853)	196.425 (10.769)	198.875 (11.812)
	LCHFHP	185.476 (10.781)	202.238 (10.592)	207.667 (10.510)	206.929 (11.527)
	HCHFHP	176.370 (10.302)	179.022 (10.121)	182.522 (10.042)	200.804 (11.014)

Sess 3	Fast	194.437 (10.636)	194.854 (10.033)	209.708 (10.029)	210.625 (9..755)
	LCLFLP	172.182 (11.109)	175.727 (10.479)	180.386 (10.475)	195.818 (10.189)
	HCLCLP	191.000 (11.954)	189.605 (11.276)	193.395 (11.271)	200.842 (10.964)
	LCHFLP	205.595 (11.370)	194.881 (10.725)	203.357 (10.721)	225.762 (10.429)
	HCHFLP	179.114 (11.109)	177.500 (10.479)	185.500 (10.475)	210.864 (10.189)
	LCLFHP	198.660 (10.421)	201.900 (9.830)	204.060 (9.826)	212.980 (9.558)
	HCLFHP	178.000 (11.651)	180.100 (10.990)	196.575 (10.986)	208.975 (10.686)
	LCHFHP	196.167 (11.370)	190.167 (10.725)	194.952 (10.721)	199.143 (10.429)
	HCHFHP	185.848 (10.865)	175.543 (10.248)	184.587 (10.244)	205.478 (9.965)

Table 4.12: Summary table for Intercept on the Hick Paradigm (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3
Intercept	Fast	307.396 (8.232)	315.071 (8.578)	305.533 (8.065)
	LCLFLP	297.400 (8.598)	286.664 (8.959)	298.400 (8.423)
	HCLCLP	278.789 (9.252)	284.895 (9.641)	290.263 (9.064)
	LCHFLP	308.971 (8.801)	301.162 (9.170)	308.395 (8.622)
	HCHFLP	294.923 (8.598)	293.564 (8.959)	289.014 (8.423)
	LCLFHP	299.528 (8.066)	293.268 (8.404)	291.288 (7.902)
	HCLFHP	289.000 (9.018)	304.410 (9.396)	292.720 (8.835)
	LCHFHP	297.424 (8.801)	294.614 (9.170)	297.590 (8.622)
	HCHFHP	298.652 (8.409)	289.900 (8.762)	283.648 (8.065)

Table 4.13: Summary table for Slope on the Hick Paradigm (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3
Slope	Fast	33.496 (4.355)	30.408 (3.981)	30.438 (4.317)
	LCLFLP	36.964 (4.459)	35.777 (4.158)	34.250 (4.509)
	HCLCLP	28.937 (4.895)	30.005 (4.474)	27.158 (4.852)
	LCHFLP	26.681 (4.656)	30.538 (4.256)	30.738 (4.615)
	HCHFLP	31.482 (4.549)	28.050 (4.158)	33.123 (4.509)
	LCLFHP	31.160 (4.267)	35.500 (3.900)	35.676 (4.230)
	HCLFHP	44.015 (4.771)	36.540 (4.361)	37.450 (4.729)
	LCHFHP	29.190 (4.656)	34.876 (4.256)	28.614 (4.615)
	HCHFHP	33.552 (4.449)	30.939 (4.066)	34.987 (4.410)

Table 4.14: Summary table for Intra-Individual Variability on the Hick Paradigm (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3
Intra-Individual Variability	Fast	225.377 (22.324)	194.713 (24.125)	199.341 (25.374)
	LCLFLP	179.203 (23.217)	197.728 (25.198)	204.870 (26.502)
	HCLCLP	2004.920 (25.090)	199.386 (27.115)	166.589 (28.518)
	LCHFLP	198.541 (23.865)	202.369 (25.791)	210.219 (27.126)
	HCHFLP	187.752 (23.317)	146.853 (25.198)	174.523 (26.502)
	LCLFHP	188.002 (21.873)	186.921 (23.638)	229.669 (24.861)
	HCLFHP	222.239 (24.455)	203.138 (26.428)	264.220 (27.796)
	LCHFHP	168.545 (23.865)	192.938 (25.791)	153.689 (27.126)
	HCHFHP	187.990 (22.804)	202.045 (24.644)	181.923 (25.920)

Table 4.15: Summary table for Correct responses on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5
Corr 1	Fast	4.240 (0.377)	3.520 (0.346)	3.320 (0.363)	3.160 (0.332)	2.440 (0.327)
	LCLFLP	4.955 (0.402)	3.545 (0.368)	3.773 (0.387)	3.591 (0.353)	2.591 (0.349)
	HCLCLP	4.522 (0.393)	4.783 (0.360)	3.217 (0.378)	3.913 (0.346)	2.913 (0.341)
	LCHFLP	4.292 (0.385)	3.667 (0.353)	3.375 (0.370)	3.583 (0.338)	2.625 (0.334)
	HCHFLP	4.391 (0.393)	4.261 (0.360)	3.522 (0.378)	3.652 (0.346)	2.870 (0.341)
	LCLFHP	4.520 (0.377)	4.760 (0.346)	3.880 (0.363)	4.120 (0.332)	2.960 (0.327)
	HCLFHP	4.682 (0.402)	3.455 (0.368)	3.318 (0.387)	3.227 (0.353)	2.545 (0.349)
	LCHFHP	4.348 (0.393)	4.043 (0.360)	3.391 (0.378)	3.522 (0.346)	2.957 (0.341)
	HCHFHP	4.760 (0.377)	4.000 (0.346)	3.440 (0.363)	3.600 (0.332)	3.200 (0.327)
Corr 2	Fast	4.480 (0.400)	4.280 (0.371)	3.280 (0.371)	3.800 (0.386)	2.720 (0.335)
	LCLFLP	4.818 (0.427)	4.364 (0.395)	3.864 (0.395)	4.091 (0.412)	2.955 (0.357)
	HCLCLP	5.304 (0.418)	5.000 (0.386)	4.000 (0.387)	4.609 (0.403)	3.348 (0.349)
	LCHFLP	4.542 (0.409)	4.792 (0.378)	3.500 (0.379)	3.542 (0.394)	2.875 (0.342)
	HCHFLP	4.304 (0.418)	4.043 (0.386)	3.826 (0.387)	3.478 (0.403)	2.957 (0.349)
	LCLFHP	5.240 (0.400)	4.880 (0.371)	3.480 (0.371)	4.240 (0.386)	2.920 (0.335)
	HCLFHP	4.636 (0.427)	4.500 (0.395)	3.136 (0.395)	3.955 (0.412)	2.955 (0.357)
	LCHFHP	4.739 (0.418)	4.174 (0.386)	3.565 (0.387)	3.9570 (0.403)	2.696 (0.349)
	HCHFHP	4.880 (0.400)	4.440 (0.371)	3.720 (0.371)	3.920 (0.386)	3.120 (0.335)

Corr 3	Fast	4.560 (0.402)	4.080 (0.376)	3.800 (0.414)	4.080 (0.387)	2.440 (0.316)
	LCLFLP	5.091 (0.428)	4.591 (0.401)	3.909 (0.441)	4.182 (0.413)	2.818 (0.337)
	HCLCLP	6.174 (0.419)	4.957 (0.392)	4.609 (0.431)	4.391 (0.403)	3.565 (0.329)
	LCHFLP	4.542 (0.410)	3.917 (0.384)	3.292 (0.422)	4.042 (0.395)	2.833 (0.323)
	HCHFLP	4.348 (0.419)	4.652 (0.392)	3.957 (0.403)	4.478 (0.403)	3.000 (0.329)
	LCLFHP	5.080 (0.402)	4.600 (0.376)	4.240 (0.414)	4.240 (0.387)	3.000 (0.316)
	HCLFHP	4.182 (0.428)	4.136 (0.401)	3.545 (0.441)	3.909 (0.413)	2.818 (0.337)
	LCHFHP	4.087 (0.419)	3.870 (0.392)	3.652 (0.431)	3.913 (0.403)	2.739 (0.329)
	HCHFHP	4.920 (0.402)	4.560 (0.376)	4.160 (0.414)	4.120 (0.387)	2.880 (0.316)

Table 4.16: Summary table for Wrong responses on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5
Wrg 1	Fast	4.920 (0.763)	3.760 (0.704)	4.200 (0.750)	3.480 (0.734)	3.480 (0.641)
	LCLFLP	4.591 (0.813)	3.136 (0.750)	3.364 (0.799)	3.227 (0.783)	2.364 (0.683)
	HCLCLP	3.261 (0.795)	3.391 (0.734)	2.870 (0.782)	2.348 (0.765)	2.174 (0.668)
	LCHFLP	3.583 (0.779)	2.875 (0.718)	2.042 (0.765)	2.917 (0.749)	2.292 (0.654)
	HCHFLP	4.609 (0.795)	3.435 (0.734)	4.130 (0.782)	4.174 (0.765)	3.913 (0.668)
	LCLFHP	3.160 (0.763)	2.840 (0.704)	4.000 (0.750)	3.200 (0.734)	2.360 (0.641)
	HCLFHP	3.591 (0.813)	2.864 (0.750)	2.682 (0.799)	3.273 (0.783)	2.591 (0.683)
	LCHFHP	3.348 (0.795)	3.435 (0.734)	3.348 (0.782)	3.870 (0.765)	3.087 (0.668)
	HCHFHP	4.040 (0.763)	3.120 (0.704)	3.480 (0.750)	3.640 (0.734)	2.640 (0.641)
Wrg 2	Fast	3.440 (0.689)	2.120 (0.706)	2.840 (0.717)	2.440 (0.704)	2.840 (0.741)
	LCLFLP	2.818 (0.735)	1.864 (0.753)	3.091 (0.764)	2.545 (0.750)	2.227 (0.790)
	HCLCLP	2.609 (0.719)	3.087 (0.736)	3.478 (0.747)	2.522 (0.734)	2.522 (0.772)
	LCHFLP	2.375 (0.704)	2.000 (0.721)	2.292 (0.731)	2.375 (0.718)	2.000 (0.756)
	HCHFLP	2.652 (0.719)	2.174 (0.736)	2.783 (0.747)	2.913 (0.734)	2.565 (0.772)
	LCLFHP	3.960 (0.689)	3.360 (0.706)	2.560 (0.717)	1.920 (0.704)	3.200 (0.741)
	HCLFHP	2.818 (0.735)	2.545 (0.753)	2.409 (0.764)	2.545 (0.750)	3.409 (0.790)
	LCHFHP	2.130 (0.719)	2.217 (0.736)	2.391 (0.747)	3.087 (0.734)	2.783 (0.772)
	HCHFHP	2.600 (0.689)	2.960 (0.706)	3.600 (0.717)	3.560 (0.704)	3.520 (0.741)

Wrg 3	Fast	3.240 (0.710)	3.360 (0.721)	2.200 (0.703)	2.640 (0.725)	3.160 (0.823)
	LCLFLP	2.500 (0.757)	2.409 (0.768)	2.773 (0.749)	3.318 (0.773)	3.591 (0.878)
	HCLCLP	2.217 (0.741)	2.478 (0.752)	2.739 (0.733)	3.174 (0.756)	4.348 (0.859)
	LCHFLP	1.667 (0.725)	3.083 (0.736)	2.125 (0.717)	2.583 (0.740)	2.792 (0.840)
	HCHFLP	1.783 (0.741)	1.870 (0.752)	2.391 (0.733)	2.174 (0.756)	2.043 (0.859)
	LCLFHP	2.280 (0.710)	1.920 (0.721)	2.640 (0.703)	2.480 (0.725)	2.560 (0.823)
	HCLFHP	3.000 (0.757)	2.364 (0.768)	2.773 (0.749)	2.364 (0.773)	3.364 (0.878)
	LCHFHP	2.304 (0.741)	2.522 (0.752)	2.913 (0.733)	2.348 (0.756)	2.478 (0.859)
	HCHFHP	2.920 (0.710)	2.160 (0.721)	3.200 (0.703)	3.640 (0.725)	4.160 (0.823)

Table 4.17: Summary table for Reaction times on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5
RT 1	Fast	528.160 (32.889)	477.520 (36.731)	585.200 (45.229)	571.280 (36.187)	550.080 (46.627)
	LCLFLP	484.773 (35.060)	594.000 (39.156)	566.545 (48.214)	553.682 (38.575)	669.773 (49.704)
	HCLCLP	554.609 (34.289)	500.739 (38.925)	538.304 (47.154)	544.652 (37.127)	627.522 (48.612)
	LCHFLP	547.750 (33.567)	549.750 (37.489)	546.292 (46.161)	607.167(36.933)	589.958(47.588)
	HCHFLP	561.043 (34.289)	577.261 (38.295)	602.913 (47.154)	552.174 (37.727)	613.957 (48.612)
	LCLFHP	567.040 (32.889)	578.200 (36.731)	607.280 (45.229)	570.920 (36.187)	587.120 (46.627)
	HCLFHP	494.000 (35.060)	645.000 (39.156)	578.591 (48.214)	560.955 (38.575)	582.364 (49.704)
	LCHFHP	550.304 (34.289)	634.174 (38.295)	548.870 (47.154)	591.391 (37.727)	545.348 (48.612)
	HCHFHP	504.080 (32.889)	575.440 (36.731)	622.880 (45.229)	600.040 (36.187)	629.960 (46.627)
RT 2	Fast	531.600 (27.107)	615.600 (33.442)	597.280 (34.167)	588.480 (40.004)	507.600 (39.482)
	LCLFLP	470.318 (28.896)	498.045 (35.649)	507.136 (36.422)	513.045 (42.644)	575.273 (42.088)
	HCLCLP	514.522 (28.261)	514.522 (34.866)	487.087 (35.622)	572.696 (41.707)	573.043 (41.163)
	LCHFLP	542.583 (27.666)	545.917 (34.132)	509.542 (34.872)	597.167 (40.829)	608.458 (40.297)
	HCHFLP	530.000 (28.261)	546.522 (34.866)	458.217 (35.622)	563.348 (41.707)	453.304 (41.163)
	LCLFHP	523.960 (27.107)	517.600 (33.442)	575.040 (34.167)	567.560 (40.004)	566.520 (39.482)
	HCLFHP	436.136 (28.896)	551.091 (35.649)	530.864 (36.442)	614.636 (42.644)	534.636 (42.088)
	LCHFHP	457.348 (28.261)	509.304 (34.866)	546.739 (35.622)	531.435 (41.707)	529.652 (41.163)
	HCHFHP	541.520 (27.107)	566.640 (33.442)	570.120 (34.167)	586.920 (40.004)	581.680 (39.482)

RT 3	Fast	511.360 (27.575)	505.920 (29.555)	558.440 (37.671)	626.800 (39.019)	512..960 (37.622)
	LCLFLP	560.455 (29.395)	520.955 (31.506)	525.000 (40.157)	553.364 (41.594)	483.455 (40.106)
	HCLCLP	485.522 (28.748)	493.913 (30.814)	478.087 (39.275)	474.522 (40.680)	559.043 (39.224)
	LCHFLP	502.667 (28.143)	526.083 (30.165)	489.625 (38.448)	524.792 (39.824)	574.708 (38.398)
	HCHFLP	554.130 (28.748)	538.435 (30.814)	458.348 (39.275)	538.739 (40.680)	512.217 (39.224)
	LCLFHP	499.040 (27.575)	488.080 (29.555)	577.720 (37.671)	599.880 (39.019)	527.360 (37.622)
	HCLFHP	538.318 (29.395)	568.318 (31.50)	503.955 (40.157)	568.091 (41.594)	552.636 (40.106)
	LCHFHP	525.130 (28.748)	506.913 (30.814)	561.087 (39.275)	592.304 (40.680)	486.000 (39.224)
	HCHFHP	557.400 (27.575)	558.400 (29.555)	610.080 (37.671)	581.800 (39.019)	603.520 (37.622)

Chapter 5: The effects of Breakfasts differing in RAG and SAG ratios

5.1 INTRODUCTION

The previous chapters have analysed the influence of different macronutrients on measures of mood, hunger and cognition. Chapter 3 reported that a medium amount of carbohydrate (30g) and low fibre intake (1.5g) was associated with enhanced mood and cognition. Chapter 4 reported that low carbohydrate (25g)/high protein (10g) meals enhanced mood, and that low blood glucose levels over the morning were associated with enhanced memory performance. In both chapters a recurrent observation was that individual differences in glucose tolerance were associated with enhanced performance.

There is increasing evidence that blood glucose levels are associated with enhanced psychological functioning and improved mood in healthy young adults and the elderly (see section 1.3). In addition, carbohydrate when consumed within a breakfast meal has also been found to influence mood and cognitive functioning (section 1.8). It has been demonstrated, therefore, that carbohydrate plays an important role in both mood and memory enhancement. A subsequent question was therefore asked, does the type of carbohydrate influence mood and memory in different ways?

The classification of dietary carbohydrates into Rapidly Available Glucose (RAG) and Slowly Available Glucose (SAG) (Englyst et al., 1996; 1999) reflects not only different digestion and absorption rates (see section 1.7.1), but also the glycaemic response to a particular food (see section 1.7.2). It has been demonstrated that blood glucose responses are substantially different depending on the quantity and nutritional content of the food that is ingested (Chapters 3 and 4), and on the participants own glucose tolerance (see section 1.3.6). It is reasonable to consider whether these differences in the nature of carbohydrate may also contribute to differences in performance.

5.1.1 AIM

This present study aimed to test the hypothesis that differing ratios of RAG and SAG consumed within breakfast cereals, influence mood, hunger and cognitive functioning, a reflection of a differential in the release of glucose into the blood. It was hypothesised that the consumption of breakfast would be beneficial with respect to measures of mood and memory, (Chapters 3 and 4) and that breakfasts high in SAG would also be beneficial to measures tested (Kaplan et al., 2000).

5.2 METHOD

5.2.1 PARTICIPANTS

175 female undergraduate students, mean age 20.92 years (SD 3.76), acted as participants. All were recruited through advertisements within the University of Wales, Swansea.

Groups of participants were compared under seven conditions:

1. Control Condition – No food (N=25; mean 20.80yrs; SD 2.81)
2. Cornflakes – 38g (Kellogg's) (N=25); mean 20.58yrs; SD 1.89)
3. Rice Krispies – 37g (Kellogg's) (N=25; mean 21.08yrs, SD 4.17)
4. Ricicles – 32g (Kellogg's) (N=25; mean 20.04yrs, SD 1.40)
5. Weetabix – 45g (Weetabix Ltd) (N=25; mean 20.16yrs; SD 1.70)
6. Shredded Wheat – 45g (Nestle) (N=25; mean 20.46yrs; SD 1.10)
7. Digestive Biscuits – 53g (McVities) (N=25; mean 23.42yrs; SD 7.80)

Table 5.1 illustrates the nutritional values of the dry weight of the meals consumed in total each meal offered 30g of carbohydrate. All participants fasted overnight, and once in the laboratory consumed their allocated breakfast meal. All participants gave written consent and the local Ethics Committee approved the procedure.

Table 5.1: Nutritional information of the dry weight of breakfast cereals consumed

	RAG (g)	SAG (g)	FAT (g)	PROTEIN (g)	FIBRE (g)	ENERGY (Kcal)
Cornflakes (38g)	28.77	1.41	0.30	3.04	1.14	140.60
Ricicles 32g)	30.19	0.27	0.22	1.28	0.32	121.60
Rice Krispies (37g)	29.71	0.63	0.37	2.22	0.56	136.90
Digestive Biscuits (53g)	23.16	6.68	11.61	3.71	1.48	262.35
Shredded Wheat (45g)	24.75	5.36	0.95	5.04	5.18	148.50
Weetabix (45g)	29.39	0.45	1.22	5.04	4.73	153.00

5.2.2 BREAKFAST

Table 5.2 illustrates the mean nutritional values of the breakfasts consumed this includes 150ml skimmed milk added to each breakfast. In addition each participant had a choice of beverages. Decaffeinated Tea (Typhoo) or Decaffeinated Coffee (Nescafe), with skimmed milk (up to 35ml) and sweetener (Hermesetas) if required, or Sugar Free Orange Squash (Robinson's R), were given. Participants also had access to unlimited water throughout the experiment.

Table 5.2: Mean Nutritional values for the test breakfast and habitual breakfasts consumed by the participants (values include 150ml skimmed milk)

Meal	Energy (Kcal)	Carbohydrate (g)	Fat (g)	Protein (g)	Fibre (g)
Cornflakes (38g)	191.60	39.04	0.45	7.99	1.14
Rice Krispies (37g)	187.90	38.95	0.52	7.17	0.56
Ricicles (32g)	172.60	35.98	0.37	6.23	0.32
Weetabix (45g)	204.00	37.92	1.37	9.99	4.72
Shredded Wheat (45g)	199.50	37.23	1.10	9.99	5.18
Digestive Biscuits (53g)	313.35	43.33	11.76	8.66	1.40
Habitual	347.20	56.03	11.43	11.53	4.46

5.2.3 WORD LISTS

Three lists of 30 words, each having five letters, were chosen to be high in frequency and imagery (Quinlan, 1992). Each list had 15 abstract words and 15 concrete words (Appendix 1). The list was presented aurally, at a rate of one word per two seconds using a tape recorder. All responses were written and the time taken was noted.

5.2.4 MOOD

The six basic dimensions of mood, Total mood and hunger were assessed (section 2.2.4).

5.2.5 COGNITIVE TESTS

The Rapid Information Processing Task (RIPT) and Hick Paradigm (Reaction Times) (section 2.2.4) were used to assess changes in cognitive functioning in response to the breakfasts consumed.

5.2.6 ADULT EPQ-R

The Adult EPR-R (Eysenck & Eysenck, 1991) was completed by each individual was used as a cognitive task to increase mental fatigue. Performance on this measure was not assessed.

5.2.7 BLOOD GLUCOSE

Blood glucose determinations were made with the use of an ExacTech sensor, made by Medisense Britain Limited. The sensor uses an enzymic method coupled with microelectronic measurement that has been shown to give valid measures (Matthews et al., 1987).

5.2.8 PROCEDURE

Table 5.3 illustrates the procedure. Blood glucose levels were determined on entering the laboratory. Informed consent was given and Mood questionnaires were completed. Subjects were allocated to one of seven conditions, receiving one of the test breakfasts.

The subjects sat for 20 minutes to allow digestion of the food to begin. Blood glucose levels and Mood were measured for a second time. The word list was then presented aurally, and immediate recall assessed (1). Subjects then completed the Hick Paradigm and the RIPT (1) on the computers. On completion of the tests the third blood glucose reading was taken, and Mood and delayed recall assessed (1).

Participants then completed the Adult EPQ-R (Eysenck & Eysenck, 1991) and then sat for 20 minutes. The second word list was then presented aurally and immediate recall (2) was assessed. Participants then completed the Hick Paradigm and the RIPT (2). On completion of the tests the fourth blood glucose reading was taken, and Mood and delayed recall (2) assessed. Participants then sat for 20 minutes to rest.

The third test session followed this, with immediate recall (3), Hick (3), RIPT (3), delayed recall (3) being assessed. The final measure of blood glucose and Mood was taken and the participants were debriefed.

Table 5.3: Profile of the testing procedure for Chapter 5

10:00	*BGL 1 / MOOD / CONSENT*	0 minutes
10:10	BREAKFAST (Table 5.1) 20 MINUTES WAIT	10 minutes
10:30	*BGL2 / MOOD*	30 minutes
10:40	**TEST SESSION 1** IMMEDIATE RECALL HICK RIPT DELAYED RECALL	40 minutes
11:00	*BGL3 / MOOD* 20 MINUTES WAIT (complete EPQ)	60 minutes
11:25	**TEST SESSION 2**	85 minutes
11:45	*BGL4 / MOOD* 20 MINUTES WAIT	105 minutes
12:10	**TEST SESSION 3**	130 minutes
12:30	*BGL5 / MOOD / DEBRIEFING*	150 minutes

5.3 STATISTICAL ANALYSIS

5.3.1 EFFECT OF BREAKFAST

- Measures of blood glucose were analysed using a two-way ANOVA:

  Breakfast (fast/breakfast) X Time (0, 30, 60, 105, 150 minutes) (repeated measure).

- Difference scores were firstly calculated for the measures of Mood (Composed/Agreeable/Elated/Confident/Energetic/Clearheaded) and Hunger using the following calculation:

  Mood at 30, 60, 105, & 150 minutes – baseline.

  These measures were then analysed using two-way ANOVA's:

  Breakfast (fast/breakfast) X Time (30, 60, 105, 150 minutes) (repeated measure).

- Measures of Word Recall, Total, Concrete and Abstract, and Recall Times were analysed using three-way ANOVA's:

  Breakfast (fast/breakfast) X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

- Measures of Decision times on the Hick Paradigm were analysed using three-way ANOVA's:

  Breakfast (fast/breakfast) X Session (1, 2, 3) (repeated measure).X Number of Lamps (1, 2, 4, 8) (repeated measure).

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVA's:

  Breakfast (fast/breakfast) X Session (1, 2, 3) (repeated measure).

- Measures of Correct responses, Wrong responses and Reaction times on the RIPT test were analysed using three-way ANOVA's:
  Breakfast (fast/breakfast) X Session (1, 2, 3) (repeated measure) X Minutes (1, 2, 3, 4, 5) (repeated measure).
- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

5.3.2 EFFECT OF MACRONUTRIENTS

Stepwise Linear Regressions, with RAG, SAG, Fat, Protein, Fibre and Kcal as the independent variables were performed. The following dependent variables were used:

- Mood at each time point (difference score).
- All aspects of Memory (Immediate and Delayed) for each session.
- Total Decision times for each session of the Hick paradigm.
- Intercept and Intra-Individual Variability at each time point.
- Total Correct, Wrong responses and Reaction times for each session.

5.3.3 EFFECT OF BLOOD GLUCOSE LEVELS AND CHANGE

Stepwise Linear Regressions, with blood glucose levels (0, 30, 60, 105, 150 minutes) and changes in blood glucose levels as the independent variables, were performed on the data set. Changes in blood glucose levels were calculated using the following equations:

- Change 1 = BG 30 – BG 0
- Change 2 = BG 60 – BG 30
- Change 3 = BG 105 – BG 60

- Change 4 = BG 150 – BG 105

The regressions were performed on the data separately for the breakfasts. The following dependent variables were used:

- Mood at each time point (difference score).
- All aspects of Memory (Immediate and Delayed) for each session
- Total Decision times for each session
- Intercept and Intra-Individual Variability at each time point
- Total Correct, Wrong responses and Reaction times for each session

5.3.4 EFFECT OF HABITUAL BREAKFAST CONSUMPTION

- Measures of Total Mood and Hunger were analysed using three-way ANOVA's: Breakfast (fast/breakfast) X Habitual breakfast consumption (Yes/No) X Difference (30, 60, 105, 150 minutes) (repeated measure).
- Measures of Word Recall were analysed using four-way ANOVA's: Breakfast (fast/breakfast) X Habitual breakfast consumption (Yes/No) X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

5.4 RESULTS

For clarity only significant results involving macronutrients or condition will be reported. It may be assumed that main effects and higher order interactions that are not reported were non-significant.

11 participants were removed from the data set due baseline blood glucose levels over 7.4mmol/L. It was assumed that either participants had eaten before arriving at the laboratory, or had a metabolic problem.

5.4.1 EFFECT OF BREAKFAST

Breakfast and Blood Glucose Levels

The interaction Meal X Time reached significance [F (24, 628) = 4.16, p<0.001]. Figure 5.1 and SME's demonstrated significant differences between the different meal groups at 30 minutes [F (6,157) = 10.11, p<0.001], 60 minutes [F (6,157) = 3.54, p<0.01], 100 minutes [F (6,157) = 5.72, p<0.001] and 150 minutes [F (6,157) = 3.55, p<0.01]. Additionally there were significant changes in blood glucose levels for each meal group over the morning (Table 5.4).

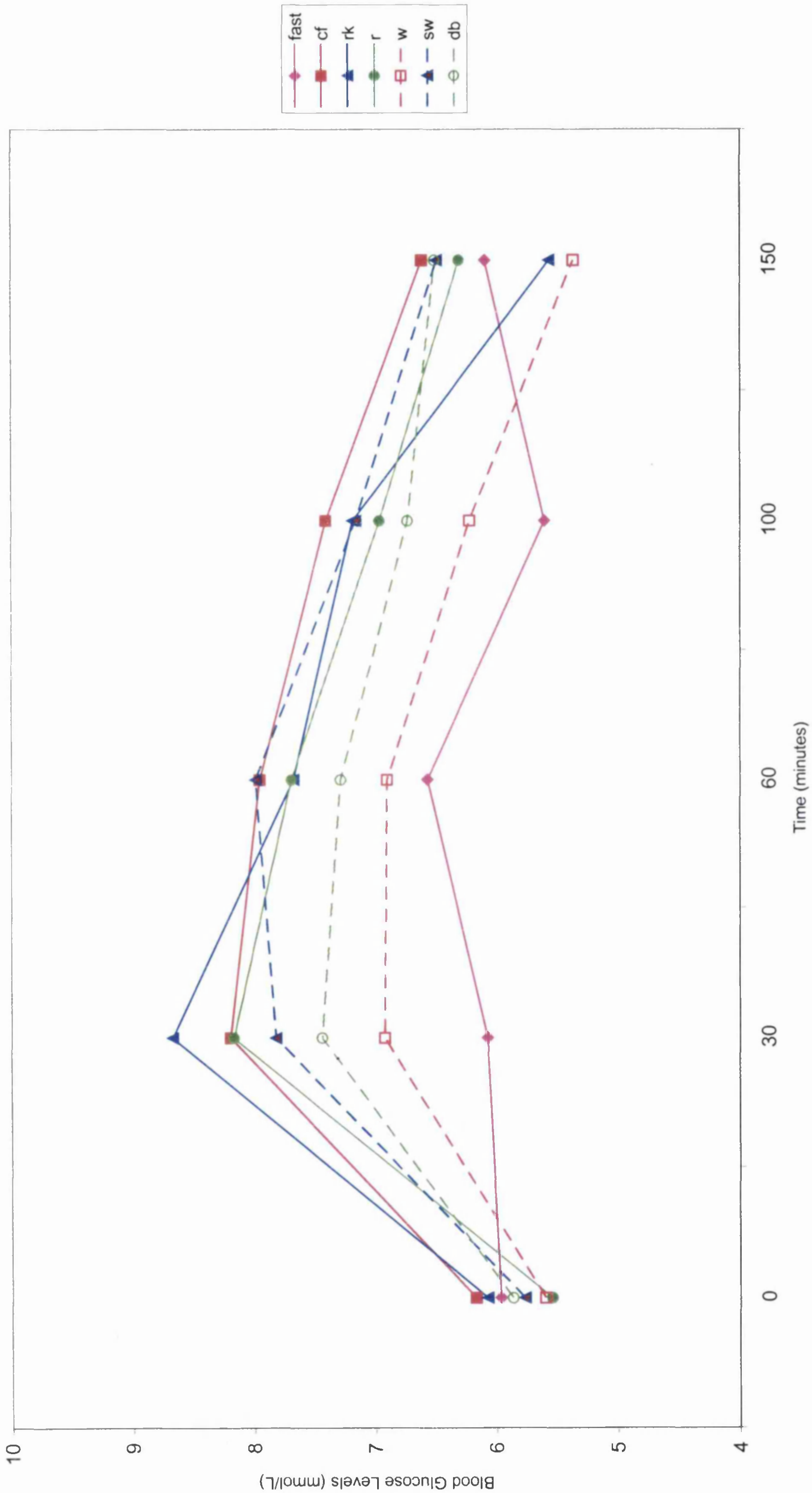

fast
cf
rk
r
w
sw
db
Blood Glucose Levels (mmol/L)
10
9
8
7
6
5
4
Time (minutes)
0
30
60
100
150

Table 5.4: Summary table for the significant differences between conditions with respect to Blood Glucose Levels at the five time points

Time	F-ratio, Sig.	Significant Differences
0 minutes	F (6,163) = 1.45, p=n.s.	No significant differences
30 minutes	F (6,163) = 10.11, p<0.001	- Fast significantly differed from CF; RK; R; SW; DB - W significantly differed from CF; RK - DB significantly differed from RK
60 minutes	F (6,163) = 3.54, p<0.01	- Fast significantly differed from CF; SW
105 minutes	F (6,163) = 5.72, p<0.001	- Fast significantly differed from CF; RK; R; SW; DB - W significantly differed from CF
150 minutes	F (6,163) = 3.55, p<0.01	- W significantly differed from CF; SW; DB

Breakfast and Mood

The interaction Meal x Time reached significance with respect to reported ratings of Composure [$F(18, 471) = 1.66, p<0.05$]. Figure 5.2 and SME's demonstrate that the fasting condition's composure significantly decreases over the course of the test session [$F(3,417) = 2.81, p<0.05$]. No significant differences were observed between any of the meals.

Figure 5.2: Profile of Composure ratings over Time (means +/- s.e.m)

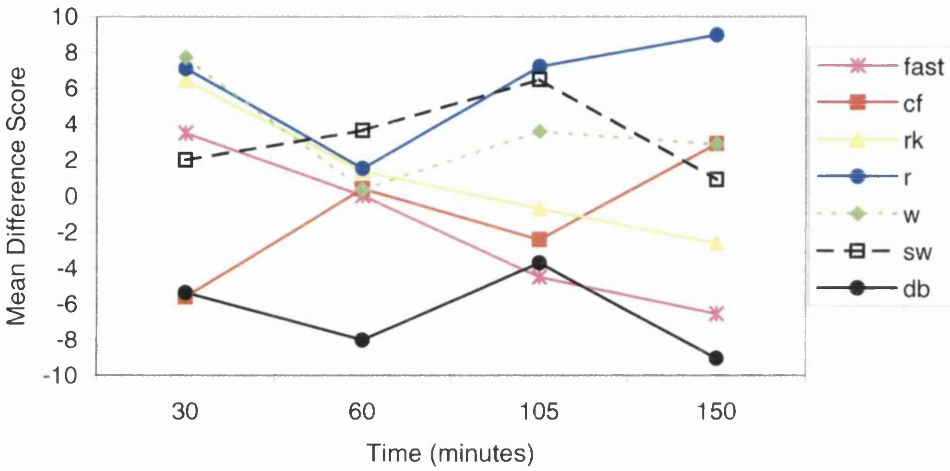
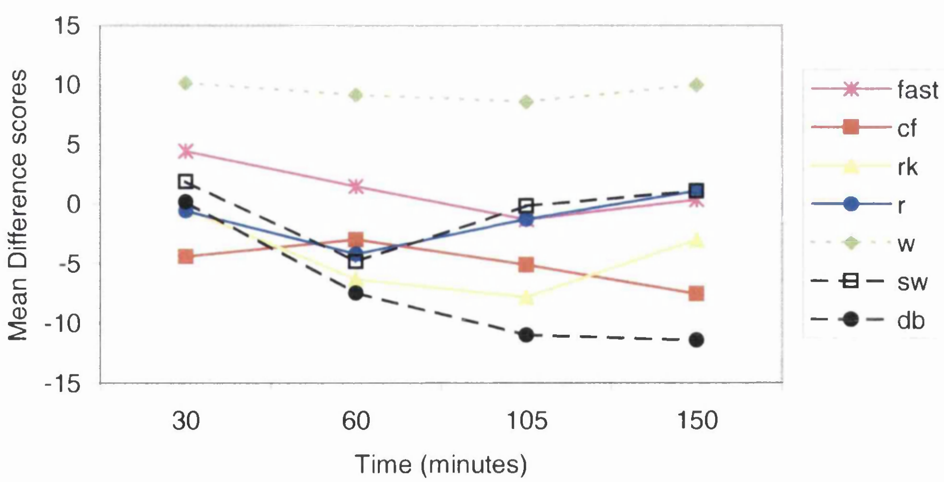


Figure 5.3: Profile of Agreeability ratings over Time (mean +/- s.e.m)



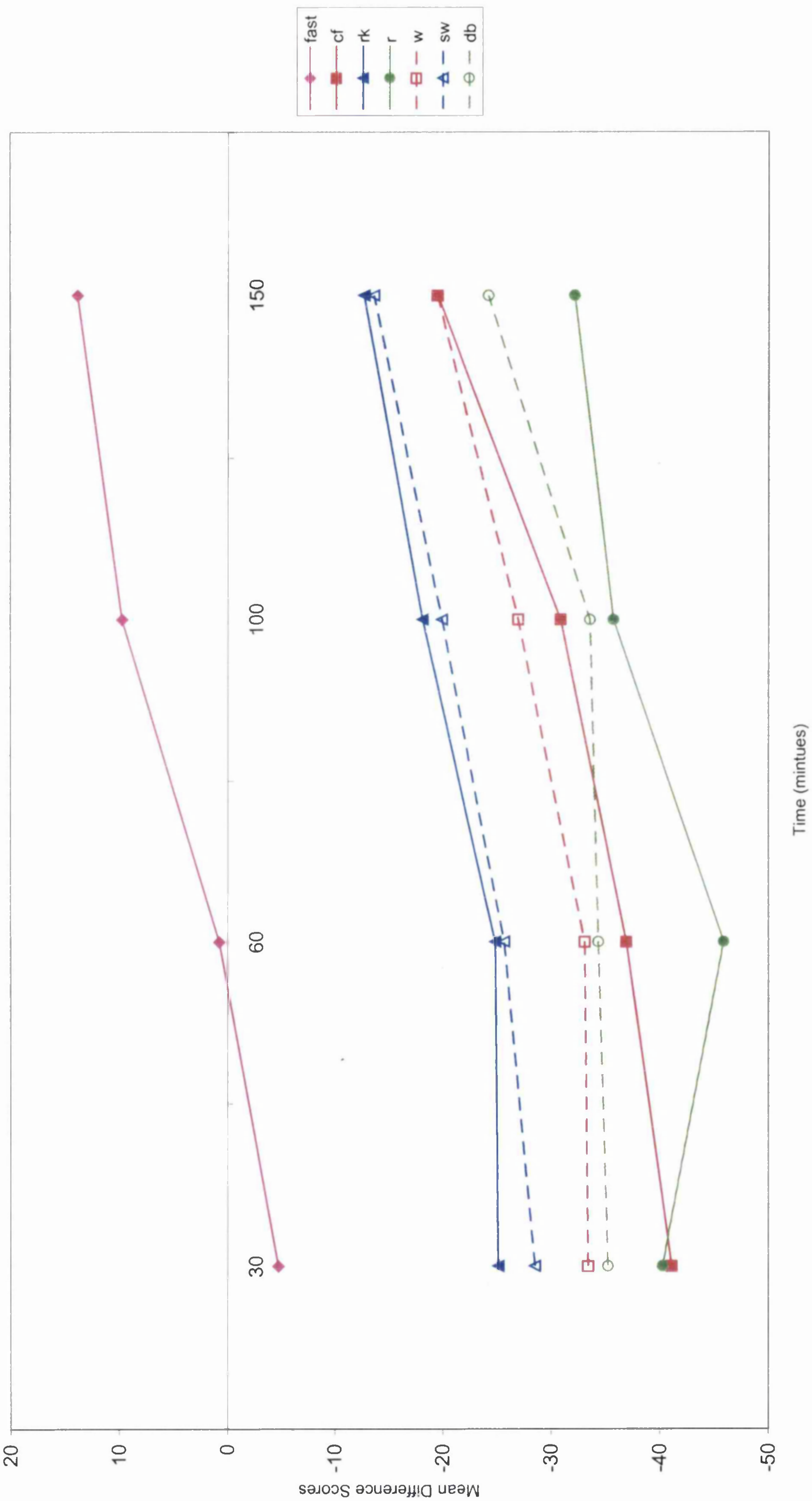
The breakfast consumed influenced ratings of Agreeability [F (6,157) = 3.19, p<0.01]. Figure 5.3 shows that participants who consumed the Weetabix breakfast were significantly more agreeable than those who consumed the Cornflakes, Rice Krispies (p<0.05), and Digestive Biscuits breakfasts (p<0.01).

Breakfast and Hunger

The interaction Meal X Time failed to reach significance [F (18,471) = 0.63, p=n.s.], however, there was a main effect of meal [F (6,157) = 8.09, p<0.001] (Figure 5.4). Further analysis demonstrated that at each time point consumption of breakfast resulted in a significantly reduced hunger rating compared to those who fasted (p<0.05) However, at 30 and 150 minutes, there was no significant difference in hunger ratings between those who consumed the Rice Krispies breakfast and those who fasted.

Breakfast and Memory

Breakfast consumed failed to influence the number of words recalled [F (6,157) = 0.53, p=n.s.]. When the type of words were analysed, the meal consumed failed to influence the recall of concrete words [F (6;157) = 0.42, p=n.s.]. The interaction Meal X Recall (immediate/delayed) reached significance with respect to abstract word recall [F (6,157) =2.21, p<0.05]. SME's demonstrated significant differences between immediate and delayed recall times for each meal group.



fast
cf
rk
r
w
sw
db
Mean Difference Scores
20
10
0
-10
-20
-30
-40
-50
30
60
100
150
Time (mintues)

The interaction Meal X Session reached significance with respect to the time taken trying to recall the word lists [$F(12,314) = 3.48$, $p<0.001$]. SME's demonstrated consistent performance in the time taken to recall the word lists over the three sessions for those who consumed the Digestive Biscuit breakfast [$F(2,314) = 1.81$, p=n.s.], unlike the other conditions that demonstrated significant decreases in recall times over the three sessions. The interaction Meal X Recall (Immediate/delayed) also reached significance [$F(6,157) = 2.15$, $p=0.05$]. SME's demonstrated significant differences between immediate and delayed recall times for each meal group.

Breakfast and the Hick Paradigm

11 participants were removed from the data set due to missing results and negative slope values.

Breakfast meal failed to influence Decision times [$F(6,146) = 0.19$, p=n.s.] or Movement times [$F(6,146) = 0.73$, p=n.s.].

Breakfast also failed to influence Intercept [$F(4,146) = 0.51$, p=n.s.], Slope [$F(6,146) = 0.55$, p=n.s.] and Intra-Individual Variability [$F(4,146) = 0.47$, p=n.s.].

Breakfast and the RIPT

12 participants were removed form the data set due to incomplete data or incorrect performance on the task (>20 wrong responses per minute).

Breakfast meal failed to influence Correct responses [F (6,145) = 0.88, p=n.s.], Wrong responses [F (6,145) = 1.75, p=n.s.] or Reaction Times [F (6,145) = 1.15, p=n.s.].

5.4.2 EFFECT OF MACRONUTRIENTS

Low fat was associated with enhanced recall performance at 40 minutes. Furthermore, low fat and low SAG breakfasts were associated with fewer wrong responses on the RIPT at 40 and 85 minutes. High fibre, low SAG breakfasts, for example Weetabix, were associated with increased Agreeability over the morning.

5 out of the 6 breakfasts contained less than 2g of fat, whilst Digestive Biscuits containing 11.76g. The stepwise regressions were re-analysed with latter meal omitted.

High fat consumption in the remaining meals was associated with enhanced Agreeability throughout the morning, with high quantities of RAG associated with greater energy 0-60 minutes. Fat failed to influence any measure of memory, however, breakfast containing low amounts of RAG were associated with increased time taken trying to recall the word lists. Macronutrients failed to influence any measure of the Hick Paradigm or the RIPT once Digestive Biscuits were removed.

5.4.3 EFFECT OF BLOOD GLUCOSE LEVELS AND CHANGE

Stepwise linear regressions were performed on the data, with the blood glucose levels, and the four changes in blood glucose as independent variables, and measures of Mood, Hunger, and measures of cognition as dependent variables. Patterns observed within the breakfast conditions are reported.

Cornflakes

High blood glucose levels at 30 minutes, followed by subsequent falling values over the next 30 minutes, were associated with better total mood over the morning. Low blood glucose levels over at 100 minutes and for the remainder of the study were associated with more time being taken trying to recall the word lists, and more words being recalled at delayed recall. No consistent patterns were observed with the Hick Paradigm. Slow falling and rising blood glucose levels over the last 50 minutes were associated with increased correct responses on first two RIPT tests.

Rice Krispies

High baseline blood glucose levels were associated with better total mood and decreased hunger after the first 30 minutes. Slow falling and Rising blood glucose levels between 30 and 60 minutes were associated with more correct responses on the first two RIPT tests. High blood glucose levels at 100 minutes were associated with an increased number of wrong responses in the last two RIPT tests.

Ricicles

Low blood glucose levels at 30 minutes were associated with more correct responses on all three RIPT tests, quicker Decision times on the last two Hick tests, increased word recall and lower Intercept values on the second test session. Slow falling blood glucose levels between 60 and 100 minutes predicted better total mood over the first 30 minutes, and increased Elation between 30 and 100 minutes.

Weetabix

High and slow falling blood glucose levels over the last hour of the morning were associated with increased Composure over the last 90 minutes, and Clearheadedness over the last hour. Falling blood glucose levels over the last hour predicted increased reports of hunger over the last 90 minutes. No consistent patterns were observed with the Hick and RIPT tests.

Shredded Wheat

No consistent patterns are observed for changes in blood glucose levels following consumption of the Shredded Wheat breakfast.

Digestive Biscuits

Slow falling blood glucose levels between 60 and 100 minutes predict better total mood over the first hour of testing, and increased delayed word recall on the first two test sessions. Slow rising blood glucose levels over the first 30 minutes are associated with increased reports of hunger over the first 60 minutes. High blood glucose levels at baseline predicted quicker reaction times and lower intercept values on the first Hick test.

5.4.4 EFFECT OF HABITUAL BREAKFAST CONSUMPTION

Table 5.4 illustrates the nutrient values for the test breakfasts and for the average habitual breakfast as reported by the participants.

There was a trend towards significance for the interaction Habitual breakfast consumers X Session with respect to the number of words recalled [F (2,300) = 2.59, p=0.08], however, SME's showed no significant differences between habitual and non-habitual breakfast at any session, but significant differences in the number of words over the three sessions were observed for both groups.

Mood was also analysed due to the possibility that non-breakfast eating participants, in consuming the test meal, may have had altered mood states compared to habitual breakfast consumers. No differences were observed for either total mood [F (1,150) = 1.39, p=n.s.] or hunger [F (1,150) = 2.48, p=n.s.].

5.5 SUMMARY

Breakfast and Blood Glucose Levels

- Consumption of Cornflakes, Rice Krispies and Shredded Wheat breakfast meals significantly increased blood glucose levels the most, whereas Weetabix breakfasts only produced a small increase despite containing a high amount of RAG.

Breakfast, Mood and Hunger

- Eating any breakfast, compared to fasting, significantly enhanced ratings of Composure over time.
- Participants who consumed the Weetabix meal were significantly more agreeable over then morning than those who consumed Cornflakes or Digestive Biscuits.
- Consumption of any breakfast significantly reduced hunger ratings compared to the fasting condition.

Breakfast and Memory

- Consumption of the Digestive Biscuit breakfast resulted in a similar amount of time being taken to recall the word lists over the three sessions.

Breakfast and other Cognitive tests

- Breakfast meal failed to influence any measure of the Hick Paradigm, or the RIPT.

Breakfast and Blood Glucose Levels

- Slow falling and stable blood glucose levels after 60 minutes was associated with enhanced mood in those who consumed Ricicles and Weetabix breakfasts. No consistent patterns were observed with hunger.
- Low and stable blood glucose levels throughout the morning were associated with enhanced memory performance for all conditions. One can suggest that good glucose tolerance was associated with better memory.

- Falling blood glucose levels were associated with better performance on the Hick Paradigm, with low and consistent blood glucose levels throughout the morning were associated with enhanced performance on the RIPT, for those who consumed the high RAG meals; Cornflakes, Rice Krispies and Ricicles. No patterns were observed across the remaining breakfast conditions.

5.6 DISCUSSION

The consumption of breakfast, as opposed to fasting, significantly enhanced mood and reduced hunger. However no breakfast meal was significantly better for either measure. Furthermore, there was no effect of breakfast on measures of cognition.

Low and consistent blood glucose levels, illustrated by a flatter response in blood glucose levels, were associated with better mood and cognitive performance. Furthermore, when blood glucose levels rose to high levels, falling blood glucose levels towards the end of the morning were associated with better performance. Again it can be suggested that individual differences in glucose tolerance are an important factor with respect to cognitive performance.

It must be noted that all meals offered 30g of carbohydrate, however, they differed on the ration of RAG to SAG, and of course, the nutritional content. One can see from Table 5.2 that the Cornflakes, Rice Krispies and Ricicles meals were very similar in nutritional content, as well as RAG and SAG ratios. The other three meals, however, were each quite different. Falling blood glucose levels, in those who consumed the high RAG meals were associated with better cognitive performance. Therefore, efficient utilisation of the carbohydrate consumed was associated with better performance.

The blood glucose levels profile of the other three meals was very similar, each exhibiting more stable levels over time. One could suggest that these meals, in particular the Weetabix (high RAG, high fibre) and Shredded Wheat (high SAG, high fibre) were more beneficial as the nutritional content failed to produce the sharp increase in blood glucose levels over the first 30 minutes.

Previous drink studies have often typically cited an intake of between 25-50g of glucose eliciting a beneficial effect on memory (Donohoe and Benton, 1999a; 1999b; Foster et al., 1998; Hall et al., 1989). This meal study used 30g carbohydrate. Previous meal experiments have typically cited an intake of approx 400kcal and upwards (Fischer et al., 2002; 2001; Kaplan et al., 2001; 2000; Cunliffe et al., 1997). This meal study typically used approx 150Kcal. It is possible that the meals given in this study were not large enough themselves to elicit positive enhancement with respect to cognition, but that the patterns observed with respect to the blood glucose levels can give indications as to what should be approached as a better breakfast meal.

A more detailed discussion of the findings is given in Chapters 8 and 9, following the meta-analysis of all breakfast studies (Chapter 7).

5.6.1 CONCLUSION

The present findings suggest again that the ability to effectively utilise the carbohydrate load ingested is an important factor influencing mood and cognitive functioning. Again it was implied that meal size may also be an important factor; the smaller meals in this study may have not be sufficient to elicit enhanced mood and cognition. These concepts will be investigated in more depth in subsequent chapters.

Table 5.5: Summary table with respect to measures of Mood (+/-s.e.m)

MOOD	MEAL	30mins – base	60mins – base	105mins – base	150mins – base	RESULT
Composure	Fast	3.478 (3.939)	0.000 (4.362)	-4.522 (4.961)	-6.5685 (4.995)	*Meal* F (6,157) = 1.242, p=0.288
	CF	-5.609 (3.939)	0.391 (4.362)	-2.435 (4.691)	2.913 (4.995)	
	RK	6.435 (3.939)	1.391 (4.362)	-0.696 (4.691)	-2.609 (4.995)	*Time* F (3,471) = 1.379, p=0.248
	R	7.120 (3.778)	1.520 (4.184)	7.240 (4.499)	9.000 (4.791)	*Meal X Time* F (18,471) = 1.661, p<0.05
	W	7.739 (3.939)	0.348 (4.362)	3.609 (4.691)	2.870 (4.995)	
	SW	2.000 (3.856)	3.667 (4.271)	6.500 (4.592)	0.917 (4.890)	
	DB	-5.348 (3.939)	-8.000 (4.362)	-3.696 (4.691)	-9.043 (4.995)	
Agreeability	Fast	4.043 (2.851)	1.435 (3.529)	-1.348 (3.926)	0.304 (3.859)	*Meal* F (6,157) = 3.190, p<0.01
	CF	-4.435 (2.851)	-3.000 (3.529)	-5.130 (3.926)	-7.565 (3.859)	
	RK	-0.435 (2.851)	-6.348 (3.529)	-7.826 (3.926)	-3.043 (3.859)	*Time* F (3,471) = 5.463, p=0.001
	R	-0.600 (2.735)	-4.240 (3.385)	-1.320 (3.766)	1.080 (3.702)	*Meal X Time* F (18,471) = 1.427, p=0.114
	W	10.130 (2.851)	9.130 (3.529)	8.565 (3.926)	8.957 (3.859)	
	SW	1.875 (2.791)	-4.833 (3.455)	-0.167 (3.843)	1.083 (3.778)	
	DB	0.174 (2.851)	-7.478 (3.529)	-11.000 (3.926)	-11.435 (3.859)	
Elation	Fast	-0.739 (2.774)	-1.217 (3.083)	-3.000 (3.301)	-3.304 (3.516)	*Meal* F (6,157) = 1.066, p=0.386
	CF	-1.870 (2.774)	-2.130 (3.083)	-1.522 (3.301)	-8.652 (3.516)	
	RK	6.609 (2.774)	0.913 (3.083)	0.261 (3.301)	3.043 (3.516)	*Time* F (3,471) = 1.628, p=0.182
	R	4.240 (2.660)	1.880 (2.957)	4.160 (3.166)	4.720 (3.372)	*Meal X Time* F (18,471) = 1.242, p=0.223
	W	1.261 (2.774)	3.652 (3.083)	3.435 (3.301)	2.217 (3.516)	
	SW	-0.458 (2.715)	-2.792 (3.018)	-1.542 (3.232)	1.042 (3.442)	
	DB	2.391 (2.774)	2.000 (3.083)	0.348 (3.301)	-3.696 (3.516)	

Confidence	Fast	3.130 (2.882)	2.696 (3.691)	4.043 (3.295)	0.609 (4.224)	*Meal* F (6,157) = 0.815, p=0.560
	CF	6.217 (2.882)	8.826 (3.691)	7.913 (3.295)	9.304 (4.224)	
	RK	5.652 (2.882)	3.217 (3.691)	2.391 (3.295)	-0.391 (4.224)	*Time* F (3,471) = 0.377, p=0.770
	R	5.040 (2.764)	5.840 (3.799)	8.000 (3.160)	9.840 (4.051)	*Meal X Time* F (18,471) = 0.746, p=0.763
	W	2.130 (2.882)	2.870 (3.691)	-0.391 (3.295)	1.609 (4.224)	
	SW	4.208 (2.821)	0.833 (3.877)	1.667 (3.225)	-1.917 (4.135)	
	DB	5.565 (2.882)	4.913 (3.691)	3.261 (3.295)	4.261 (4.224)	
Energy	Fast	-0.522 (3.980)	-4.957 (5.109)	-7.957 (5.706)	-7.913 (5.916)	*Meal* F (6,157) = 1.801, p=0.102
	CF	1.478 (3.980)	-1.478 (5.109)	-7.174 (5.706)	-11.826 (5.916)	
	RK	12.696 (3.980)	9.000 (5.109)	7.609 (5.706)	9.391 (5.916)	*Time* F (3,471) = 14.922, p<0.001
	R	11.320 (3.818)	4.280 (4.901)	3.240 (5.473)	1.760 (5.674)	
	W	11.087 (3.980)	8.261 (5.109)	-1.826 (5.706)	-1.957 (5.916)	*Meal X Time* F (18,471) = 0.756, p=0.752
	SW	0.583 (3.897)	-5.458 (5.002)	-7.792 (5.586)	-6.542 (5.791)	
	DB	8.304 (3.980)	10.043 (5.109)	5.000 (5.706)	-0.565 (5.916)	
Clearheaded	Fast	0.174 (3.340)	-6.391 (4.537)	-1.696 (4.797)	-8.652 (4.962)	*Meal* F (6,157) = 0.834, p=0.545
	CF	1.565 (3.340)	-1.565 (4.537)	-2.174 (4.797)	-3.696 (4.962)	
	RK	7.913 (3.340)	3.739 (4.537)	6.130 (4.797)	2.348 (4.962)	*Time* F (3,471) = 7.687, p<0.001
	R	6.000 (3.204)	4.880 (4.351)	2.200 (4.601)	3.360 (4.759)	*Meal X Time* F (18,471) = 0.689, p=0.823
	W	5.913 (3.340)	0.174 (4.537)	-6.565 (4.797)	-5.261 (4.962)	
	SW	7.042 (3.270)	2.917 (4.441)	0.458 (4.696)	2.542 (4.858)	
	DB	1.826 (3.340)	-0.957 (4.537)	-3.565 (4.797)	-2.478 (4.962)	

Total Mood	Fast	9.565 (12.527)	-8.438 (17.471)	-14.478 (17.362)	-25.522 (18.404)	*Meal* F (6,157) = 1.002, p=0.426
	CF	-2.652 (12.527)	1.043 (17.471)	-10.522 (17.362)	-19.522 (18.404)	
	RK	38.870 (12.527)	11.913 (17.471)	7.870 (17.362)	8.739 (18.404)	*Time* F (3,471) = 9.525, p<0.001
	R	33.120 (12.015)	14.160 (16.757)	23.520 (16.653)	29.760 (17.652)	*Meal X Time* F (18,471) = 0.689, p=0.823
	W	38.261 (12.527)	24.435 (17.471)	6.826 (17.362)	8.435 (18.404)	
	SW	15.250 (12.263)	-5.667 (17.103)	-0.875 (16.996)	-2.875 (18.016)	
	DB	12.913 (12.527)	0.522 (17.471)	-9.652 (17.362)	-22.957 (18.404)	
Hunger	Fast	-4.739 (5.176)	0.783 (5.285)	9.739 (5.859)	13.826 (6.461)	*Meal* F (6,157) = 8.088, p<0.001
	CF	-41.130 (5.176)	-36.957 (5.285)	-30.870 (5.859)	-19.478 (6.461)	
	RK	-25.130 (5.176)	-24.826 (5.285)	-18.087 (5.859)	-12.652 (6.461)	*Time* F (3,471) = 31.847, p<0.001
	R	-40.280 (4.964)	-45.880 (5.069)	-35.760 (5.620)	-32.160 (6.198)	
	W	-33.435 (5.176)	-33.087 (5.285)	-26.957 (5.859)	-19.435 (6.461)	*Meal X Time* F (18,471) = 0.628, p=0.878
	SW	-28.542 (5.607)	-25.667 (5.174)	-19.875 (5.736)	-13.542 (6.325)	
	DB	-35.261 (5.176)	-34.348 (5.285)	-33.565 (5.859)	-24.174 (6.461)	

Table 5.6: Summary table with respect to the total number of words recalled on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	10.174 (0.527)	8.130 (0.569)	8.696 (0.573)	4.957 (0.625)	8.609 (0.614)	3.696 (0.668)	*Meal* F (6,157) = 0.532, p=0.783
CF	10.565 (0.527)	7.478 (0.569)	9.348 (0.573)	4.696 (0.625)	8.478 (0.614)	3.522 (0.668)	*Session* F (2,314) =
RK	10.957 (0.527)	8.435 (0.569)	9.435 (0.573)	4.913 (0.625)	8.870 (0.614)	4.870 (0.668)	108.419, p<0.001 *Meal X Session*
R	10.480 (0.505)	7.800 (0.546)	9.320 (0.549)	5.640 (0.599)	8.480 (0.589)	4.360 (0.640)	F (12,314) = 1.545, p=0.107 *Recall*
W	10.174 (0.527)	8.130 (0.569)	9.478 (0.573)	5.652 (0.625)	9.348 (0.614)	4.522 (0.668)	F (1,157) = 1356.675, p<0.001
SW	11.583 (0.516)	9.125 (0.557)	9.958 (0.561)	5.083 (0.612)	9.417 (0.601)	4.292 (0.654)	*Meal X Recall* F (6,157) = 1.199, p=0.310
DB	9.391 (0.527)	6.652 (0.569)	9.348 (0.573)	5.000 (0.625)	9.043 (0.614)	4.739 (0.668)	*Session X Recall* F (2,314) = 53.042, p<0.001 *Meal X Session X Recall* F (12,314) = 0.962, p=0.486

Table 5.7: Summary table with respect to the number of Concrete words recalled on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	6.609 (0.404)	5.696 (0.448)	5.174 (0.413)	3.435 (0.425)	4.609 (0.389)	2.130 (0.395)	*Meal* $F(6,157) = 0.419, p=0.866$
CF	6.652 (0.404)	5.304 (0.448)	5.609 (0.413)	3.304 (0.425)	4.609 (0.389)	2.087 (0.395)	*Session* $F(2,314) = 136.170, p<0.001$
RK	7.217 (0.404)	5.913 (0.448)	5.609 (0.413)	3.217 (0.425)	5.130 (0.389)	3.000 (0.395)	*Meal X Session* $F(12,314) = 1.374, p=0.177$
R	6.320 (0.388)	5.640 (0.430)	5.720 (0.397)	3.720 (0.408)	4.440 (0.373)	2.640 (0.379)	*Recall* $F(1,157) = 640.547, p<0.001$
W	6.696 (0.404)	5.739 (0.448)	5.478 (0.413)	3.609 (0.425)	4.783 (0.389)	2.565 (0.395)	*Meal X Recall* $F(6,157) = 1.052, p=0.394$
SW	6.875 (0.396)	6.167 (0.439)	5.875 (0.405)	3.417 (0.416)	4.792 (0.381)	2.708 (0.387)	*Session X Recall* $F(2,314) = 42.674, p<0.001$
DB	5.696 (0.404)	4.478 (0.448)	5.565 (0.413)	3.348 (0.425)	5.043 (0.389)	2.739 (0.395)	*Meal X Session X Recall* $F(12,314) = 0.701, p=0.751$

Table 5.8: Summary table with respect to the number of Abstract words recalled on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	3.565 (0.315)	2.435 (0.307)	3.522 (0.329)	1.522 (0.302)	4.000 (0.328)	1.565 (0.336)	*Meal* F (6,157) = 0.631, p=0.705
CF	3.913 (0.315)	2.174 (0.307)	3.739 (0.329)	1.304 (0.302)	3.870 (0.328)	1.435 (0.336)	*Session* F (2,314) = 6.236, p<0.01
RK	3.739 (0.315)	2.522 (0.307)	3.826 (0.329)	1.696 (0.302)	4.130 (0.328)	1.870 (0.336)	*Meal X Session* F (12,314) = 0.802, p=0.649
R	4.080 (0.303)	2.160 (0.294)	3.600 (0.316)	1.920 (0.290)	4.040 (0.315)	1.720 (0.322)	*Recall* F (1,157) = 1283.452, p<0.001
W	3.478 (0.315)	2.391 (0.307)	4.000 (0.329)	2.043 (0.302)	4.565 (0.328)	1.957 (0.336)	*Meal X Recall* F (6,157) = 2.208, p<0.05
SW	4.708 (0.309)	2.958 (0.300)	4.083 (0.322)	1.583 (0.296)	4.625 (0.321)	1.583 (0.329)	*Session X Recall* F (2,314) = 21.869, p<0.001
DB	3.696 (0.315)	2.174 (0.307)	3.783 (0.329)	1.652 (0.302)	4.000 (0.328)	2.000 (0.336)	*Meal X Session X Recall* F (12,314) = 1.019, p=0.431

Table 5.9: Summary table with respect to the time taken to recall the word lists on the Memory tests (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	30.087 (2.957)	25.826 (1.966)	33.348 (2.655)	22.652 (2.136)	31.217 (2.598)	21.174 (1.908)	*Meal* $F(6,157) = 1.148$, $p=0.337$
CF	46.391 (2.957)	31.217 (1.966)	36.870 (2.655)	25.783 (2.136)	31.826 (2.598)	21.391 (1.908)	*Session*
RK	40.522 (2.957)	29.957 (1.966)	36.957 (2.655)	29.000 (2.136)	34.565 (2.598)	22.913 (1.908)	$F(2,314) = 75.692$, $p<0.001$ *Meal X Session*
R	43.080 (2.836)	31.080 (1.886)	34.920 (2.547)	22.280 (2.049)	38.680 (2.492)	22.880 (1.830)	$F(12,314) = 3.478$, $p<0.001$ *Recall*
W	40.174 (2.957)	30.000 (1.966)	37.783 (2.655)	25.739 (2.136)	37.565 (2.598)	21.478 (1.908)	$F(1,157) = 595.372$, $p<0.001$
SW	46.542 (2.895)	33.375 (1.925)	42.833 (2.599)	27.208 (2.091)	39.958 (2.544)	23.292 (1.866)	*Meal X Recall* $F(6,157) = 2.150$, $p=0.05$
DB	42.087 (2.957)	27.913 (1.966)	41.435 (2.655)	26.435 (2.136)	40.130 (2.598)	24.348 (1.908)	*Session X Recall* $F(2,314) = 2.183$, $p=0.114$ *Meal X Session X Recall* $F(12,314) = 1.300$, $p=0.217$

Table 5.10: Summary table for Decision Times on the Hick Paradigm (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	302.071 (8.606)	324.143 (8.139)	346.857 (9.539)	378.762 (13.028)	*Meal* F (6,146) = 0.191,
	CF	296.568 (8.408)	327.318 (7.952)	349.000 (9.320)	399.318 (12.728)	p=0.979
	RK	307.762 (8.606)	329.452 (8.139)	352.595 (9.539)	380.714 (13.028)	*Session* F (2,292) = 0.721,
	R	300.667 (8.050)	315.854 (7.613)	347.938 (8.293)	405.375 (12.186)	p=0.487 *Meal X Session*
	W	303.304 (8.224)	320.609 (7.777)	337.935 (9.115)	384.217 (12.449)	F (12,292) = 0.349, p=0.979
	SW	316.130 (8.224)	324.761 (7.777)	358.717 (9.115)	394.478 (12.449)	*Lamps* F (3,438) = 403.701,
	DB	304.632 (9.048)	325.974 (8.557)	356.237 (10.029)	389.921 (13.696)	p<0.001 *Meal X Lamps*
Sess 2	Fast	302.762 (7.500)	323.643 (8.163)	350.119 (10.199)	387.881 (14.215)	F (18,438) = 0.519, p=0.949
	CF	288.977 (7.328)	326.750 (7.975)	358.341 (9.964)	396.273 (13.888)	*Session X Lamps* F (6,876) = 1.448,
	RK	302.048 (7.500)	321.310 (8.163)	345.429 (10.199)	391.286 (14.215)	p=0.193 *Meal X Session X*
	R	300.979 (7.016)	326.750 (7.635)	341.688 (9.540)	387.917 (13.297)	*Lamps* F (36,876) = 0.787,
	W	290.391 (7.167)	313.870 (7.800)	336.065 (9.745)	387.000 (13.583)	p=0.811
	SW	303.391 (7.167)	333.000 (7.800)	354.522 (9.745)	389.261 (13.583)	
	DB	295.921 (7.885)	313.158 (8.581)	344.684 (10.722)	385.447 (14.945)	
Sess 3	Fast	303.667 (7.424)	320.071 (8.013)	347.310 (10.058)	389.738 (18.272)	
	CF	295.273 (7.254)	326.659 (7.829)	351.886 (9.827)	403.977 (17.852)	
	RK	303.405 (7.424)	324.690 (8.013)	350.381 (10.058)	392.214 (18.272)	
	R	299.542 (6.945)	327.833 (7.495)	347.917 (9.048)	390.604 (17.092)	
	W	293.826 (7.094)	312.630 (7.656)	349.130 (9.611)	394.696 (17.459)	
	SW	300.652 (7.094)	321.087 (7.656)	343.022 (9.611)	399.652 (17.459)	
	DB	286.684 (7.805)	311.447 (8.424)	339.921 (10.574)	398.316 (19.206)	

Table 5.11: Summary table for Movement Times on the Hick Paradigm (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	187.643 (9.737)	194.452 (9.801)	205.548 (10.116)	218.071 (9.904)	*Meal* $F(6,146) = 0.734$, $p=0.623$
	CF	173.659 (9.513)	179.364 (9.576)	184.568 (9.884)	192.455 (9.676)	
	RK	186.952 (9.737)	195.524 (9.801)	201.190 (10.116)	206.690 (9.904)	*Session* $F(2,292) = 0.823$, $p=0.440$
	R	191.000 (9.108)	187.104 (9.168)	199.979 (9.463)	204.833 (9.264)	*Meal X Session* $F(12,292) = 1.007$, $p=0.442$
	W	179.000 (9.304)	176.543 (9.365)	181.630 (9.666)	196.978 (9.464)	
	SW	181.804 (9.304)	180.761 (9.365)	189.326 (9.666)	190.761 (9.464)	*Lamps* $F(3,438) = 68.402$, $p<0.001$
	DB	185.105 (10.237)	197.000 (10.304)	203.263 (10.635)	208.789 (10.412)	*Meal X Lamps* $F(18,438) = 0.920$, $p=0.554$
Sess 2	Fast	192.500 (11.087)	200.143 (11.173)	205.643 (10.976)	220.119 (10.668)	
	CF	186.045 (10.832)	192.023 (10.916)	193.477 (10.724)	200.045 (10.423)	*Session X Lamps* $F(6,876) = 0.777$, $p=0.588$
	RK	189.357 (11.087)	193.833 (11.173)	200.571 (10.976)	213.167 (10.668)	*Meal X Session X Lamps* $F(36,876) = 1.399$, $p=0.061$
	R	179.250 (10.371)	181.729 (10.452)	193.313 (10.267)	192.479 (9.979)	
	W	179.652 (10.594)	177.370 (10.676)	189.435 (10.488)	200.130 (10.193)	
	SW	174.587 (10.594)	181.000 (10.676)	184.391 (10.488)	195.391 (10.193)	
	DB	218.526 (11.656)	210.263 (11.747)	206.184 (11.539)	211.500 (11.215)	
Sess 3	Fast	192.048 (11.305)	197.548 (10.869)	197.333 (10.830)	211.738 (11.452)	
	CF	188.318 (11.045)	191.045 (10.619)	194.591 (10.581)	203.909 (11.188)	
	RK	190.000 (11.305)	191.690 (10.869)	206.643 (10.830)	218.048 (11.452)	
	R	181.813 (10.575)	183.917 (10.167)	190.875 (10.130)	204.583 (10.712)	
	W	177.174 (10.903)	178.261 (10.386)	190.522 (10.348)	195.087 (10.942)	
	SW	175.283 (10.903)	177.630 (10.386)	185.304 (10.348)	193.000 (10.942)	
	DB	189.895 (11.885)	201.474 (11.427)	200.553 (11.385)	212.895 (12.039)	

Table 5.12: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3	RESULT
Intercept	Fast	300.024 (8.158)	298.824 (7.723)	297.390 (7.809)	*Meal* F (6,146) = 0.508, p=0.801
	CF	293.564 (7.971)	289.573 (7.545)	291.755 (7.630)	
	RK	306.329 (8.158)	296.248 (7.723)	298.857 (7.809)	*Session* F (2,292) = 5.749, p<0.01
	R	290.521 (7.631)	297.971 (7.224)	297.475 (7.305)	*Meal X Session* F (12,292) = 1.574, p=0.098
	W	297.500 (7.796)	285.039 (7.380)	286.713 (7.462)	
	SW	308.191 (7.796)	303.187 (7.380)	293.261 (7.462)	
	DB	301.279 (8.577)	289.795 (8.119)	279.600 (8.210)	
Slope	Fast	25.290 (3.713)	28.176 (4.178)	28.543 (5.500)	*Meal* F (6,146) = 0.549, p=0.770
	CF	33.009 (3.628)	35.359 (4.082)	35.145 (5.373)	
	RK	24.205 (3.713)	29.186 (4.178)	29.214 (5.500)	*Session* F (2,292) = 1.866, p=0.157
	R	34.629 (3.474)	27.588 (3.909)	29.317 (5.145)	*Meal X Session* F (12,292) = 0.589, p=0.851
	W	26.013 (3.548)	31.204 (3.993)	33.922 (5.255)	
	SW	26.909 (3.548)	27.904 (3.933)	31.900 (5.255)	
	DB	28.621 (3.904)	30.016 (4.393)	36.332 (5.782)	
Intra-Individual Variability	Fast	166.174 (20.372)	171.650 (22.626)	175.760 (24.750)	*Meal* F (6,146) = 0.472, p=0.828
	CF	182.200 (19.903)	212.216 (22.106)	205.224 (24.181)	
	RK	151.717 (20.372)	169.299 (22.626)	171.079 (24.750)	*Session* F (2,292) = 0.278, p=0.757
	R	196.740 (19.056)	167.351 (21.165)	167.514 (23.152)	*Meal X Session* F (12,292) = 0.458, p=0.937
	W	175.208 (19.466)	166.032 (21.620)	183.359 (23.650)	
	SW	187.076 (19.466)	182.643 (21.620)	197.730 (23.650)	
	DB	186.513 (21.417)	183.541 (23.787)	188.070 (26.020)	

Table 5.13: Summary table for Correct responses on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Correct 1	Fast	4.682 (0.435)	4.364 (0.411)	2.864 (0.370)	3.500 (0.410)	3.182 (0.359)	*Meal* F (6,145) =
	CF	4.500 (0.435)	4.318 (0.411)	3.773 (0.370)	4.318 (0.410)	3.000 (0.359)	0.878, p=0.513
	RK	4.636 (0.435)	4.136 (0.411)	3.364 (0.370)	3.591 (0.410)	3.045 (0.359)	*Session* F (2,290) =
	R	5.045 (0.435)	4.136 (0.411)	3.818 (0.370)	4.409 (0.410)	3.409 (0.359)	1.919, p=0.149 *Meal X Session*
	W	5.182 (0.435)	4.818 (0.411)	4.045 (0.370)	5.091 (0.410)	3.682 (0.359)	F (12,290) = 0.922, p=0.525
	SW	5.190 (0.455)	4.714 (0.421)	3.333 (0.378)	3.476 (0.419)	2.524 (0.367)	*Minute* F (4,580) =
	DB	4.619 (0.455)	3.952 (0.421)	4.429 (0.378)	3.762 (0.419)	2.952 (0.367)	95.928, p<0.001 *Meal X Minute*
Correct 2	Fast	4.727 (0.452)	4.545 (0.422)	3.727 (0.376)	4.727 (0.424)	2.955 (0.343)	F (24,580) = 0.872, p=0.642
	CF	4.455 (0.452)	4.455 (0.422)	3.727 (0.376)	4.500 (0.424)	2.955 (0.343)	*Session X Minute* F (8,1160) =
	RK	4.364 (0.452)	4.000 (0.422)	3.818 (0.376)	3.955 (0.424)	2.864 (0.343)	1.227, p=0.279 *Meal X Session*
	R	4.909 (0.452)	4.500 (0.422)	4.000 (0.376)	4.727 (0.424)	3.000 (0.343)	*X Minute* F (48,1160) =
	W	5.455 (0.452)	4.727 (0.422)	4.409 (0.376)	4.955 (0.424)	3.318 (0.343)	1.199, p=0.169
	SW	4.762 (0.463)	4.143 (0.432)	3.857 (0.385)	3.952 (0.434)	3.095 (0.352)	
	DB	5.143 (0.463)	4.667 (0.432)	4.095 (0.385)	4.286 (0.434)	3.429 (0.352)	
Correct 3	Fast	4.636 (0.433)	4.182 (0.414)	3.591 (0.415)	4.364 (0.435)	2.682 (0.366)	
	CF	4.909 (0.433)	4.182 (0.414)	3.227 (0.415)	3.955 (0.435)	2.818 (0.366)	
	RK	4.364 (0.433)	4.682 (0.414)	3.227 (0.415)	3.955 (0.435)	2.773 (0.366)	
	R	4.273 (0.433)	4.864 (0.414)	3.545 (0.415)	3.864 (0.435)	2.773 (0.366)	
	W	5.727 (0.433)	5.136 (0.414)	4.273 (0.415)	4.455 (0.435)	3.500 (0.366)	
	SW	4.429 (0.444)	4.000 (0.424)	3.619 (0.424)	4.048 (0.445)	3.095 (0.375)	
	DB	5.190 (0.444)	4.667 (0.424)	4.857 (0.424)	4.095 (0.445)	3.429 (0.375)	

Table 5.14: Summary table for Wrong responses on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrong 1	Fast	2.136 (0.673)	1.545 (0.598)	1.636 (0.597)	2.182 (0.699)	1.955 (0.735)	*Meal* F (6,145) =
	CF	2.500 (0.673)	1.909 (0.598)	1.818 (0.597)	2.091 (0.699)	2.773 (0.735)	1.753, p=0.113
	RK	2.000 (0.673)	1.955 (0.598)	2.045 (0.597)	2.409 (0.699)	2.636 (0.735)	*Session* F (2,290) =
	R	3.182 (0.673)	2.136 (0.598)	2.000 (0.597)	2.273 (0.699)	1.727 (0.735)	6.313, p<0.01 *Meal X Session*
	W	1.136 (0.673)	0.864 (0.598)	1.045 (0.597)	1.091 (0.699)	1.682 (0.735)	F (12,290) = 1.309, p=0.212
	SW	2.286 (0.689)	2.905 (0.612)	1.619 (0.611)	2.048 (0.716)	1.810 (0.753)	*Minute* F (4,580) =
	DB	4.190 (0.689)	4.048 (0.612)	4.000 (0.611)	4.381 (0.716)	3.381 (0.753)	2.766, p<0.05 *Meal X Minute*
Wrong 2	Fast	1.545 (0.572)	1.136 (0.704)	1.227 (0.659)	1.318 (0.644)	1.909 (0.704)	F (24,580) = 1.178, p=0.255
	CF	1.955 (0.572)	2.273 (0.704)	1.318 (0.659)	2.136 (0.644)	1.682 (0.704)	*Session X Minute*
	RK	1.955 (0.572)	2.182 (0.704)	2.045 (0.659)	2.136 (0.644)	2.091 (0.704)	F (8,1160) = 1.779, p=0.077
	R	1.182 (0.572)	1.364 (0.704)	1.545 (0.659)	1.545 (0.644)	1.500 (0.704)	*Meal X Session X Minute*
	W	0.591 (0.572)	1.000 (0.704)	1.636 (0.659)	1.182 (0.644)	1.500 (0.704)	F (48,1160) = 0.780, p=0.860
	SW	1.714 (0.586)	1.857 (0.721)	1.524 (0.675)	1.667 (0.659)	1.762 (0.720)	
	DB	2.905 (0.586)	3.952 (0.721)	3.048 (0.675)	3.238 (0.659)	3.667 (0.720)	
Wrong 3	Fast	1.182 (0.662)	1.000 (0.643)	1.091 (0.630)	1.727 (0.692)	1.636 (0.783)	
	CF	1.545 (0.662)	1.545 (0.643)	1.273 (0.630)	1.955 (0.692)	1.455 (0.783)	
	RK	1.273 (0.662)	1.591 (0.643)	1.818 (0.630)	1.682 (0.692)	2.591 (0.783)	
	R	2.273 (0.662)	1.682 (0.643)	1.136 (0.630)	1.273 (0.692)	2.182 (0.783)	
	W	1.091 (0.662)	1.182 (0.643)	1.773 (0.630)	1.909 (0.692)	3.273 (0.783)	
	SW	1.810 (0.678)	1.381 (0.658)	1.429 (0.645)	1.952 (0.708)	1.714 (0.802)	
	DB	3.571 (0.678)	3.238 (0.658)	3.429 (0.645)	3.429 (0.708)	3.762 (0.802)	

Table 5.15: Summary table for Reaction times on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	Fast	506.818 (34.538)	557.136 (35.920)	529.182 (30.681)	559.136 (36.309)	541.636 (10.470)	*Meal* F (6,145) = 1.154,
	CF	521.682 (34.538)	565.364 (35.920)	500.636 (30.681)	521.455 (36.309)	526.955 (10.470)	p=0.334
	RK	473.818 (34.538)	475.182 (35.920)	527.227 (30.681)	512.182 (36.309)	565.455 (10.470)	*Session* F (2,290) = 2.165,
	R	507.409 (34.538)	556.045 (35.920)	495.773 (30.681)	534.000 (36.309)	521.636 (10.470)	p=0.117 *Meal X Session*
	W	474.500 (34.538)	498.136 (35.920)	545.818 (30.681)	563.727 (36.309)	642.864 (10.470)	F (12,290) = 1.008, p=0.441
	SW	507.857 (35.350)	530.619 (36.765)	601.810 (31.403)	532.857 (37.164)	498.333 (41.422)	*Minute* F (4,580) = 5.526,
	DB	542.190 (35.350)	556.810 (36.765)	601.619 (31.403)	493.667 (37.164)	563.429 (41.422)	p<0.001 *Meal X Minute*
RT 2	Fast	525.955 (32.851)	499.045 (27.805)	512.773 (34.169)	543.455 (34.612)	587.045 (38.662)	F (24,580) = 1.508, p=0.058
	CF	508.364 (32.851)	523.227 (27.805)	560.591 (34.169)	561.500 (34.612)	523.818 (38.662)	*Session X Minute* F (8,1160) = 0.219,
	RK	465.409 (32.851)	465.682 (27.805)	537.864 (34.169)	504.864 (34.612)	571.818 (38.662)	p=0.988 *Meal X Session X*
	R	492.364 (32.851)	517.955 (27.805)	504.182 (34.169)	568.000 (34.612)	519.682 (38.662)	*Minute* F (48,1160) = 1.202,
	W	480.682 (32.851)	471.182 (27.805)	515.455 (34.169)	472.318 (34.612)	493.864 (38.662)	p=0.166
	SW	489.476 (33.264)	491.048 (28.459)	565.905 (34.973)	445.619 (35.436)	532.429 (39.572)	
	DB	524.000 (33.264)	584.667 (28.459)	535.000 (34.973)	584.381 (35.436)	584.429 (39.572)	
RT 3	Fast	503.818 (30.439)	531.682 (32.365)	489.500 (32.415)	534.955 (40.080)	574.136 (37.154)	
	CF	490.818 (30.439)	526.227 (32.365)	527.136 (32.415)	452.136 (40.080)	476.682 (37.154)	
	RK	489.455 (30.439)	441.182 (32.365)	558.773 (32.415)	571.000 (40.080)	513.909 (37.154)	
	R	478.591 (30.439)	567.136 (32.365)	513.318 (32.415)	510.500 (40.080)	498.636 (37.154)	
	W	480.136 (30.439)	512.091 (32.365)	501.682 (32.415)	482.318 (40.080)	527.273 (37.154)	
	SW	448.810 (31.155)	502.857 (33.126)	489.905 (33.178)	531.714 (41.023)	475.667 (38.028)	
	DB	537.286 (31.155)	541.190 (33.126)	596.143 (33.178)	509.667 (41.023)	659.857 (38.028)	

Table 5.5: Summary table with respect to measures of Mood and habitual breakfast consumption (+/-s.e.m)

Total Mood	Fast	9.565 (12.527)	-8.438 (17.471)	-14.478 (17.362)	-25.522 (18.404)	*Meal* F (6,157) =
	CF	-2.652 (12.527)	1.043 (17.471)	-10.522 (17.362)	-19.522 (18.404)	1.002, p=0.426
	RK	38.870 (12.527)	11.913 (17.471)	7.870 (17.362)	8.739 (18.404)	*Time* F (3,471) =
	R	33.120 (12.015)	14.160 (16.757)	23.520 (16.653)	29.760 (17.652)	9.525, p<0.001 *Meal X Time*
	W	38.261 (12.527)	24.435 (17.471)	6.826 (17.362)	8.435 (18.404)	F (18,471) = 0.689, p=0.823
	SW	15.250 (12.263)	-5.667 (17.103)	-0.875 (16.996)	-2.875 (18.016)	
	DB	12.913 (12.527)	0.522 (17.471)	-9.652 (17.362)	-22.957 (18.404)	
Hunger	Fast	-4.739 (5.176)	0.783 (5.285)	9.739 (5.859)	13.826 (6.461)	*Meal* F (6,157) =
	CF	-41.130 (5.176)	-36.957 (5.285)	-30.870 (5.859)	-19.478 (6.461)	8.088, p<0.001
	RK	-25.130 (5.176)	-24.826 (5.285)	-18.087 (5.859)	-12.652 (6.461)	*Time* F (3,471) =
	R	-40.280 (4.964)	-45.880 (5.069)	-35.760 (5.620)	-32.160 (6.198)	31.847, p<0.001
	W	-33.435 (5.176)	-33.087 (5.285)	-26.957 (5.859)	-19.435 (6.461)	*Meal X Time* F (18,471) =
	SW	-28.542 (5.607)	-25.667 (5.174)	-19.875 (5.736)	-13.542 (6.325)	0.628, p=0.878
	DB	-35.261 (5.176)	-34.348 (5.285)	-33.565 (5.859)	-24.174 (6.461)	

Chapter 6: The effects of Breakfast biscuits differing in RAG and SAG ratios

6.1 INTRODUCTION

The previous chapter demonstrated that compared to those who fasted, those who ate breakfast demonstrated significantly better mood and reported less hunger over the morning. However, consumption of the various breakfast meals differing in RAG and SAG ratios failed to influence cognitive performance and mood differently. No breakfast was significantly better than the other breakfast meals across all measures. Once again it was suggested that individual differences in glucose tolerance were an important factor with respect to cognitive performance.

In this chapter, the influence of breakfast biscuits, specifically manufactured to contain a high amount of SAG, and to release glucose slowly over a period of four hours (Prince Petit Dej, LU Biscuits, Danone) were compared with the effects of breakfast bars high in RAG (Choco Krispies cereal bars, Kelloggs).

6.1.1 AIM

This chapter aimed to further test the hypothesis that breakfast bars (RAG) and biscuits (SAG) effect cognitive functioning and mood differently. It was hypothesised that those participants who consumed the SAG breakfast would have enhanced psychological functioning and mood due to a slow and steady release of glucose (Kaplan et al., 2000). It was also hypothesised that consumption of either breakfast would improve performance compared to fasting (Chapters 3-5).

6.2 METHOD

6.2.1 PARTICIPANTS

106 female undergraduate students, mean age 21.13 years (SD 2.64), acted as participants. All were recruited through advertisements within the University of Wales, Swansea.

Groups of participants were compared under three conditions:

1. Control Condition – No food (N=35; mean 21.51; SD 2.96)
2. RAG Condition – 49g Choco Krispies Bars (Kelloggs)

   (N=35; mean 20.23yrs; SD 1.57)
3. SAG Condition – 50g Prince Petit Dej' Biscuits by LU (Danone) #

   (N=36; mean 21.24yrs; SD 2.96).

Table 6.1 illustrates the nutritional content of the meals. All participants fasted overnight, and once in the laboratory consumed their allocated breakfast meal. All participants gave written consent and the local Ethics Committee approved the procedure.

Table 6.1: Mean Nutritional values for the test breakfast and habitual breakfasts consumed by the participants

Meal	Weight (g)	Energy (Kcal)	Carb (g)	Fat (g)	Protein (g)	Fibre (g)
Choco Krispies	49.00	220.50	34.30	7.35	4.90	0.49
Prince Petit Dej	50.00	230.00	34.00	9.00	3.25	2.25
Habitual	396.17	347.20	56.03	11.43	11.53	4.46

6.2.2 BREAKFAST

In addition to each participant receiving the allocated breakfast (Table 6.1), a choice of beverages were offered. Decaffeinated Tea (Typhoo) or Decaffeinated Coffee (Nescafe), with skimmed milk (up to 35ml) and sweetener (Hermesetas) if required, or Sugar Free Orange Squash (Robinson's R) were given. Participants also had unlimited access to water throughout the experiment.

6.2.3 WORD LISTS

Four lists of 30 words, having four and six letters (15 of each), were chosen to be high in frequency and imagery (Quinlan, 1992). Each list had 12 abstract words and 18 concrete words (Appendix 1). The list was presented aurally, at a rate of one word per two seconds using a tape recorder. All responses were written and the time taken was noted.

6.2.4 MOOD

The six basic dimensions of mood dimensions of mood, Total mood and hunger were assessed (section 2.2.4).

6.2.5 COGNITIVE TESTS

The Rapid Information Processing Task (RIPT) and Hick Paradigm (Reaction Times) (section 2.2.4) were used to assess changes in cognitive functioning in responses to the breakfasts consumed.

6.2.6 ADULT EPQ-R

The Adult EPQ-R (Eysenck & Eysenck, 1991) was completed by each individual was used as a cognitive task to increase mental fatigue. Performance on this measure was not assessed.

6.2.7 BLOOD GLUCOSE

Blood glucose determinations were made with the use of an ExacTech sensor, made by Medisense Britain Limited. The sensor uses an enzymic method coupled with microelectronic measurement that has been shown to give valid measures (Matthews et al., 1987).

6.2.8 PROCEDURE

Table 6.2 illustrates the procedure. Blood glucose levels were determined on entering the laboratory. Informed consent was given and Mood questionnaires were completed. Subjects were allocated to one of three conditions, receiving one of test breakfasts. The subjects sat for 20 minutes to allow digestion of the food to begin. Blood glucose levels and Mood were measured for a second time. The word list was then presented aurally, and immediate recall (1) assessed. Subjects then completed the Hick Paradigm and the RIPT (1) on computers. On completion of the tests the third blood glucose reading was taken, and Mood and delayed recall assessed (1) (Table 1). Participants then completed the Adult EPQ-R (Eysenck & Eysenck, 1991) and then sat for 20 minutes.

Following the rest period, blood glucose levels and mood were measured for the fourth time. The second word list was then presented aurally and immediate recall (2) was assessed. Participants then completed the Hick Paradigm (2) and the RIPT (2). On completion of the tests the fifth blood glucose reading was taken, and Mood and delayed recall (2) assessed. Participants then sat for 30 minutes to rest.

The third test session followed this, with immediate recall (3), Hick (3), RIPT (3), delayed recall (3) and the sixth measure of blood glucose and Mood. Participants again sat for 30 minutes to rest.

The fourth test session followed this, with immediate recall (4), Hick (4) RIPT (4) and delayed recall (4). The final measure of blood glucose and Mood was taken and the participants were debriefed.

Table 6.2: Profile of the testing procedure for Chapter 6

9:00	*BGL 1 / MOOD / CONSENT*	0 minutes
9:10	BREAKFAST (Table 5.1) 20 MINUTES WAIT	10 minutes
9:30	*BGL2 / MOOD*	30 minutes
9:40	**TEST SESSION 1** IMMEDIATE RECALL HICK VIGILANCE DELAYED RECALL	40 minutes
10:00	*BGL3 / MOOD* 20 MINUTES WAIT (complete EPQ)	60 minutes
10:30	*BGL4 / MOOD*	90 minutes
10:40	**TEST SESSION 2**	100 minutes
11:00	REST	120 minutes
11:30	*BGL5 / MOOD*	150 minutes
11:40	**TEST SESSION 3**	160 minutes
12:00	REST	180 minutes
12:30	*BGL6 / MOOD*	210 minutes
12:40	**TEST SESSION 4**	220 minutes
13.00	*BGL7 / MOOD / DEBRIEFING*	240 minutes

6.3 STATISTICAL ANALYSIS

6.3.1 EFFECT OF BREAKFAST

- Measures of Blood Glucose were analysed using a two-way ANOVA:

  Breakfast (fast/breakfast) X Time (0, 30, 60, 90, 150, 210, 240 minutes) (repeated measure).

- Difference scores were firstly calculated for the measures of Mood (Composed/Agreeable/Elated/Confident/Energetic/Clearheaded) and Hunger using the following calculation:

  Mood at 30, 60, 90, 150, 210 & 240 minutes – baseline.

  These measures were then analysed using two-way ANOVA's:

  Breakfast (fast/breakfast) X Time (30, 60, 90, 150, 210, 240) (repeated measure).

- Measures of Word Recall, Total, Concrete and Abstract, and Recall Times were analysed using three-way ANOVA's:

  Breakfast (fast/breakfast) X Session (1, 2, 3, 4) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

- Measures of Decision times on the Hick Paradigm were analysed using three-way ANOVA's:

  Breakfast (fast/breakfast) X Session (1, 2, 3, 4) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVA's: Breakfast (fast/breakfast) X Session (1, 2, 3, 4) (repeated measure).

- Measures of Correct responses, Wrong responses and Reaction times on the Vigilance test were analysed using three-way ANOVA's:
  Breakfast (fast/breakfast) X Session (1, 2, 3, 4) (repeated measure) X Minutes (1, 2, 3, 4, 5) (repeated measure).
- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

6.3.2 EFFECT OF MACRONUTRIENTS

As there were only 2 breakfast groups it was not appropriate to calculate Stepwise regression equations using the data set.

6.3.3 EFFECT OF BLOOD GLUCOSE LEVELS AND CHANGE

Stepwise Linear Regressions, with Independent variables of blood glucose levels (0, 30, 60, 90, 150, 210, 240 minutes) and changes in blood glucose levels were performed on the data set. Changes in blood glucose levels were calculated using the following equations:

- Change 1 = BG 30 – BG 0
- Change 2 = BG 60 – BG 30
- Change 3 = BG 90 – BG 60
- Change 4 = BG 150 – BG 90
- Change 5 = BG 210 – BG 150
- Change 6 = BG 240 – BG 210

The regressions were performed on the data separately for each breakfast. The following dependent variables were used:

- Mood at each time point (difference score)
- All aspects of Memory (Immediate and Delayed) for each session
- Total Decision times for each session
- Intercept and Intra-Individual Variability at each time point
- Total Correct, Wrong responses and Reaction times for each session

6.3.4 EFFECT OF HABITUAL BREAKFAST CONSUMPTION

- Measures of Total Mood and Hunger were analysed using three-way ANOVA's: Breakfast (fast/breakfast) X Habitual breakfast consumption (Yes/No) X Difference (30, 60, 90 150, 210, 240) (repeated measure).
- Measures of Word Recall and Recall Times were analysed using four-way ANOVA's: Breakfast (fast/breakfast) X Habitual breakfast consumption (Yes/No) X Session (1, 2, 3, 4) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

6.4 RESULTS

For clarity only significant results involving macronutrients or condition (RAG/SAG) will be reported. It may be assumed that main effects and higher order interactions that are not reported were non-significant.

6.4.1 EFFECT OF BREAKFAST

Breakfast and Blood Glucose Levels

The interaction Breakfast X Time reached significance [F (12,618) = 10.94, p<0.001]. Figure 6.1 and SME's demonstrate that both active meals produced significant changes in blood glucose levels over the test session (Choco Krispies – RAG [F (6,618) = 44.11, p<0.001]; Biscuits – SAG [F (6,618) = 6.03, p<0.001]). Additionally those who consumed the RAG breakfast had significantly higher blood glucose levels than the control and SAG conditions at 30 minutes [F (2,103) = 43.21, p<0.001], 60 minutes [F (2,103 = 14.09, p<0.001) and 90 minutes [F (2,103) = 6.66, p<0.01].

Breakfast and Mood

The breakfast meal consumed influenced subjective ratings of Composure [F (2,103) = 3.31, p<0.05], Energy [F (2,103) = 4.73, p<0.05] and Total Mood [F (2,103) = 3.33, p<0.05]. In each case, participants who consumed the RAG breakfast had significantly better mood over the morning than the fasting condition (Figure 6.2).

Figure 6.1: Profile of Blood Glucose Levels over Time (means +/- s.e.m)

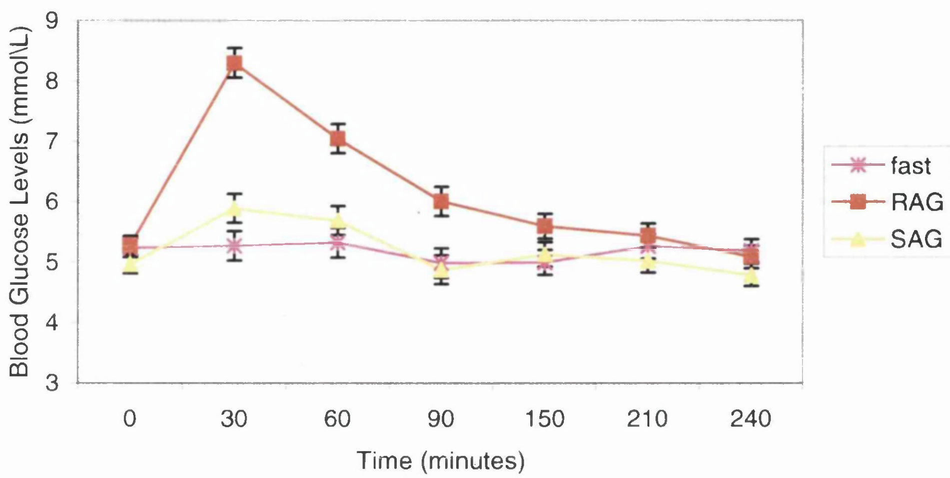
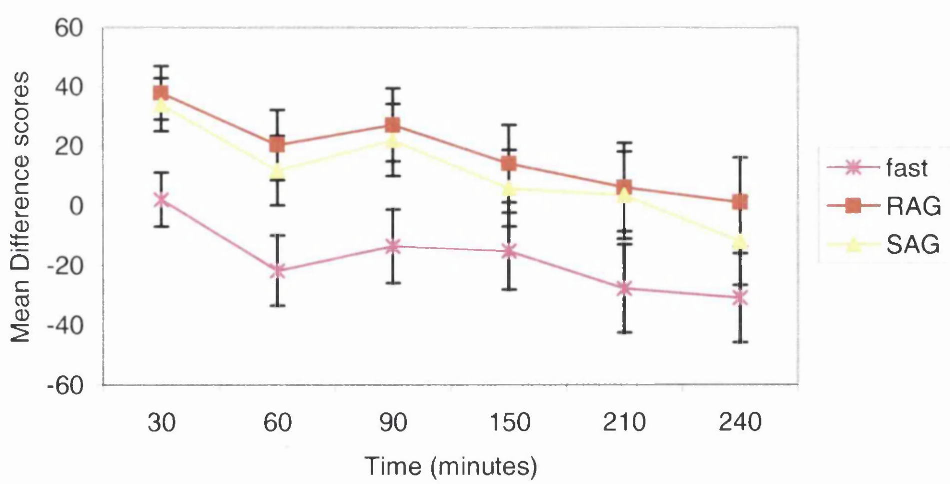


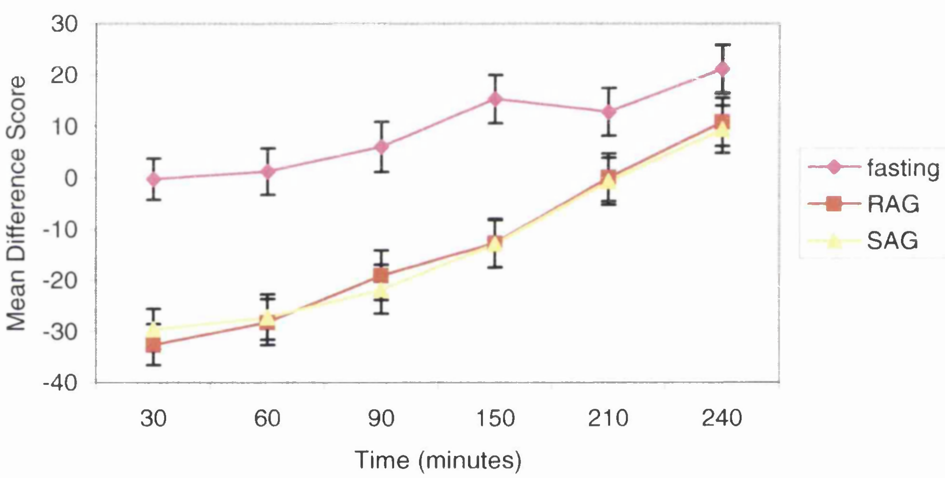
Figure 6.2: Profile of Total mood ratings over Time (means +/- s.e.m)



Breakfast and Hunger

The interaction Breakfast X Time reached significance [F (10,515) = 3.68, p<0.001]. Figure 6.3 illustrates that eating breakfast significantly reduced the ratings of hunger expressed by the participants over the first 150 minutes, it made no difference which breakfast was consumed. There were no significant differences at baseline [F (2,103) = 0.43, p=0.65].

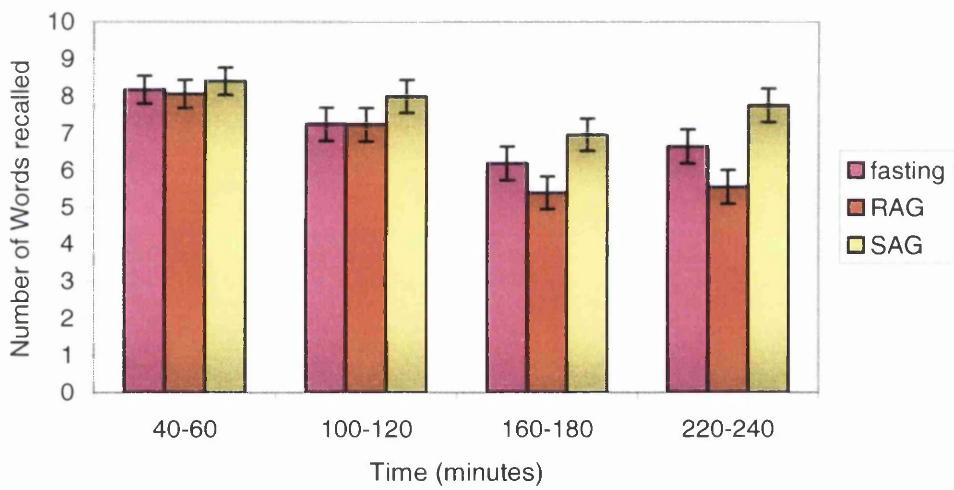
Figure 6.3: Profile of Hunger ratings over Time (mean +/- s.e.m)



Breakfast and Memory

The interaction Breakfast X Session reached significance with respect to total word recall [F (6,309) = 2.12, p=0.05]. Figure 6.4 and SMEs demonstrate that there are significant differences between the three meal conditions at 160 minutes [F (2,103) = 3.11, p<0.05] and 220 minutes after the meal [F (2,103) = 5.83, p<0.01], with those who consumed SAG recalling significantly more words than those who consumed RAG (p<0.05).

Figure 6.4: The effect of Breakfast on Total word recall (means +/- s.e.m)



When the type of words used was analysed, it was found that breakfast meal failed to influence concrete words [F (2,103) = 2.26, p=n.s.], however, the interaction Breakfast X Session approached significance [F (6,309) = 2.03, p=0.06]. SME's show that towards the end of the test session the SAG meal improved memory (160 minutes [F (2,103) = 2.93, p=0.06]; 220 minutes [F (2,103) = 4.05, p<0.05]). When the recall of abstract words was analysed, the type of breakfast influenced recall throughout the morning [F (2,103) = 3.48, p<0.05]. Participants who consumed the SAG meal recalled significantly more words than those who consumed the RAG meal (p<0.05).

Figure 6.6: Profile of the time taken to recall the word lists for Breakfast conditions (means +/- s.e.m)

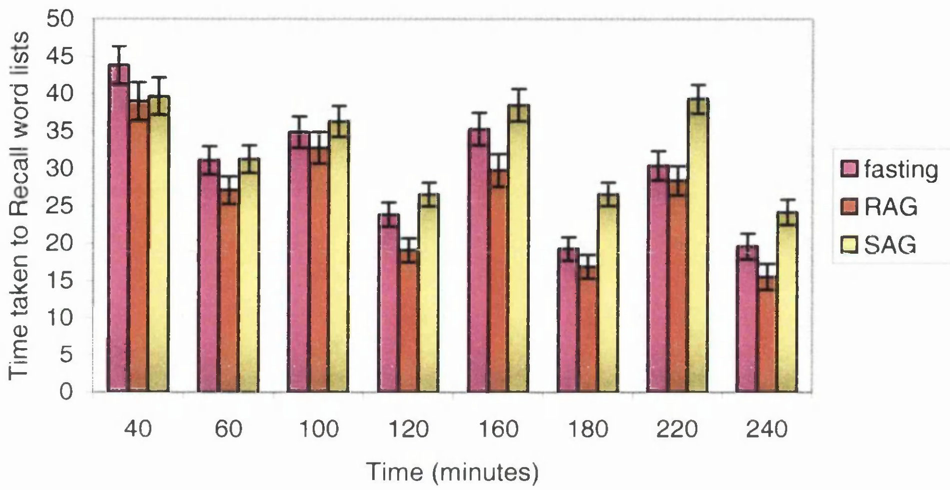


Figure 6.6 illustrates the time taken at immediate (40, 100, 160, 220mins) and delayed recall (60, 120, 180, 240mins). The interaction Breakfast X Recall X Session reached significance with respect to the time taken to recall the word lists [F (6,309) = 2.48, p<0.05]. SSME's demonstrate that there are significant differences between the conditions at 160 [F (2,103 = 4.11, p<0.05] and 220 minutes [F (2,103) = 8.88, p<0.001] at immediate recall. In addition there were significant differences between the conditions at 100, 160 and 220 minutes at delayed recall ([F (2,103) = 5.57, p<0.01]; [F (2,103) = 10.39, p<0.001]; [F (2,103) = 6.34, p<0.01]). In each case, those who had consumed the SAG meal took significantly longer to recall the word lists than those in the RAG condition (p<0.05).

Breakfast and the Hick Paradigm

8 participants were removed from the analysis due to negative slopes.

Breakfast meal failed to influence Decision times on the Hick Paradigm [$F(2,95) = 0.10$, p=n.s.] or Movement times [$F(2,95) = 0.25$, p=n.s.]. Breakfast meal also failed to effect Intercept [$F(2,95) = 2.02$, p=n.s.] or Intra-Individual Variability [$F(2,95) = 2.48$, p=n.s.].

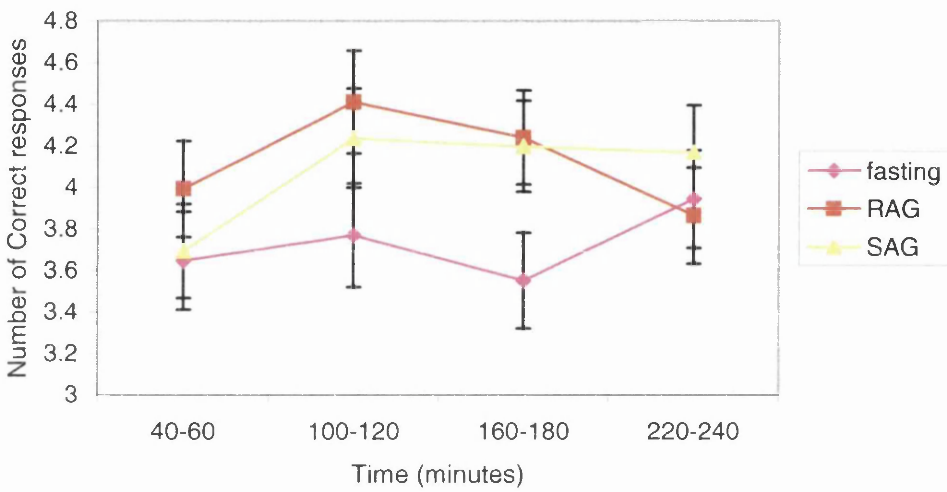
Breakfast consumed influenced Slope values on the Hick Paradigm [$F(2,95) = 3.18$, $p<0.05$]. Participants in the control condition had lower slope values that those who ate either breakfast ($p=0.08$), again the type of breakfast consumed did not have any effect. These results reflected poor performance on the Hick paradigm, as there is an inverse relationship between slope and intercept values (section 9.4).

Breakfast and the RIPT

3 participants were removed from the data set due to incomplete data or incorrect performance on the task (>20 wrong responses per minute).

The interaction Breakfast X Session reached significance with respect to Correct responses on the Vigilance task [$F(6,300) = 2.43$, $p<0.05$]. Figure 6.7 and SMEs demonstrate that there are significant changes in correct responses over the four sessions for those who consumed the RAG breakfast [$F(3,300) = 3.32$, $p<0.05$] and the SAG breakfast [$F(3,300) = 3.83$, $p=0.01$], but not the control [$F(3,300) = 1.54$, $p=0.20$]. Additionally on the third test sessions there was a trend towards significance for those who fasted to record fewer correct responses [F (2,100) = 2.89, p=0.06] compare to those who consumed either RAG or SAG.

Figure 6.7: The effect of Breakfast on Correct responses on the RIPT (means +/- s.e.m)



Breakfast meal consumed failed to influence wrong responses [F (2,100) = 0.01, p=n.s.] or reaction times [F (2,100) = 0.21, p=n.s.].

6.4.2 EFFECT OF BLOOD GLUCOSE LEVELS AND CHANGE

Stepwise linear regressions were performed on the data, with blood glucose levels, and change during the six periods between as the independent variables, and the measures of Mood, Hunger, and Cognition as the dependent variables. Patterns observed within the breakfast conditions are reported.

RAG condition

Low blood glucose levels at 60 minutes and falling levels between 150 and 210 minutes were associated with better mood. Slow falling blood glucose levels between 90 and 150 minutes were associated with increased reports of energy. Rapidly rising blood glucose levels over the first 30 minutes and falling levels after 150 minutes were significantly associated with better word recall. No consistent patterns were observed with either the Hick paradigm or the Vigilance test.

SAG condition

Falling blood glucose levels between 30 and 60 minutes were associated with increased overall mood and Energy over the first 30 minutes of the test session. High blood glucose levels over the first 90 minutes, followed by a subsequent fall between 150 and 210 minutes, were significantly associated with increased word recall over the test sessions. No consistent patterns were observed with either the Hick paradigm or the Vigilance test.

6.4.3 HABITUAL BREAKFAST EATING

Details of what participants usually consumed for breakfast were collected and analysed. As expected the test meals that were given were much smaller in quantity and nutrient value than what was habitually eaten (Table 6.1).

There was a trend towards significance for habitual non-breakfast consumers to recall more words than habitual breakfast consumers following breakfast consumption, suggesting that non-breakfast consumers benefited from consumption of breakfast [$F(1,67) = 3.34$,

$p=0.07$]. Further analysis demonstrated that following RAG consumption, habitual non-breakfast consumers recalled significantly more words compared to habitual breakfast consumers [$F(1,33) = 5.38$, $p<0.05$].

Mood and hunger were also analysed due to the possibility that habitual non-breakfast consumers, following the test meal, may have had altered mood states, however, no effects were observed in either total mood [$F(1,67) = 0.22$, p=n.s.] or hunger $F(1,67) = 1.27$, p=n.s.].

6.5 SUMMARY

Breakfast and Blood Glucose Levels

- Significant changes over time were observed for both active breakfasts, however, the RAG breakfast produced the greatest change in blood glucose levels.
- Low blood glucose levels at 60 minutes and falling levels between 150 and 210 minutes were associated with better mood for those who consumed the RAG breakfast, whereas falling blood glucose levels between 30 and 60 minutes were associated with increased overall mood for those who consumed the SAG breakfast.
- Rapidly rising blood glucose levels over the first 30 minutes and falling levels after 150 minutes were significantly associated with better word recall for those who consumed the RAG breakfast, whereas high blood glucose levels over the first 90

minutes, followed by a subsequent fall between 150 and 210 minutes profiled memory enhancement with respect to the SAG breakfasts.

Breakfast, Mood and Hunger

- Participants who consumed the RAG breakfast reported increased energy and better total mood over the morning.
- The consumption either RAG or SAG, reduced ratings of hunger over the morning compared to those who fasted.

Breakfast and Memory

- Participants who consumed the SAG breakfast took significantly more time, and recalled significantly more words on the recall tests than the other two conditions.

Breakfast and other Cognitive tests

- Participants in the fasting condition had significantly lower Slope values over the morning than either of the breakfast conditions, that is they performed more poorly.
- Participants who consumed the SAG breakfast recorded more correct responses over time.

6.6 DISCUSSION

Breakfasts high in SAG enhanced word list recall after 160 minutes. This effect was observed throughout the morning with the more difficult abstract words. Additionally performance over the test sessions was more consistent in those who had consumed the SAG breakfast, the amount of words recalled did not significantly decline over time. These results are in line with Kaplan et al., (2000) who also reported that SAG breakfasts were associated with enhanced psychological functioning. In addition, the present study demonstrated superior performance following the SAG meal in a healthy young adult sample, which is often suggested to have a somewhat optimal cognitive functioning ability compared to the elderly (Manning et al., 1997).

Subjective energy and total mood was significantly enhanced in those who consumed the RAG breakfast compared to either those who consumed SAG or who fasted. This is consistent with evidence from previous studies (Chapters 2-5), that increasing blood glucose levels, especially after an overnight fast, will increase energy and in turn overall mood.

Again it was demonstrated that low and stable blood glucose levels over the morning were associated with better mood and cognitive performance. This profile was commonly observed after consumption of the SAG meal. Following the RAG meal falling blood glucose levels were associated with enhanced performance. Again one can suggest that the individual's ability to effectively utilise the carbohydrate load is an important factor in relation to mood and cognitive enhancement.

It is clear from the results that different types of glucose influence measures tested differentially. A more detailed discussion of the findings is given in Chapter 8 and 9.

6.6.1 CONCLUSION

The present findings suggest that the type of carbohydrate consumed can influence mood and cognitive performance, in particular memory. Once again individual differences in glucose tolerance were also considered important. Taken together these results demonstrate that in a healthy young adult sample there may be susceptibility to memory dysfunction that can be overcome through changes in blood glucose levels.

Table 6.3: Summary table with respect to measures of Mood (+/- s.e.m)

MOOD	MEAL	30mins – baseline (s.e.m)	60mins – baseline (s.e.m)	105mins – baseline (s.e.m)	150mins – baseline (s.e.m)	210mins – baseline (s.e.m)	240mins – baseline (s.e.m)	RESULT
CP	Fast	0.200 (2.534)	-9.686 (3.237)	-5.571 (3.315)	-4.171 (3.178)	-4.429 (3.653)	-8.771 (3.508)	*Meal* F (2,103) = 3.307, p<0.05
	RAG	5.771 (2.534)	4.629 (3.237)	6.114 (3.315)	2.457 (3.178)	2.571 (3.653)	0.257 (3.508)	*Time*
	SAG	3.944 (2.499)	0.889 (3.191)	3.667 (3.269)	2.139 (3.134)	0.361 (3.602)	-1.222 (3.459)	F (5,515) = 3.418, p<0.01 *Meal X Time* F (10,515) = 0.716, p=0.710
AG	Fast	-2.400 (2.895)	-5.029 (2.840)	-4.229 (3.084)	-2.257 (3.034)	-9.343 (3.393)	-3.171 (3.603)	*Meal* F (2,103) = 1.002, p=0.371
	RAG	0.543 (2.895)	-1.343 (2.840)	-0.886 (3.084)	-0.743 (3.034)	-1.143 (3.393)	-6.543 (3.603)	*Time*
	SAG	3.361 (2.855)	0.833 (2.800)	0.694 (3.041)	0.056 (2.992)	0.806 (3.346)	-0.639 (3.552)	F (5,515) = 1.848, p=0.102 *Meal X Time* F (10,515) = 1.194, p=0.292
EL	Fast	2.800 (2.154)	1.543 (2.393)	2.800 (2.853)	0.486 (2.826)	0.114 (2.858)	-2.829 (3.092)	*Meal* F (2,103) = 0.566, p=0.570
	RAG	4.600 (2.154)	1.743 (2.393)	3.229 (2.853)	0.257 (2.826)	-0.914 (2.858)	-3.314 (3.092)	*Time*
	SAG	5.000 (2.124)	4.694 (2.360)	5.306 (2.813)	3.972 (2.786)	4.000 (2.818)	-0.250 (3.049)	F (5,515) = 5.785, p<0.001 *Meal X Time* F (10,515) = 0.228, p=0.994
CF	Fast	0.543 (1.786)	-4.200 (3.075)	-0.200 (2.789)	-1.086 (3.264)	-2.343 (3.462)	-0.286 (3.165)	*Meal* F (2,103) = 1.474, p=0.234
	RAG	1.600 (1.786)	1.200 (3.075)	2.200 (2.789)	3.567 (3.264)	1.514 (3.462)	5.714 (3.165)	*Time*
	SAG	7.750 (1.761)	2.861 (3.032)	7.806 (2.750)	2.000 (3.218)	4.139 (3.414)	0.722 (3.121)	F (5,515) = 1.247, p=0.286 *Meal X Time* F (10,515) = 1.229, p=0.269

CP – Composed, AG – Agreeability, EL – Elation, CF - Confidence

EN	Fast	-0.686 (3.284)	-0.514 (3.482)	-6.600 (4.254)	-8.029 (4.247)	-8.343 (4.308)	-11.971 (4.368)	*Meal* F (2,103) = 4.730, p<0.05 *Time* F (5,515) = 13.246, p<0.001 *Meal X Time* F (10,515) = 0.513, p=0.881
	RAG	16.886 (3.284)	11.000 (3.482)	11.057 (4.254)	6.514 (4.247)	1.629 (4.308)	3.257 (4.368)	
	SAG	7.444 (3.238)	1.028 (3.433)	-0.306 (4.194)	-2.861 (4.187)	-5.944 (4.248)	-6.611 (4.306)	
CL	Fast	1.629 (2.413)	-3.857 (3.495)	0.257 (3.354)	-0.143 (3.700)	-3.429 (3.960)	-3.886 (4.181)	*Meal* F (2,103) = 0.882, p=0.417 *Time* F (5,515) = 4.521, p<0.001 *Meal X Time* F (10,515) = 0.390, p=0.951
	RAG	8.486 (2.413)	3.171 (3.495)	5.400 (3.354)	1.943 (3.700)	2.571 (3.960)	1.800 (4.181)	
	SAG	6.417 (2.379)	1.389 (3.446)	4.861 (3.307)	0.583 (3.648)	0.194 (3.905)	-3.917 (4.123)	
Total Mood	Fast	2.086 (8.984)	-21.743 (11.778)	-13.543 (12.282)	-15.200 (12.943)	-27.771 (14.793)	-30.914 (14.928)	*Meal* F (2,103) = 3.328, p<0.05 *Time* F (5,515) = 8.277, p<0.001 *Meal X Time* F (10,515) = 0.219, p=0.995
	RAG	37.886 (8.984)	20.400 (11.778)	27.114 (12.282)	14.086 (12.943)	6.229 (14.793)	1.171 (14.928)	
	SAG	33.917 (8.858)	11.964 (11.613)	22.028 (12.110)	5.889 (12.762)	3.556 (14.587)	-11.917 (14.719)	
Hunger	Fast	-0.229 (3.971)	1.257 (4.515)	6.057 (4.865)	15.286 (4.706)	12.800 (4.628)	21.143 (4.656)	*Meal* F (2,103) = 11.928, p<0.001 *Time* F (5,515) = 76.146, p<0.001 *Meal X Time* F (10,515) = 3.675, p<0.001
	RAG	-32.571 (3.971)	-28.171 (4.515)	-18.971 (4.865)	-12.657 (4.706)	0.086 (4.628)	10.857 (4.656)	
	SAG	-29.556 (3.915)	-27.167 (4.452)	-21.722 (4.797)	-12.833 (4.640)	-0.667 (4.563)	9.472 (4.591)	

EN – Energy, CL - Clearheadedness

Table 6.4: Summary table with respect to the Total number of words recalled, Concrete and Abstract words recalled and Recall times on the Memory tests (+/-s.e.m)

MEM	MEAL	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	Imm 4	Del 4	RESULT
Total Word Recall	Fast	9.286 (0.426)	7.086 (3.900)	9.429 (0.458)	5.086 (0.505)	8.543 (0.490)	3.857 (0.482)	8.971 (0.444)	4.343 (0.552)	*Meal:* F (2,103) = 3.108, p<0.05 *Session:* F (3,309) = 28.027, p<0.001 *Session X Meal:* F (6,309) = 2.121, p=0.05 *Recall:* F (1,103) = 970.550, p<0.001 *Recall X Meal:* F (2,103) = 0.555,p=0.576 *Session X Recall:* F (3,309) = 26.384, p<0.001 *Meal X Session X Recall:* F (6,309) = 1.076, p=0.377
	RAG	9.514 (0.426)	6.629 (0.390)	9.657 (0.458)	4.829 (0.505)	7.657 (0.490)	3.143 (0.482)	7.943 (0.444)	3.171 (0.552)	
	SAG	9.806 (0.420)	7.022 (0.385)	9.861 (0.451)	6.139 (0.498)	9.250 (0.484)	4.694 (0.475)	10.139 (0.437)	5.389 (0.545)	
Conc Word Recall	Fast	6.371 (0.308)	5.114 (0.283)	6.657 (0.340)	4.029 (0.375)	5.200 (0.375)	2.771 (0.380)	6.257 (0.344)	3.400 (0.434)	*Meal:* F (2,103) = 2.263, p=0.109 *Session:* F (3,309) = 26.737, p<0.001 *Session X Meal:* F (6,309) = 2.034,p=0.061 *Recall:* F (1,103) = 694.314, p<0.001 *Recall X Meal:* F (2,103) = 2.130,p=0.124 *Session X Recall:* F (3,309) = 22.323, p<0.001 *Meal X Session X Recall:* F (6,309) = 1.005, p=0.422
	RAG	6.229 (0.308)	4.714 (0.283)	6.971 (0.340)	3.657 (0.375)	4.800 (0.375)	2.057 (0.380)	5.571 (0.344)	2.543 (0.434)	
	SAG	6.194 (0.304)	4.889 (0.279)	6.750 (0.336)	4.583 (0.370)	5.972 (0.370)	3.278 (0.374)	6.681 (0.340)	4.139 (0.428)	

Abst Word Recall	Fast	3.200 (0.284)	1.971 (0.204)	2.771 (0.244)	1.200 (0.199)	3.371 (0.199)	1.086 (0.194)	2.714 (0.215)	0.943 (0.186)	*Meal:* F (2,103) = 3.481, p<0.05 *Session:* F (3,309) = 14.438, p<0.001 *Session X Meal:* F (6,309) = 0.470,p=0.830 *Recall:* F (1,103) = 665.836, p<0.001 *Recall X Meal:* F (2,103) = 0.229,p=0.796 *Session X Recall:* F (3,309) = 8.849, p<0.001 *Meal X Session X Recall:* F (6,309) = 0.658, p=0.684
	RAG	3.200 (0.284)	1.914 (0.204)	2.714 (0.244)	1.171 (0.199)	2.943 (0.199)	1.086 (0.194)	2.371 (0.215)	0.629 (0.186)	
	SAG	3.611 (0.280)	2.333 (0.201)	3.111 (0.241)	1.611 (0.196)	3.278 (0.197)	1.417 (0.192)	3.250 (0.212)	1.250 (0.183)	
Time taken	Fast	43.857 (2.518)	31.114 (1.866)	34.914 (2.115)	23.857 (1.605)	35.314 (2.190)	19.286 (1.577)	30.400 (1.971)	19.629 (1.731)	*Meal:* F (2,103) = 5.068, p<0.01 *Session:* F (3,309) = 36.598, p<0.001 *Session X Meal:* F (6,309) = 3.482, p<0.01 *Recall:* F (1,103) = 533.421, p<0.001 *Recall X Meal:* F (2,103) = 0.811p=0.447 *Session X Recall:* F (3,309) = 2.063, p=0.105 *Meal X Session X Recall:* F (6,309) = 2.481, p<0.05
	RAG	39.029 (2.518)	27.143 (1.866)	32.800 (2.115)	19.114 (1.605)	29.800 (2.190)	16.914 (1.577)	28.400 (1.971)	15.543 (1.731)	
	SAG	39.694 (2.483)	31.278 (1.840)	36.333 (2.086)	26.556 (1.583)	38.528 (2.159)	26.583 (1.555)	39.333 (1.944)	24.194 (1.707)	

Table 6.5: Summary table for Decision Times on the Hick Paradigm (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	307.313 (7.253)	334.156 (7.308)	356.500 (7.959)	392.688 (12.084)	*Meal* F (2,95) = 0.098, p=0.907 *Session* F (3,285) = 1.566, p=0.198 *Meal X Session* F (6,285) = 0.185, p=0.981 *Lamps* F (3,285) = 247.572, p<0.001 *Meal X Lamps* F (6,285) = 2.912, p<0.01 *Session X Lamps* F (9,855) = 0.748, p=0.665 *Meal X Session X Lamps* F (18,855) = 0.544, p=0.938
	RAG	308.859 (7.253)	326.578 (7.308)	356.750 (7.959)	406.094 (12.084)	
	SAG	306.088 (7.036)	325.941 (7.089)	352.353 (7.722)	398.500 (11.723)	
Sess 2	Fast	303.359 (6.338)	328.422 (5.991)	348.516 (8.047)	373.438 (11.481)	
	RAG	296.297 (6.338)	325.453 (5.991)	353.797 (8.047)	394.828 (11.481)	
	SAG	301.221 (6.148)	319.912 (5.812)	350.235 (7.807)	398.529 (11.138)	
Sess 3	Fast	313.406 (5.530)	330.766 (6.116)	353.234 (7.388)	377.703 (13.010)	
	RAG	300.094 (5.530)	323.781 (6.116)	358.031 (7.388)	401.094 (13.010)	
	SAG	298.544 (5.365)	321.088 (5.933)	350.000 (7.167)	399.706 (12.622)	
Sess 4	Fast	307.484 (5.736)	329.641 (6.310)	352.063 (7.912)	382.656 (14.578)	
	RAG	300.531 (5.736)	330.828 (6.310)	355.781 (7.912)	408.969 (14.578)	
	SAG	293.853 (5.565)	324.882 (6.122)	349.618 (7.676)	408.941 (14.143)	

Table 6.6: Summary table for Movement Times on the Hick Paradigm (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	189.016 (8.495)	190.359 (9.262)	200.188 (9.901)	208.219 (10.102)	*Meal* F (2,95) = 0.229,
	RAG	197.875 (8.495)	191.406 (9.262)	201.281 (9.901)	216.922 (10.102)	p=0.796
	SAG	187.559 (8.241)	197.176 (8.985)	208.221 (9.605)	215.235 (9.800)	*Session* F (3,285) = 0.261,
Sess 2	Fast	193.500 (10.785)	190.953 (11.133)	198.844 (10.387)	204.266 (10.150)	p=0.849 *Meal X Session*
	RAG	191.328 (10.785)	202.031 (11.133)	211.875 (10.387)	226.469 (10.150)	F (6,285) = 1.231, p=0.291
	SAG	198.632 (10.463)	200.353 (10.801)	210.662 (10.077)	214.397 (9.846)	*Lamps* F (3,285) = 46.865,
Sess 3	Fast	195.375 (9.291)	193.578 (9.253)	207.391 (9.349)	214.516 (8.659)	p<0.001 *Meal X Lamps*
	RAG	197.906 (9.291)	196.062 (9.253)	212.547 (9.349)	218.938 (8.659)	F (6,285) = 1.445, p=0.197
	SAG	193.824 (9.014)	188.662 (8.977)	203.676 (9.070)	204.485 (8.401)	*Session X Lamps* F (9,855) = 0.701,
Sess 4	Fast	197.938 (8.771)	198.172 (8.876)	203.063 (9.539)	215.281 (9.153)	p=0.708 *Meal X Session X*
	RAG	196.203 (8.771)	204.937 (8.876)	207.406 (9.539)	228.281 (9.153)	*Lamps* F (18,855) = 0.907,
	SAG	186.397 (8.509)	187.353 (8.611)	197.412 (9.254)	199.368 (8.880)	p=0.570

Table 6.7: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3	Session 4	RESULT
Intercept	Fast	305.888 (7.719)	303.881 (6.040)	311.469 (5.306)	305.766 (5.683)	*Meal* F (2,95) = 2.019, p=0.138
	RAG	301.291 (7.719)	294.000 (6.040)	295.163 (5.306)	296.487 (5.683)	*Session* F (3,285) = 1.025, p=0.382
	SAG	300.165 (6.965)	294.144 (5.860)	292.482 (5.148)	288.829 (5.513)	*Meal X Session* F (6,285) = 0.660, p=0.682
Slope	Fast	27.850 (3.431)	23.044 (3.302)	21.537 (3.688)	24.806 (4.173)	*Meal* F (2,95) = 3.183, p<0.05
	RAG	32.191 (3.431)	32.391 (3.302)	33.728 (3.688)	35.031 (4.173)	*Session* F (3,285) = 0.890, p=0.447
	SAG	30.359 (3.329)	32.226 (3.203)	33.250 (3.578)	36.994 (4.048)	*Meal X Session* F (6,285) = 0.868, p=0.519
Intra-Individual Variability	Fast	179.792 (18.506)	145.580 (16.958)	146.683 (17.280)	159.398 (19.905)	*Meal* F (2,95) = 2.483, p=0.089
	RAG	186.884 (18.506)	178.560 (16.958)	202.891 (17.280)	231.784 (19.905)	*Session* F (3,285) = 1.529, p=0.207
	SAG	197.887 (17.953)	189.985 (16.452)	177.306 (16.764)	183.839 (19.311)	*Meal X Session* F (6,285) = 1.586, p=0.151

Table 6.8: Summary table for Correct responses on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Corr 1	Fast	4.909 (0.309)	4.152 (0.348)	3.152 (0.316)	3.424 (0.332)	2.606 (0.266)	*Meal* F (2,100) = 1.126, p=0.328
	RAG	5.147 (0.305)	4.265 (0.343)	3.618 (0.311)	3.912 (0.327)	3.029 (0.262)	
	SAG	4.389 (0.296)	4.306 (0.334)	3.556 (0.302)	3.639 (0.318)	2.583 (0.255)	*Session* F (3,300) = 3.697, p<0.05
Corr 2	Fast	4.667 (0.344)	3.909 (0.333)	3.455 (0.354)	3.636 (0.330)	3.182 (0.283)	*Meal X Session* F (6,300) = 2.425, p<0.05
	RAG	5.235 (0.339)	4.471 (0.328)	4.294 (0.349)	4.382 (0.325)	3.676 (0.279)	
	SAG	4.972 (0.329)	4.500 (0.319)	4.139 (0.339)	4.167 (0.316)	3.417 (0.271)	*Minute* F (4,400) = 65.788, p<0.001
Corr 3	Fast	4.242 (0.339)	3.879 (0.290)	3.394 (0.310)	3.576 (0.328)	2.667 (0.238)	*Meal X Minute* F (8,400) = 0.461, p=0.883
	RAG	4.824 (0.334)	4.412 (0.285)	4.235 (0.306)	4.441 (0.323)	3.294 (0.235)	
	SAG	4.861 (0.325)	4.278 (0.277)	3.806 (0.297)	4.583 (0.314)	3.472 (0.228)	*Session X Minute* F (12,1200) = 1.566, p=0.095
Corr 4	Fast	4.636 (0.330)	4.515 (0.329)	3.667 (0.314)	3.818 (0.315)	3.091 (0.282)	*Meal X Session X Minute* F (24,1200) = 0.538, p=0.967
	RAG	4.471 (0.325)	4.147 (0.324)	3.706 (0.309)	4.088 (0.310)	2.912 (0.278)	
	SAG	5.028 (0.316)	4.472 (0.315)	3.750 (0.301)	4.167 (0.301)	3.444 (0.270)	

Table 6.9: Summary table for Wrong responses on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrg 1	Fast	3.515 (0.719)	2.818 (0.744)	3.424 (0.744)	3.000 (0.611)	3.121 (0.738)	*Meal* F (2,100) =
	RAG	3.412 (0.708)	3.588 (0.733)	3.882 (0.733)	3.500 (0.601)	3.706 (0.727)	0.013, p=0.987
	SAG	3.861 (0.688)	3.278 (0.712)	2.750 (0.713)	3.111 (0.585)	3.722 (0.706)	*Session* F (3,300) =
Wrg 2	Fast	3.000 (0.634)	2.939 (0.642)	3.273 (0.651)	3.970 (0.751)	4.515 (0.791)	1.293, p=0.277 *Meal X Session*
	RAG	3.000 (0.625)	3.000 (0.633)	2.853 (0.641)	3.353 (0.740)	3.588 (0.779)	F (6,300) = 0.516, p=0.796
	SAG	2.9744 (0.607)	2.389 (0.615)	2.861 (0.623)	3.472 (0.719)	3.556 (0.757)	*Minute* F (4,400) =
Wrg 3	Fast	2.303 (0.630)	2.727 (0.740)	4.030 (0.758)	3.515 (0.703)	3.788 (0.854)	7.381, p<0.001 *Meal X Minute*
	RAG	3.029 (0.620)	3.500 (0.729)	3.559 (0.747)	3.529 (0.693)	3.971 (0.842)	F (8,400) = 1.219, p=0.286
	SAG	3.0000 (0.603)	3.639 (0.709)	3.278 (0.726)	3.083 (0.673)	3.972 (0.818)	*Session X Minute* F (12,1200) =
Wrg 4	Fast	2.939 (0.703)	3.455 (0.701)	3.939 (0.768)	4.182 (0.833)	4.545 (0.912)	1.912, p<0.05 *Meal X Session*
	RAG	3.118 (0.692)	3.059 (0.690)	3.441 (0.756)	3.500 (0.820)	4.971 (0.899)	*X Minute* F (24,1200) =
	SAG	3.722 (0.673)	3.306 (0.671)	2.944 (0.735)	4.389 (0.797)	3.806 (0.873)	0.825, p=0.708

Table 6.10: Summary table for Reaction times on the RIPT (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	Fast	524.424 (28.933)	524.000 (24.808)	547.364 (37.878)	470.909 (35.202)	487.424 (33.982)	*Meal* F (2,100) = 0.205,
	RAG	514.029 (28.505)	499.441 (24.441)	580.382 (37.317)	552.235 (34.680)	618.176 (33.479)	p=0.815
	SAG	490.667 (27.702)	516.778 (23.752)	509.917 (36.265)	522.056 (33.703)	510.028 (32.536)	*Session* F (3,300) = 2.097,
RT 2	Fast	534.909 (28.686)	526.697 (27.691)	480.606 (31.651)	529.515 (28.292)	555.758 (33.885)	p=0.101 *Meal X Session*
	RAG	516.647 (28.261)	505.412 (27.281)	511.176 (31.182)	540.412 (27.873)	546.294 (33.383)	F (6,300) = 1.654, p=0.132
	SAG	478.750 (27.465)	578.500 (26.512)	527.611 (30.304)	508.583 (27.088)	504.111 (32.443)	*Minute* F (4,400) = 1.991,
RT 3	Fast	500.606 (20.786)	540.364 (26.360)	533.121 (29.942)	553.545 (33.178)	572.939 (31.919)	p=0.095 *Meal X Minute*
	RAG	531.441 (20.478)	551.412 (25.970)	549.382 (29.499)	552.706 (32.686)	604.559 (31.446)	F (8,400) = 0.822, p=0.584
	SAG	526.972 (19.901)	512.694 (25.238)	549.583 (28.667)	591.000 (31.765)	545.194 (30.560)	*Session X Minute* F (12,1200) =
RT 4	Fast	487.576 (24.680)	498.788 (29.454)	536.030 (22.973)	552.848 (30.490)	548.879 (31.759)	0.897, p=0.549 *Meal X Session X*
	RAG	498.500 (24.315)	528.382 (29.018)	513.324 (22.633)	522.647 (30.038)	486.912 (31.288)	*Minute* F (24,1200) =
	SAG	529.972 (23.629)	569.111 (28.200)	576.750 (21.995)	530.917 (29.192)	526.222 (30.407)	1.198, p=0.233

Chapter 7: Meta-Analysis of all Breakfast Studies

7.1 INTRODUCTION

As each breakfast study conducted followed the same experimental design, and similar time constraints, the four studies were approached collectively to determine if predictions could be made regarding the macronutrient profile that makes up the 'better' breakfast.

7.1.1 AIM

This chapter aimed to discover if amounts of carbohydrate, fat, protein, fibre and the caloric intake could be identified that enhance mood and cognition.

7.2 METHOD

Please refer to sections 3.2, 4.2, 5.2, and 6.2 for the experimental methods.

7.3 STATISTICAL ANALYSIS

The interaction between macronutrients and their different effects over the test sessions were important concerns. Therefore, the studies with similar designs, that could be compared, were analysed together.

With respect to measures of mood, the first five time points were compared, for all four studies (Chapters 3-6). It must be noted that the duration of the study in Chapter 3 was only 2 hours, whereas in Chapters 4-6 it was 2.5 hours. However, preliminary analysis showed this did not to influence the results.

Chapter 3 was omitted from the cognition analysis, as it had only two sessions of cognitive testing.

Chapter 6 reported the effects on memory following manipulation of the type of carbohydrate consumed. It was clear that the effects of SAG (slowly available glucose) were significantly better that those observed following RAG (rapidly available glucose) consumption; SAG significantly enhanced abstract word retrieval. Therefore, Chapter 6 was omitted from the meta-analysis of memory measures as the unusual nature of the carbohydrate prevented meaningful comparisons. Chapters 4 and 5 had identical time scales and word lists, but had different participants, allowing direct comparison.

With respect to measures of Reaction Times and the RIPT, a similar problem with test timing occurred. Chapters 4 and 5 had identical schedules, whereas Chapter 6 had longer rest periods. Again, preliminary analysis found this did not influence the results for Chapters 4-6.

7.3.1 EFFECT OF BREAKFAST

- Difference scores were firstly calculated for the measures of Mood (Composed/Agreeable/Elated/Confident/Energetic/Clearheaded) and Hunger using the following calculation:

  Mood at 30, 60, 100, & 120/150 minutes – baseline.

  These measures were then analysed using two-way ANOVA's:

  Breakfast (fast/breakfast) X Time (30, 60, 90, 120/150mins) (repeated measure).

  (Data from Chapters 3, 4, 5 and 6)

- Measures of Word Recall, Total, Concrete and Abstract, and Recall Times were analysed using three-way ANOVA's:

  Breakfast (fast/breakfast) X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

  (Data from Chapter 4 and 5)

- Measures of Decision times on the Hick Paradigm were analysed using three-way ANOVA's:

  Breakfast (fast/breakfast) X Session (1, 2, 3) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

  (Data from Chapters 4, 5 and 6)

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVA's:
  Breakfast (fast/breakfast) X Session (1, 2, 3) (repeated measure).
  (Data from Chapters 4, 5 and 6)
- Measures of Correct responses, Wrong responses and Reaction times on the Vigilance test were analysed using three-way ANOVA's:
  Breakfast (fast/breakfast) X Session (1, 2, 3) (repeated measure) X Minutes (1, 2, 3, 4, 5) (repeated measure).
  (Data from Chapters 4, 5 and 6)
- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

7.3.2 EFFECT OF CARBOHYDRATE

- Difference scores for measures of mood were calculated as in 7.3.1.
  These measures were then analysed using two-way ANOVA's:
  Carbohydrate (0-20g/20.1-35g/35.1-50g/50.1g+) X Time (30, 60, 90, 120/150mins) (repeated measure).
  (Data from Chapters 3, 4, 5 and 6)
- Measures of Word Recall, Total, Concrete and Abstract, and Recall Times were analysed using three-way ANOVA's:
  Carbohydrate (20.1-35g/35.1-50g/50.1g+) X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).
  (Data from Chapters 4 and 5, no meals contained less than 20g of carbohydrate)

- Measures of Decision times on the Hick Paradigm were analysed using three-way ANOVA's:

  Carbohydrate (20.1-35g/35.1-50g/50.1g+) X Session (1, 2, 3) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained less than 20g of carbohydrate)

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVA's:

  Carbohydrate (20.1-35g/35.1-50g/50.1g+) X Session (1, 2, 3) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained less than 20g of carbohydrate)

- Measures of Correct responses, Wrong responses and Reaction times on the Vigilance test were analysed using three-way ANOVA's:

  Carbohydrate (20.1-35g/35.1-50g/50.1g+) X Session (1, 2, 3) (repeated measure) X Minutes (1, 2, 3, 4, 5) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained less than 20g of carbohydrate)

- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

7.3.3 *EFFECT OF PROTEIN*

- Difference scores for measures of mood were calculated as in 7.3.1.

  These measures were then analysed using two-way ANOVA's:

  Protein (0-2g/2.01-8g/8.01-12g/12.01g+) X Time (30, 60, 90, 120/150mins (repeated measure).

  (Data from Chapters 3, 4, 5 and 6)

- Measures of Word Recall, Total, Concrete and Abstract, and Recall Times were analysed using three-way ANOVA's:

  Protein (0-2g/6.01-8g/8.01-10g) X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

  (Data from Chapters 4 and 5, no meals contained 2-6g, or over 10g, of protein)

- Measures of Decision times on the Hick Paradigm were analysed using three-way ANOVA's:

  Protein (0-4g/4.01-8g/8.01-10g) X Session (1, 2, 3) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained over 10g of protein)

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVA's:

  Protein (0-4g/4.01-8g/8.01-10g) X Session (1, 2, 3) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained over 10g of protein)

- Measures of Correct responses, Wrong responses and Reaction Times on the Vigilance test were analysed using three-way ANOVA's:

  Protein (0-4g/4.01-8g/8.01-10g) X Session (1, 2, 3) (repeated measure) X Minutes (1, 2, 3, 4, 5) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained over 10g of protein)

- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

7.3.4 EFFECT OF FAT

- Difference scores for measures of mood were calculated as in 7.3.1.

  These measures were then analysed using two-way ANOVA's:

  Fat (0-2.5g/7-12g/16g+) X Time (30, 60, 90, 120/150mins) (repeated measure).

  (Data from Chapters 3, 4, 5 and 6, no meals contained 2.5-7g, or 12-15g)

- Measures of Word Recall, Total, Concrete and Abstract, and Recall Times were analysed using three-way ANOVA's:

  Fat (0-2g/11g+) X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

  (Data from Chapters 4 and 5, no meals contained 2-11g of fat)

- Measures of Decision times on the Hick Paradigm were analysed using three-way ANOVA's:

  Fat (0-2.5g/7-12g/16g+) X Session (1, 2, 3) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained 2.5-7g, or 12-15g)

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVA's:

  Fat (0-2.5g/7-12g/16g+) X Session (1, 2, 3) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained 2.5-7g, or 12-15g)

- Measures of Correct responses, Wrong responses and Reaction Times on the Vigilance test were analysed using three-way ANOVA's:

  Fat (0-2.5g/7-12g/16g+) X Session (1, 2, 3) (repeated measure) X Minutes (1, 2, 3, 4, 5) (repeated measure).

(Data from Chapters 4, 5 and 6, no meals contained 2.5-7g, or 12-15g)

- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

7.3.5 *EFFECT OF FIBRE*

- Difference scores for measures of mood were calculated as in 7.3.1.

  These measures were then analysed using two-way ANOVA's:

  Fibre (0-2g/2.01-5g/5.01-7g/12g+) X Time (30, 60, 90, 120/150mins) (repeated measure).

  (Data from Chapters 3, 4, 5 and 6, no meals contained 7-12g of fibre)

- Measures of Word Recall, Total, Concrete and Abstract, and Recall Times were analysed using three-way ANOVA's:

  Fibre (0-2g/2.01-4g/4.01-6g) X Session (1, 2, 3) (repeated measure) X Recall (Immediate/Delayed) (repeated measure).

  (Data from Chapters 4 and 5, no meals contained over 6g of fibre)

- Measures of Decision times on the Hick Paradigm were analysed using three-way ANOVA's:

  Fibre (0-3g/3.01-6g) X Session (1, 2, 3) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained over 6g of fibre)

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVA's:

  Fibre (0-3g/3.01-6g) X Session (1, 2, 3) (repeated measure).

(Data from Chapters 4, 5 and 6, no meals contained over 6g of fibre)

- Measures of Correct responses, Wrong responses and Reaction Times on the Vigilance test were analysed using three-way ANOVA's:

  Fibre (0-3g/3.01-6g) X Session (1, 2, 3) (repeated measure) X Minutes (1, 2, 3, 4, 5) (repeated measure).

  (Data from Chapters 4, 5 and 6, no meals contained over 6g of fibre)

- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

7.3.6 *EFFECT OF CALORIC INTAKE*

- Difference scores for measures of mood were calculated as in 7.3.1.

  These measures were then analysed using two-way ANOVA's:

  Energy Intake (0-100kcal/101-200kcal/201-300kcal/301kcal+) X Time (30, 60, 90, 120/150mins) (repeated measure).

  (Data from Chapters 3, 4, 5 and 6)

  Measures of Word Recall, Total, Concrete and Abstract, and Recall Times were analysed using three-way ANOVA's:

  Energy Intake (100-200kcal/201-300kcal/301kcal+) X Session (1, 2, 3) (repeated

  (Data from Chapters 4 and 5, no meals below 100Kcal)

- Measures of Decision times on the Hick Paradigm were analysed using three-way ANOVA's:

  Energy Intake (100-200kcal/201-300kcal/301kcal+) X Session (1, 2, 3) (repeated measure) X Number of Lamps (1, 2, 4, 8) (repeated measure).

(Data from Chapters 4, 5, and 6, no meals below 100Kcal)

- Measures of Intercept, Intra-Individual Variability and Slope were analysed using two-way ANOVA's:

  Energy Intake (100-200kcal/201-300kcal/301kcal+) X Session (1, 2, 3) (repeated measure).

  (Data from Chapters 4, 5, and 6, no meals below 100Kcal)

- Measures of Correct responses, Wrong responses and Reaction Times on the Vigilance test were analysed using three-way ANOVA's:

  Energy Intake (100-200kcal/201-300kcal/301kcal+) X Session (1, 2, 3) (repeated measure) X Minutes (1, 2, 3, 4, 5) (repeated measure).

  (Data from Chapters 4, 5, and 6, no meals below 100Kcal)

- Where Post-Hoc tests are reported, Tukey Honestly Significant Difference was used.

7.4 RESULTS

For clarity only significant results involving macronutrients or condition (breakfast/no breakfast) will be reported. It may be assumed that main effects and higher order interactions that are not reported were non-significant.

7.4.1 EFFECT OF BREAKFAST

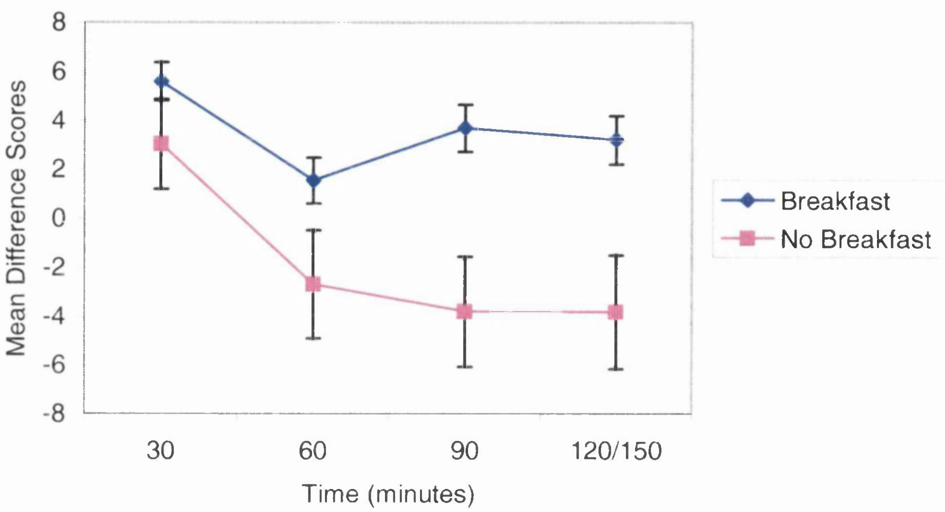
Breakfast and Mood

The interaction Breakfast X Time reached significance with respect to ratings of Composure [$F(3,1947) = 3.022, p<0.05$]. Figure 7.1 and SME's demonstrate that those participants who ate breakfast were significantly more composed at 90 minutes [$F(1,649) = 9.32, p<0.01$] and 120/150 minutes [$F(1,649) = 7.722, p<0.01$], than those who fasted. Additionally there was a significant decrease in Composure ratings over the morning for those who did not consume breakfast [$F(3,1947) = 10.00, p<0.001$], and a significant change in Composure ratings over the morning for those who did consume breakfast [$F(3,1947) = 6.99, p<0.001$].

Breakfast consumption influenced ratings of Energy [$F(1,649) = 7.568, p<0.01$] and Total Mood [$F(1,649) = 7.697, p<0.01$]. Ratings of Clearheadedness just missed significance [$F(1,649) = 3.554, p=0.06$]. In each case, participants who had consumed breakfast had significantly better mood over the course of the morning.

Figure 7.1 also shows that the significant differences in ratings between those who consumed breakfast, and those who did not, becomes more noticeable following 90 minutes. Breakfast significantly improves mood later on in the morning.

Figure 7.1: Profile of Composure ratings over Time (means +/- s.e.m)



Breakfast and Hunger

Breakfast consumption effected ratings of Hunger [F (1,649) = 140.153, p<0.001], unremarkably breakfast significantly reduced ratings of hunger throughout the morning.

Breakfast and Memory

Breakfast failed to influence the total number of words recalled [F (1,376) = 0.077, p=n.s.], concrete word recall [F (1,376) = 0.069, p=n.s.] or abstract word recall [F (1,376) = 0.879, p=n.s.].

The interaction Breakfast X Session reached significance when the time taken to recall the word lists was analysed [F (2,752) = 3.910, p<0.05]. SME's demonstrated that participants who consumed breakfast took significantly longer to recall the lists than those who fasted at 40 minutes [F (1,376) = 6.15, p<0.05] and 80 mintues [F (1,376) = 4.42, p<0.05], in addition to significant decreases in the time taken over the morning for both conditions (p<0.001).

Breakfast and the Hick Paradigm

34 participants were removed from the analysis due to negative slope values, that is their performance was better an the harder tasks. It was assumed they had not taken the task seriously.

The interaction Breakfast X Lamps reached significance with respect to Decision Times [F (3,1344) = 4.675, p<0.01], this reflected an increase in Decision times over each session as the number of lamps increased. Breakfast failed to influence Movement Times [F (1,448) = 2.593, p=n.s.].

Consumption of Breakfast influenced Intercept values [F (1,448) = 7.510, p<0.01], those who consumed breakfast had significantly lower intercepts. Additionally the consumption of breakfast influenced Slope values [F (1,448) = 5.854, p<0.05], that is, participants who consumed breakfast had higher slope values. This interaction is discussed in section 9.4. Intra-Individual Variability was not influenced by breakfast [F (1,448) = 1.314, p=n.s.].

Breakfast and the RIPT

16 participants were removed from the data set due to incomplete data or incorrect performance on the task (>20 wrong responses per minute).

The consumption of breakfast just failed to influence the number of correct responses on the RIPT [$F (1,466) = 3.715$, $p=0.06$], participants who consumed breakfast recorded more correct responses than those who fasted.

Breakfast failed to influence wrong responses [$F (1,466) = 0.044$, p=n.s.].

The interaction Breakfast X Session reached significance [$F (2,932) = 4.029$, $p<0.05$]. SME's demonstrated a significant decrease in the time taken to respond to the stimuli over the three sessions in those who consumed breakfast [$F (2,932) = 10.56$, $p<0.001$].

Summary of the effects of Breakfast consumption

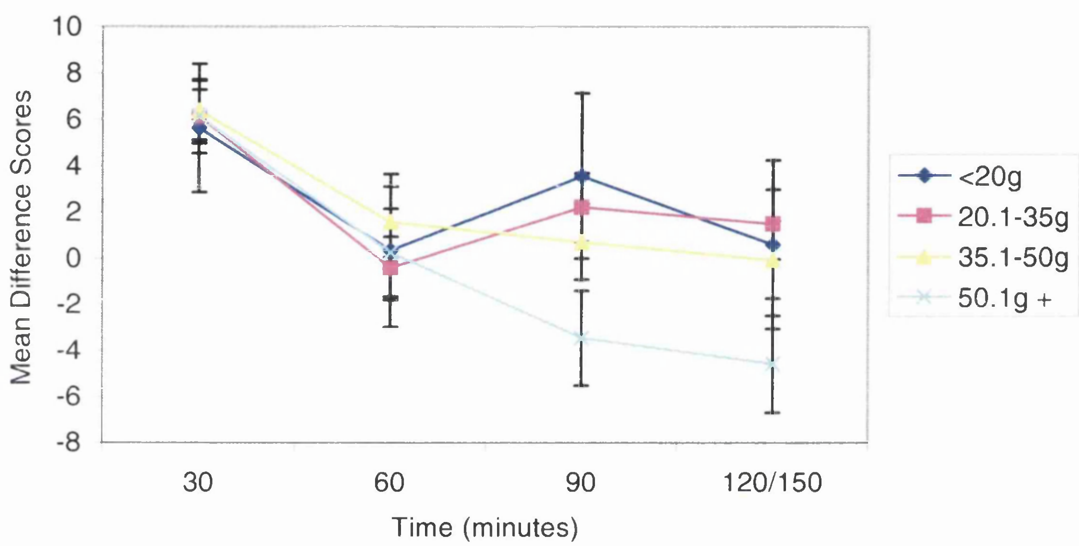
- Breakfast consumption is beneficial in that it enhanced some aspects of mood and cognitive functioning.

7.4.2 EFFECT OF CARBOHYDRATE

Carbohydrate and Mood

The interaction Carbohydrate X Time reached significance with respect to ratings of Clearheadedness [$F (9,1644) = 2.576$, $p<0.01$]. Figure 7.2 and SME's demonstrate that all conditions reported a significant overall decline in Clearheadedness over the morning, with those consuming over 50.1g of carbohydrate reporting the greatest decline [F (3,1941) = 17.55, p<0.001]. There were no significant differences between the groups at any time point.

Figure 7.2: Profile of Clearheadedness ratings over Time for Carbohydrate (means +/- s.e.m)



A significant Carbohydrate X Time interaction was also observed for ratings of Total Mood [F (9,1644) = 2.186, p<0.05]. Figure 7.3 and SME's show that there is a significant difference between the carbohydrate groupings at 30 minutes [F (3,548) = 3.34, p<0.05]. Post-Hoc tests (Tukey HSD) show that at 30 minutes, there are trends for those who consumed over 50.1g of carbohydrate to have better mood than those who consumed less than 20g (p=0.09), and those who consumed 35.1-50g (p=0.07). Additionally there were significant decreases in total mood over the morning for all carbohydrate groupings (p<0.05).

Figure 7.3: Profile of Total Mood ratings over Time for Carbohydrate (means +/- s.e.m)

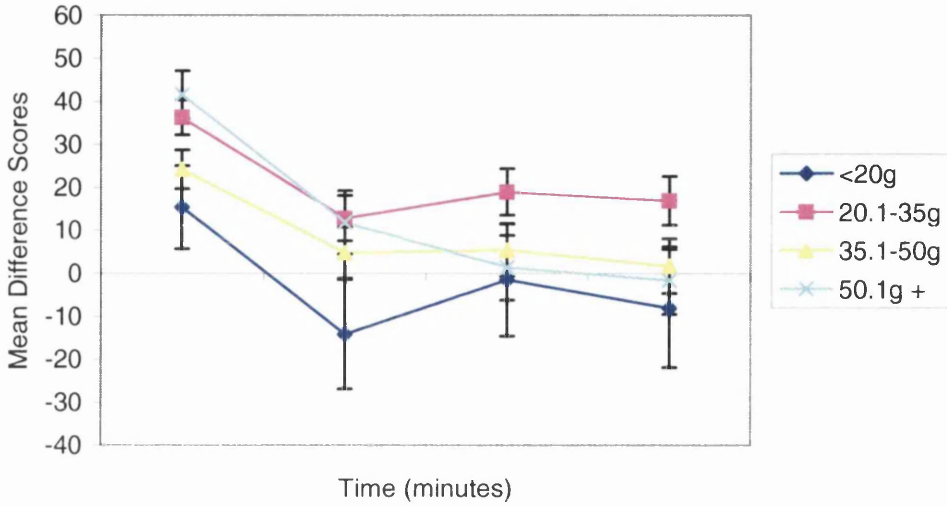
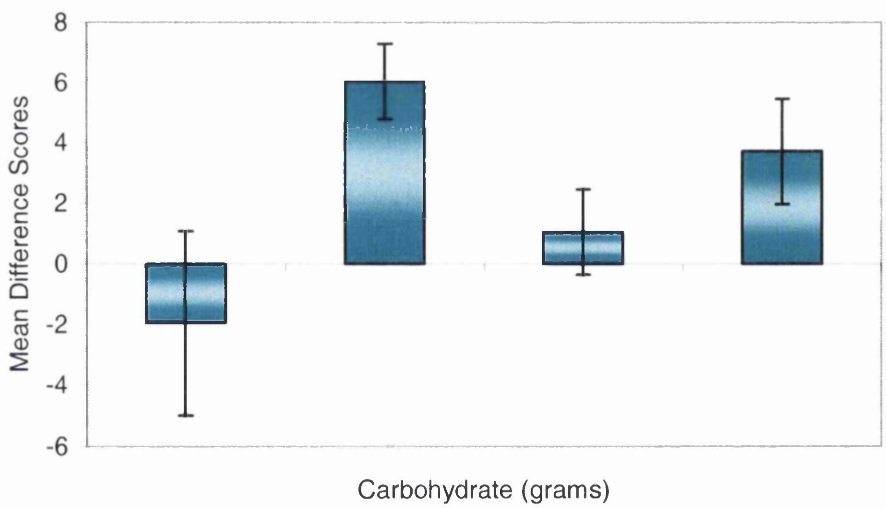


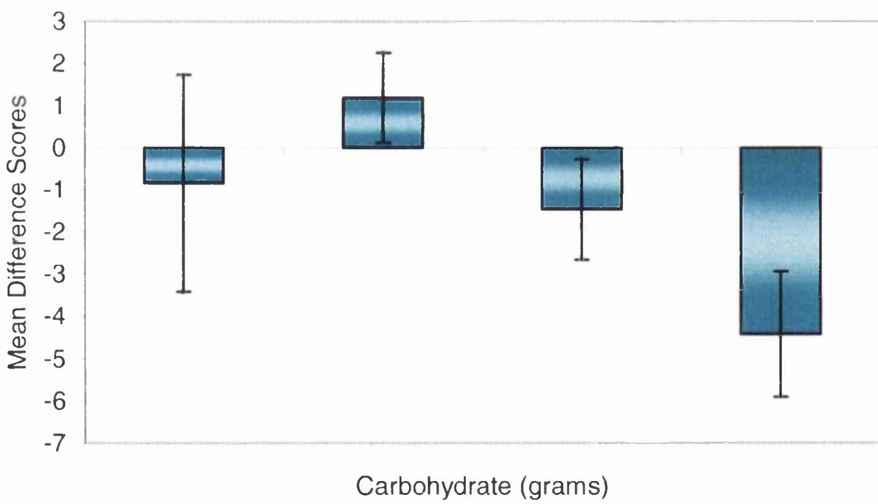
Figure 7.4: Main effect of Composure ratings for Carbohydrate (<20, 20.1-35, 35.1-50, 50.1g and above) (means +/- s.e.m)



The amount of Carbohydrate consumed significantly influenced ratings of Composure [F (3,548) = 3.161, p<0.05]. Figure 7.4 and Post-Hoc tests illustrated trends for participants who consumed less than 20g (p=0.07), and 35.1-50g (p=0.07), to be less Composed compared to 20.1-35g of carbohydrate, over the morning.

Carbohydrate also influenced ratings of Agreeability [F (3,548) = 3.223, p<0.05]. Figure 7.5 and further analyses showed that participants who consumed 20.1-35g, compared to 50.1g of carbohydrate, were significantly more agreeable over the morning (p=0.01).

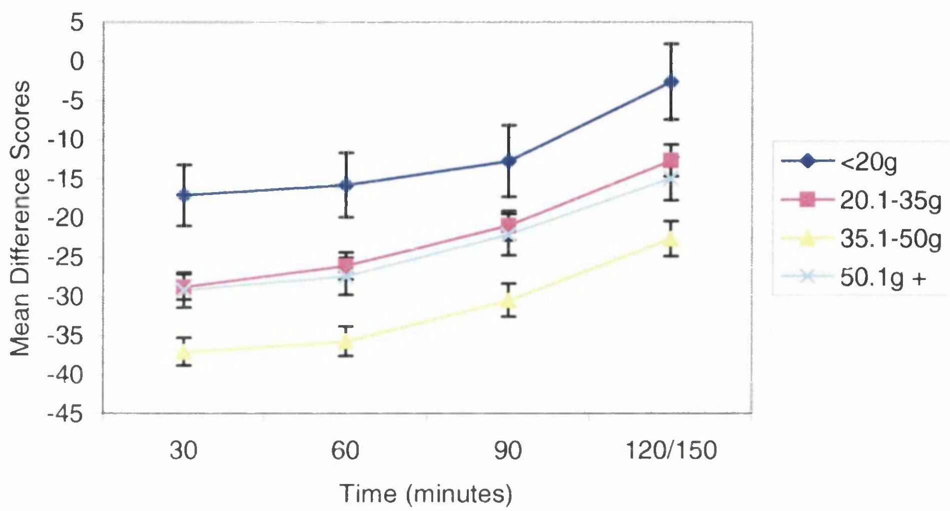
Figure 7.5: Main effect of Agreeability ratings for Carbohydrate (<20, 20.1-35, 35.1-50, 50.1g and above) (means +/- s.e.m)



Carbohydrate and Hunger

There was a significant main effect of Carbohydrate [F (3,548) = 9.134, p<0.001]. Figure 7.6 and Post-Hoc tests showed that participants who consumed 35.1-50g were significantly less hungry over the morning than all other groups (p<0.05). Additionally participants who consumed between 20.1-35g and over 50.1g showed no significant differences in their hunger response, despite consuming very different amounts of carbohydrate.

Figure 7.6: Profile of Hunger ratings over Time for Carbohydrate (means +/- s.e.m)

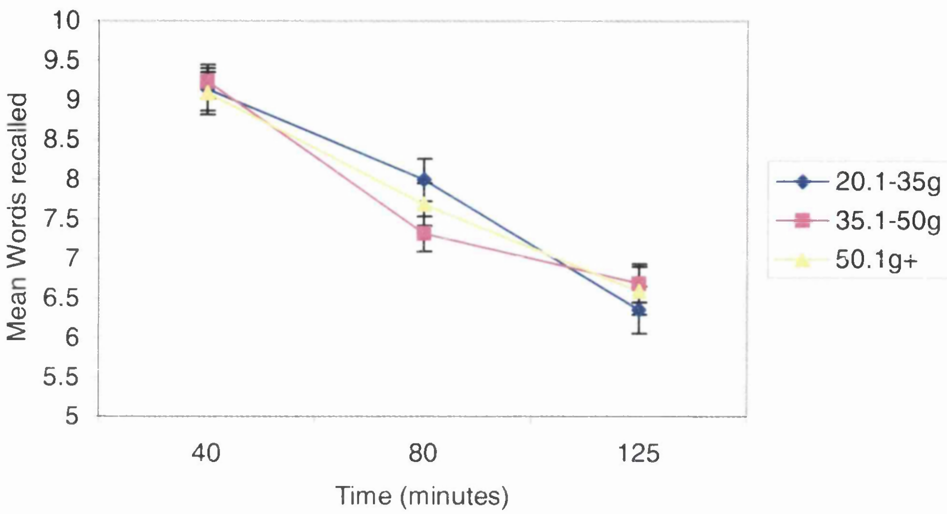


Carbohydrate and Memory

The interaction Carbohydrate X Session reached significance with respect to the total number of words recalled [F (4,654) = 2.687, $p<0.05$]. Figure 7.7 and SME's demonstrated that, for all three carbohydrate groupings, there were significant decreases in the words recalled over the three test sessions ($p<0.001$), however there were no significant differences between the groupings at any time point.

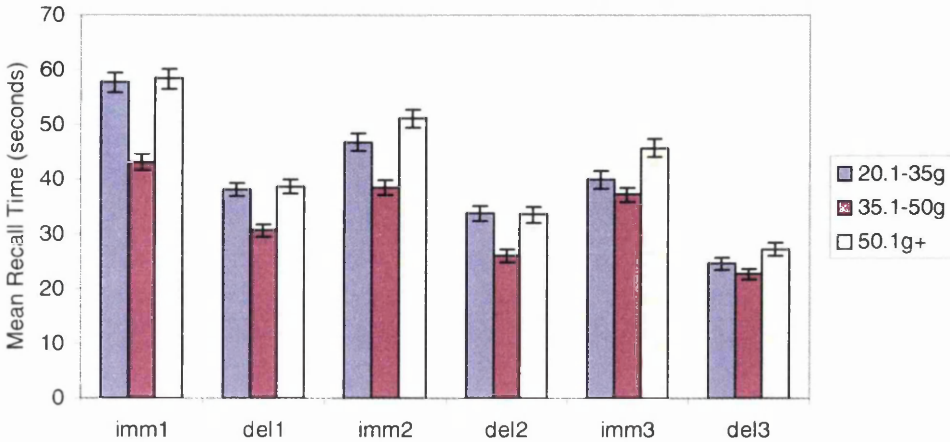
In addition, the interaction Carbohydrate X Session reached significance with respect to the number of Concrete words recalled [F (4,654) = 3.71, $p<0.01$]. The effects observed mirrored those of total words recalled. Carbohydrate consumed failed to influence Abstract word recall [F (2,327) = 1.13, p=0.326].

Figure 7.7: Profile of Total Words recalled over Time for each Carbohydrate grouping (means +/- s.e.m)



The three-way interaction Carbohydrate X Recall X Session reached significance with respect to recall times [F (4,654) = 3.26, p<0.05]. SSME's and Figure 7.8 demonstrated that there were significant differences between the carbohydrate groupings, both at immediate and delayed recall, for each session; all SSME's were highly significant. Overall, there was a main effect of Carbohydrate [F (2,327) = 19.91, p<0.001], participants who consumed 35.1-50g took significantly less time to recall the word lists over the morning than those who consumed either 20.1-35g or 50.1g and above (p<0.001). In addition, there were significant decreases in the time taken to recall the word lists over the sessions for all carbohydrate groupings (p<0.001), and significant decreases in the time taken to recall the word lists from immediate to delayed recall (p<0.001).

Figure 7.8: Profile of the time taken to recall the word lists over Time for each carbohydrate grouping (means +/- s.e.m)



Carbohydrate and the Hick Paradigm

29 participants were removed from the analysis as they had negative slope values.

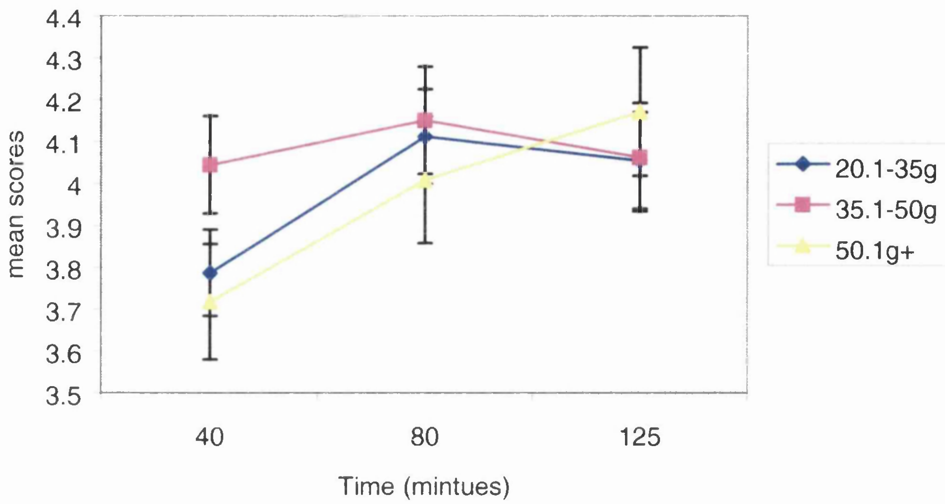
Carbohydrate consumed failed to influence either Decision Times [F (2,369) = 0.849, p=n.s] or Movement times [F (2,369) = 2.235, p=n.s].

Carbohydrate consumed also failed to influence Intercept [F (2,369) = 1.105, p=n.s.], Slope [F (2,369) = 0.721, p=n.s.] or Intra-Individual Variability [F (2,369) = 0.636, p=n.s.].

Carbohydrate and the RIPT

13 participants were removed from the data set due to incomplete data or incorrect performance on the task (>20 wrong responses per minute).

Figure 7.9: The influence of Carbohydrate on Correct responses over Time (means +/- s.e.m)



The interaction Carbohydrate X Session reached significance with respect to correct responses [F (4,770) = 2.892, p<0.05]. Figure 7.9 and SME's demonstrate significant increases in correct responses over time for participants who consumed 20-35g [F (2,770) = 9.36, p<0.001] and over 50.1g of carbohydrate [F (2,770) = 9.27, p<0.001].

There was a significant main effect of carbohydrate with respect to Wrong responses [F (2,385) = 4.375, p=0.01], participants who consumed 35.1-50g recorded significantly fewer wrong responses than those who consumed 20.1-35g of carbohydrate (p<0.05). In addition, participants consuming 35-50g of carbohydrate had significantly quicker reaction times on the RIPT throughout the morning compared with the other conditions [F (2,385) = 4.433, p=0.01].

Summary of the effects of Carbohydrate consumption

- Consumption of 20.1-35g of carbohydrate resulted in the greatest enhancement of mood over the course of the morning. Furthermore, consumption of over 50.1g was detrimental after 2 hours.
- Hunger was significantly decreased following consumption of 35.1-50g compared to the other conditions. Following consumption of 20.1-35g and over 50.1g of carbohydrate, there was no difference in hunger ratings between the 2 conditions, despite consuming very different amounts of carbohydrate.
- Significant decreases in the number of both total and concrete words recalled over time were observed for all conditions, however no significant differences were observed between the groups at any time point. Furthermore, participants who consumed 35.1-50g of carbohydrate took significantly less time to recall the word lists than the other conditions.
- Carbohydrate consumed failed to influence any measure of Reaction Times.
- Consumption of 20.1-35g and over 50.1g of carbohydrate resulted in an increased number of correct responses over time. Participants who consumed 20.1-35g of carbohydrate, compared to 35.1-50g, recorded significantly more wrong responses. Consumption of 35.1-50g of carbohydrate, compared to the other conditions, resulted in the quickest reaction times over time.

7.4.3 *EFFECT OF PROTEIN*

Protein and Mood

The interaction Protein X Time reached significance with respect to ratings of Elation [$F(9,1644) = 2.453$, $p<0.01$]. Figure 7.10 and SME's demonstrate significant changes in ratings over time for all groups except 8.01-12g [$F(3,1644) = 0.41$, p=n.s.], however there were no significant differences between the groups at any time point.

The interaction Protein X Time also reached significance with respect to ratings of Energy [$F(9,1644) = 2.081$, $p<0.05$]. Figure 7.11 and SME's show significant differences between the four groups at 30 [$F(3,548) = 2.759$, $p<0.05$], 60 [$F(3,548) = 6.432$, $p<0.001$] and 90 minutes [$F(3,548) = 3.112$, $p<0.05$]. Participants who consumed over 12.01g of Protein were significantly less energetic than those who consumed 0-12g ($p<0.05$). All groups report significant decreases in Energy over the course of the morning ($p<0.001$).

Figure 7.10: Profile of Elation ratings over Time for Protein (means +/- s.e.m)

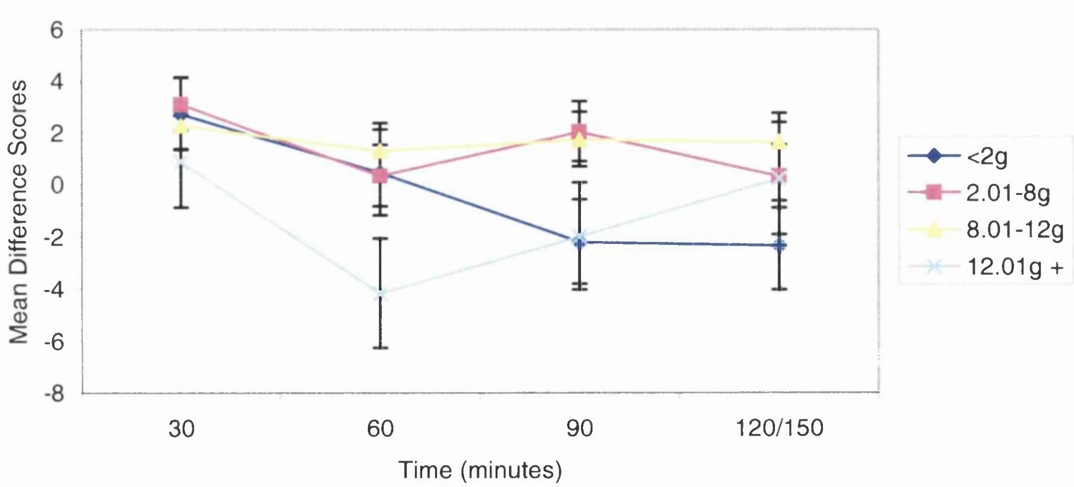
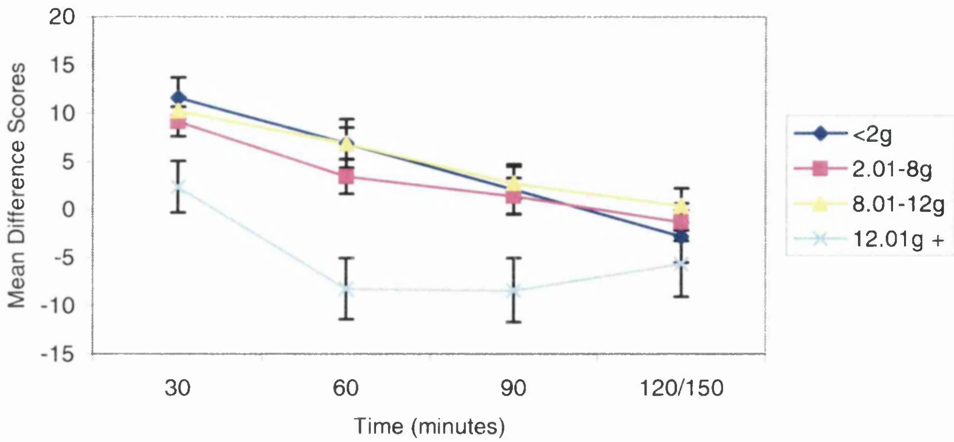


Figure 7.11: Profile of Energy ratings over Time for Protein (means +/- s.e.m)



Ratings of Agreeability [F (3,548) = 3.71, p<0.05] were significantly influenced by the amount of protein consumed. Figure 7.12 illustrates that participants who consumed 8.01-12g of protein were significantly more Agreeable over the morning than those who consumed over 12.01g (p<0.05) and 0-2g of protein (p=0.05).

Ratings of Total Mood were also influenced by the amount of protein consumed [F (3,548) = 2.622, p=0.05], with participants who consumed over 12g of protein, compared to 8.01-12g (p<0.05), having significantly poorer moods over the morning (Figure 7.13).

Composure ratings were also influenced by the amount of protein consumed [F (3,548) = 2.592, p=0.05), although Post-Hoc tests were non-significant, there was a trend for those who consumed over 12.01g to show poorer Composure than either those who consumed 0-2g (p=0.12), or 8.01-12g (p=0.12).

Figure 7.12: Main effect of Agreeable ratings for Protein (<2, 2.01-8, 8.01-12, 12.01g and above) (means +/- s.e.m)

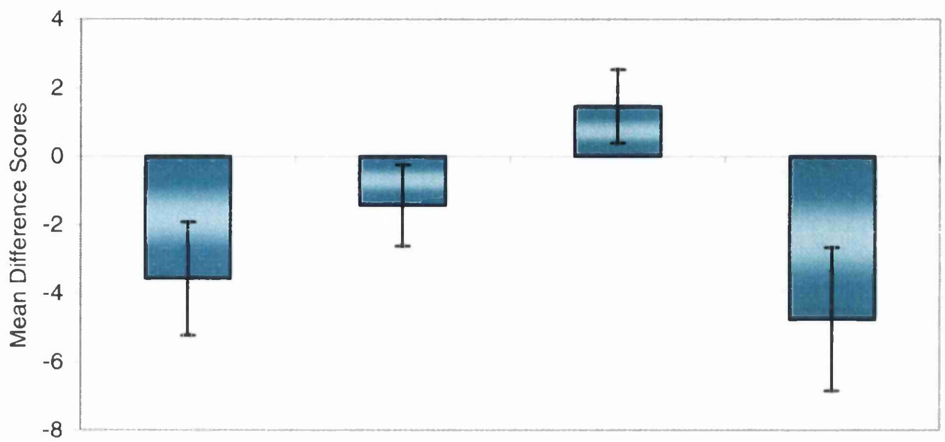
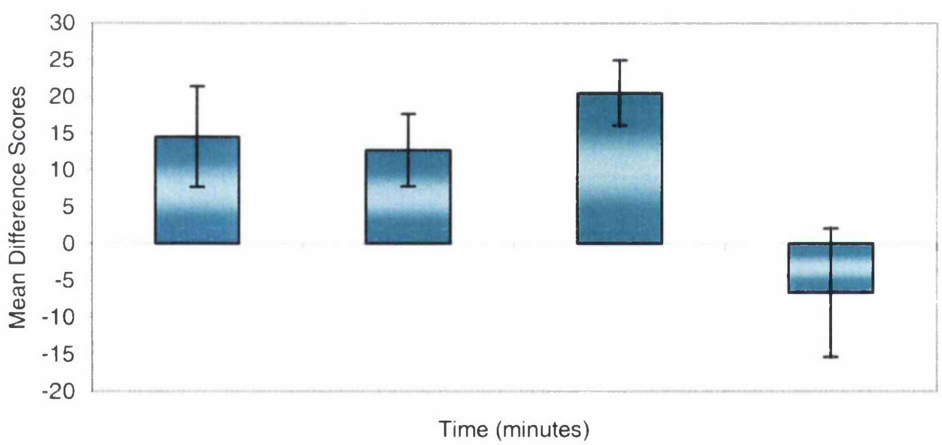


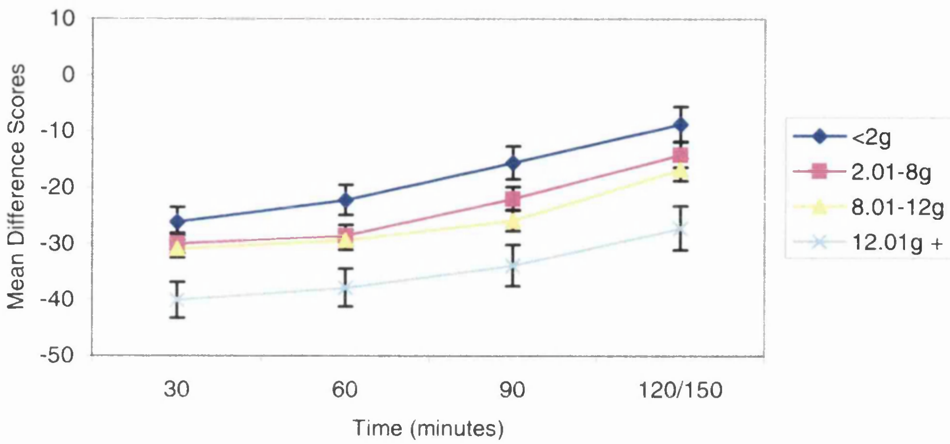
Figure 7.13: Main effect of Total Mood ratings for Protein (<2, 2.01-8, 8.01-12, 12.01g and above) (means +/- s.e.m)



Protein and Hunger

Protein consumed significantly effected hunger ratings over the morning [$F(3,548) = 5.817$, $p<0.001$]. Figure 7.14 illustrates that as the amount of protein in the meal increases, hunger responses decrease, with those consuming 0-8g of protein reporting significantly more hunger over the morning than those who consumed over 12g ($p<0.05$).

Figure 7.14: Profile of Hunger ratings over Time for Protein (means +/- s.e.m)

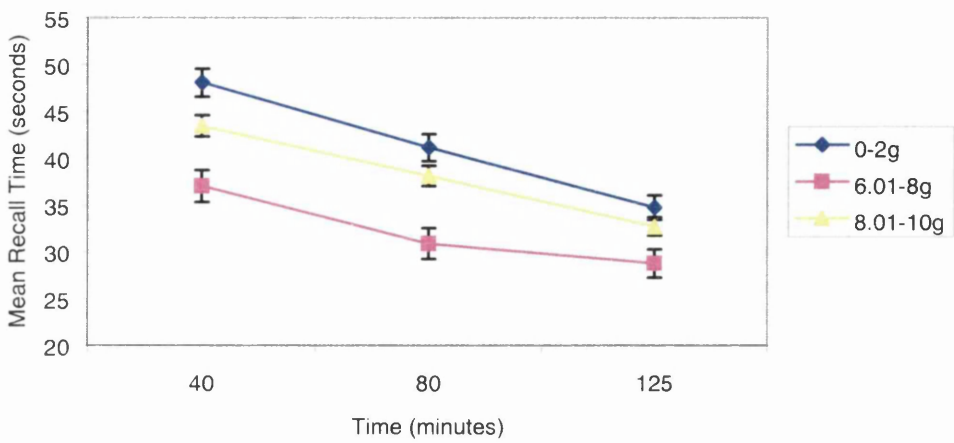


Protein and Memory

The amount of protein consumed failed to influence the total number of words recalled [F (2,327) = 1.019, p=n.s.], concrete word recall [F (2,327) = 1.112, p=n.s.] or abstract word recall [F (2,327) = 1.484, p=n.s.].

The interaction Protein X Session reached significance with respect to the time taken to recall the word lists [F (4,654) = 3.225, $p<0.05$]. Figure 7.15 and SME's demonstrate that participants who consumed 6.01-8g of protein took significantly less time to recall the word lists than the other groupings ($p<0.01$), and that there were significant decreases in the time taken to recall the word lists over the three test sessions ($p<0.001$).

Figure 7.15: Profile of the time taken to recall the word lists over Time for each Protein grouping (means +/- s.e.m)



The interaction Protein X Recall also reached significance [F (2,327) = 8.28, p<0.001], SME's demonstrate that, as above, there were significant differences between the protein groupings (p<0.001), and that there were significant decreases in recall times from immediate to delayed recall (p<0.001).

Protein and the Hick Paradigm

29 participants were removed from the analysis due to negative slope values.

Neither Decision Times [F (2,369) = 0.002, p=n.s.], nor Movement Times [F (2.369) = 0.521, p=n.s.] were influenced by the amount of protein consumed.

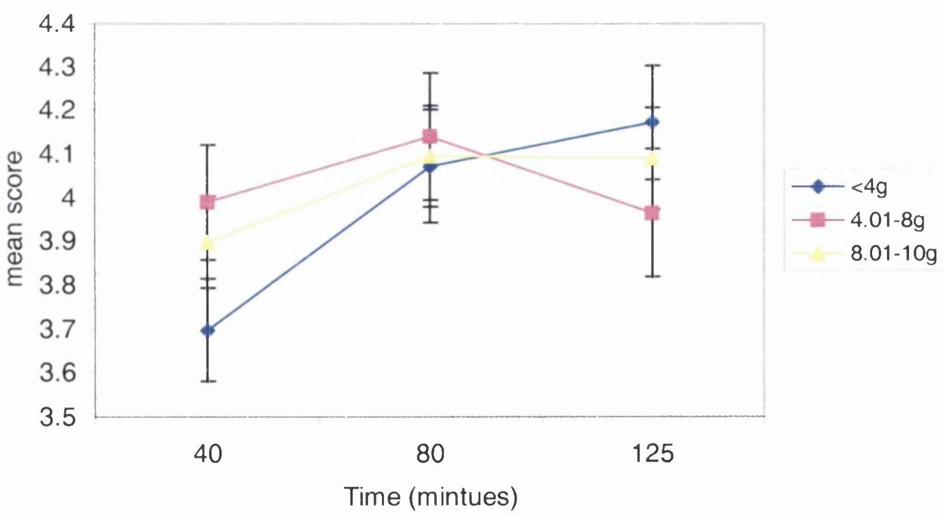
The amount of protein consumed also failed to influence Intercept values [F (2,369) = 0.111, p=n.s.], Slope values [F (2,369) = 0.190, p=n.s.] and Intra-Individual Variability [F (2, 396) = 0.272, p=n.s.].

Protein and the RIPT

13 participants were removed form the data set due to incomplete data or incorrect performance on the task (>20 wrong responses per minute).

The interaction Protein X Session reached significance with respect to the number of correct responses [F (4,770) = 3.491, p<0.01]. Figure 7.16 and SME's demonstrate that participants who consumed 0-4g [F (2,770) = 15.19, p<0.001] and over 8.01g [F (2,770) = 3.76, p<0.05] increased the number of correct responses given over the three sessions.

Figure 7.16: The influence of Protein on Correct responses over Time (means +/- s.e.m)



The three-way interaction Protein X Session X Minute reached significance with respect to the number for wrong responses recorded [F (16, 3080) = 2.015, p= 0.01]. SSME's demonstrated that significant changes in the number of wrong responses were observed over the 5-minute task following consumption of 0-4g at 40 [$F(4,1540) = 5.09$, $p<0.001$] and 125 minutes [$F(4,1540) = 5.03$, $p<0.001$], and consumption of 8.01-10g at 125 minutes [$F(4,1540) = 4.75$, $p<0.01$]. Performance on the RIPT was more consistent over the morning in those who consumed 4.01-8g of protein.

Protein consumed failed to influence reaction times [$F(2,385) = 1.687$, $p=0.186$].

Summary of the effects of Protein consumption

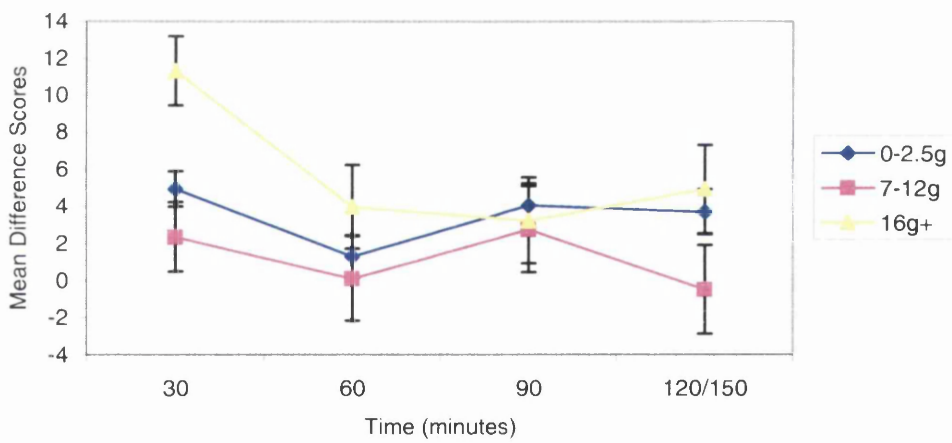
- Consumption of 8.01-12g of protein resulted in significantly enhanced mood throughout the morning compared to the other conditions. Consumption of 12g and over was detrimental to mood.
- Hunger decreased as a function of increased protein in the meal.
- Protein consumed failed to influence the number of words recall, however, participants who consumed 6.01-8g of protein took significantly less time to recall the word lists.
- Protein consumed failed to influence any measure of Reaction Times
- Consumption of 0-4g and over 8.01g of protein significantly increased the number of correct responses over the morning. However, consumption of 4.01-8g of protein was associated with more stable performance.

7.4.4 EFFECT OF FAT

Fat and Mood

The interaction Fat X Time reached significance with respect to ratings of Composure [F (6,1647) = 2.969, p<0.01]. Figure 7.17 and SME's demonstrate that those who consumed over 16g of fat, compared to less than 12g, were significantly more composed at 30 minutes [F (2,549) = 6.419, p<0.01]. Additionally there were significant decreases in Composure over time for those who consumed less than 2.5g of fat [F (3,1647) = 5.81, p=0.001], and those who consumed over 16g [F (3,1647) = 8.59, p<0.001].

Figure 7.17: Profile of Composed over Time for Fat (means +/- s.e.m)

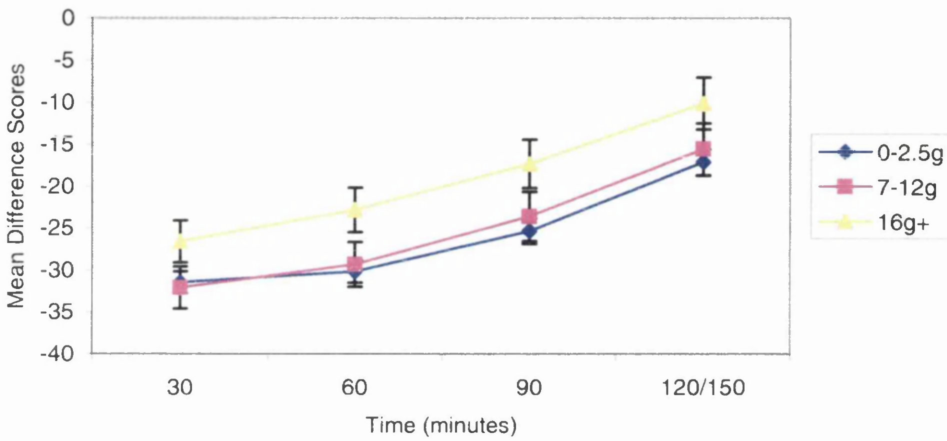


The interaction Fat X Time also reached significance for ratings of Total Mood [F (6,1647) = 2.793, p=0.01]. As found with ratings of Composure, those who consumed over 16g of fat, compared to less than 2.5g, reported significantly better Total Mood at 30 minutes [F (2,549) = 4.012, p<0.05]. Also there were significant decreases in Total Mood over the morning for all three conditions (p<0.001).

Fat and Hunger

The effects of fat consumed on hunger reached significance [F (2,549) = 2.931, p=0.05]. Figure 7.18 and further analysis demonstrated that those who consumed over 16g of fat were significantly less hungry than those who consumed less than 2.5g (p<0.05).

Figure 7.18: Profile of Hunger over Time for Fat (means +/- s.e.m)



Fat and Memory

Fat consumed failed to influence the total number of words recalled [F (1,328) = 2.491, p=n.s.].

The interaction Fat X Session reached significance with respect to concrete word recall [F (2,656) = 3.442, p<0.05]. SME's demonstrated that participants who consumed less than 2g of fat, compared to consumption of over 11g, recalled significantly more concrete words at 40 minutes [F (1,328) = 5.73, p<0.05]. In addition, both groupings demonstrated significant decreases in the number of concrete words recalled over the 3 sessions ($p<0.001$).

The interaction Fat X Recall reached significance with respect to abstract word recall [F (1.328) = 4.228, $p<0.05$]. SME's demonstrated that participants who consumed less than 2g of fat, compared to consumption of over 11g, recalled significantly more abstract words at immediate recall (40 minutes) [F (1,328) = 5.01, $p<0.05$]. Again, there were significant decreases from immediate to delayed recall for both fat groupings ($p<0.001$).

The three-way interaction Fat X Recall X Session reached significance when the time taken to recall the word lists was considered [F (2,656) = 3.887, $p<0.05$]. SSME's demonstrated that participants who consumed 0-2g of fat, compared to those who consumed over 11g, took significantly longer to recall the word lists at delayed recall, at 40 minutes [F (1,328) = 5.26, $p<0.05$], 80 [F (1,328) = 4.66, $p<0.05$] and 125 minutes [F (1,328) = 4.11, $p<0.05$].

Fat and the Hick Paradigm

29 participants were removed from the analysis due to negative slope values.

Fat failed to influenced Decision Times [F (2,369) = 0.015, p=n.s.]. The three-way interaction Fat X Session X Lamp reached signifcance with respect to Movement Times [F (12,2214) = 1.836, $p<0.05$]. SSME's performed on the data showed this to reflect the significant main effect of fat consumption [F (2,369) = 3.552, $p<0.05$]. Participants who consumed 7-12g of fat were significantly slower than those who consumed less than 2.5g of fat throughout the morning ($p<0.05$)

Fat consumed also failed to influence Intercept [F (2,369) = 0.125, p=n.s.], Slope [F (2,369) = 0.140, p=n.s.] or Intra-Individual Variability [F (2,369) = 0.196, p=n.s.].

Fat and the RIPT

13 participants were removed from the data set due to incomplete data or incorrect performance on the task (>20 wrong responses per minute).

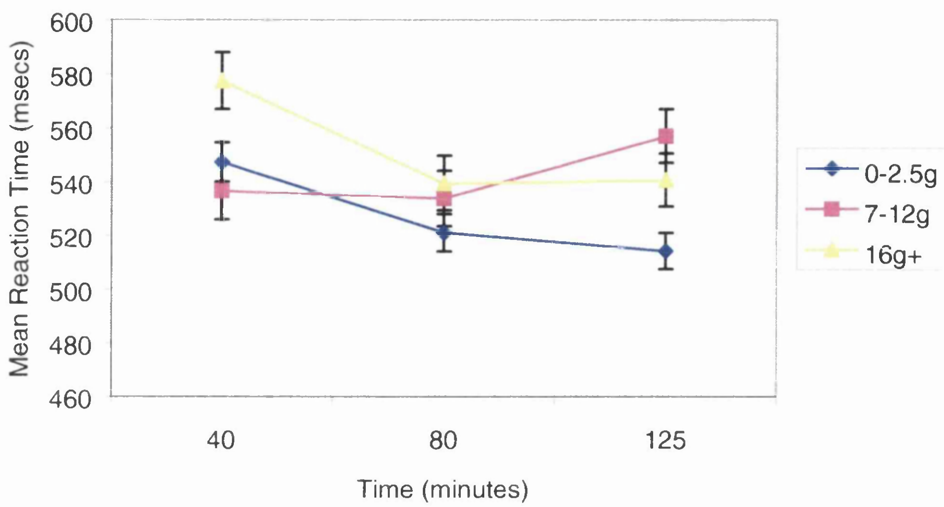
Fat consumed failed to influence the number of correct responses given [F (2,385) = 1.784, p=n.s.]

The amount of fat consumed influenced the number of wrong responses given [F (2,385) = 5.565, $p<0.01$], participants who consumed 7-12g of fat, compared to those who consumed less than 2.5g, recorded significantly more wrong responses over the morning ($p<0.01$).

The interaction Fat X Session also reached significance with respect to reaction times [F (4,770) = 4.453, $p=0.001$]. Figure 7.19 and SME's demonstrate that participants who consumed over 16g of fat were significantly slower than the other conditions at session1 [F (2,385) = 4.15, $p<0.05$]. In addition, at session 3 participants who consumed 7-12g were significantly slower than those who consumed under 2.5g [F (2,385) = 7.00, $p=0.001$]. Participants who consumed less that 2.5g [F (2,770) = 10.00, $p<0.001$] and over 16g of fat

[F (2,770) = 7.19, p=0.001] displayed significant decreases in reaction times over the three sessions.

Figure 7.19: The effect of Fat on total Reaction times on the RIPT over time (means +/- s.e.m)



Summary of the effects of Fat consumption

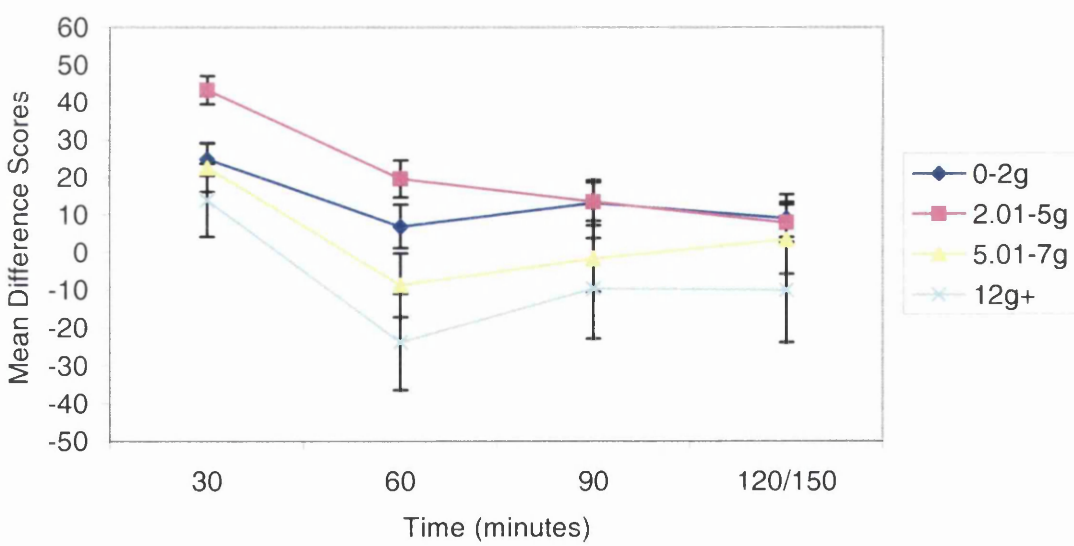
- Consumption of over 16g of fat, compared to lower amounts, was associated with enhanced Composure and Total Mood at 30 minutes.
- Consumption of over 16g of fat, compared to less than 2.5g, resulted in significantly less hunger over the morning.
- Fat consumption failed to influence total word recall. Participants who consumed 0-2g of fat, compared to over 11g, recalled significantly more concrete words at 40 minutes, and significantly more abstract words at immediate recall at 40 minutes. Furthermore, participants who consumed 0-2g of fat, compared to over 11g, took significantly longer to recall the word lists at delayed recall.

- Consumption of 7-12g of fat, compared to 0-2.5g, resulted in significantly slower movement times over the morning.
- Consumption of 7-12g of fat, compared to 0-2.5g, resulted in significantly more wrong responses recorded over the morning. The consumption of high amounts of fat was associated with increased reaction times over the morning.

7.4.5 EFFECT OF FIBRE

Fibre and Mood

Figure 7.20: Profile of Total Mood ratings over Time for Fibre (means +/- s.e.m)

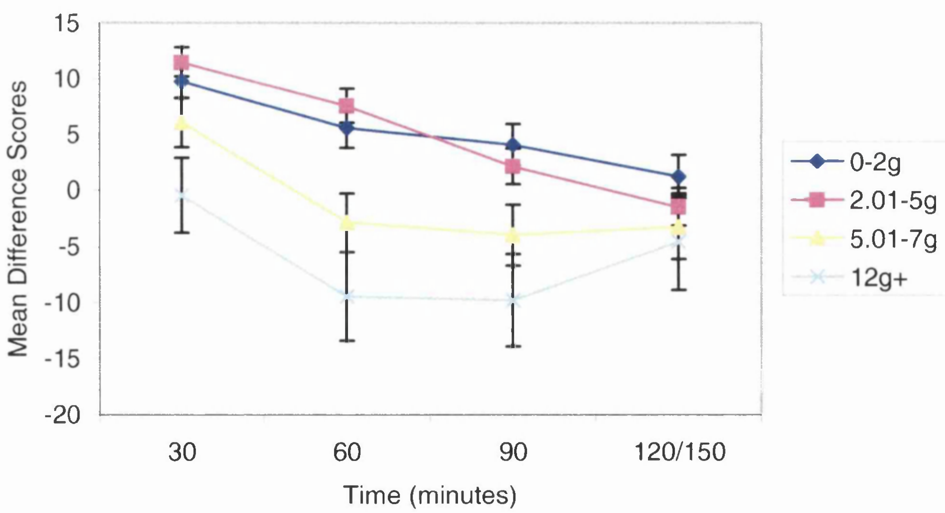


The interaction Fibre X Time reached significance with respect to ratings of Elation [F (9,1644) = 2.125, p<0.05] and Total Mood [F (9,1644) = 2.645, p<0.01]. Figure 7.20 and SME's demonstrate that there are significant differences between the groups at 30 minutes [F (3,548) = 5.71, p=0.001] and 60 minutes [F (3,548) = 5.22, p=0.001].

Participants who consumed 2.01-5g reported significantly better mood than all other groups at 30 minutes ($p<0.05$), and reported significantly better mood than those who consumed over 5.01g of fibre at 60 minutes ($p<0.05$). A similar profile was observed with ratings of Elation, with participants who consumed 2.01-5g of fibre, compared to 12.01g and above ($p<0.05$), reporting significantly enhanced Elation.

Ratings of Energy also displayed a significant Fibre X Time interaction [$F(9,1644) = 2.741$, $p<0.01$]. Figure 7.21 and SME's show that at 30 minutes [$F(3,548) = 4.502$, $p<0.01$] and 90 minutes [$F(3,548) = 4.506$, $p<0.01$], those who consumed over 12g of fibre were significantly less energetic than those who consumed 0-5g ($p<0.05$). At 60 minutes, those who consumed those who consumed over 5.01g were significantly less energetic than those who consumed 0-5g [$F(3,548) = 8.253$, $p<0.001$].

Figure 7.21: Profile of Energy ratings over Time for Fibre (means +/- s.e.m)



The amount of fibre consumed also influenced ratings of Composure [F (3,548) = 2.596, p=0.05]. Participants who consumed 2.01-5g of fibre were significantly more composed than the other conditions over the first 30 minutes (p<0.05).

Fibre and Hunger

Fibre influenced ratings of Hunger [F (3,548) = 6.105, p<0.001], those who consumed over 12g of Fibre were significantly less hungry than those who consumed 2-7g (p<0.01).

Fibre and Memory

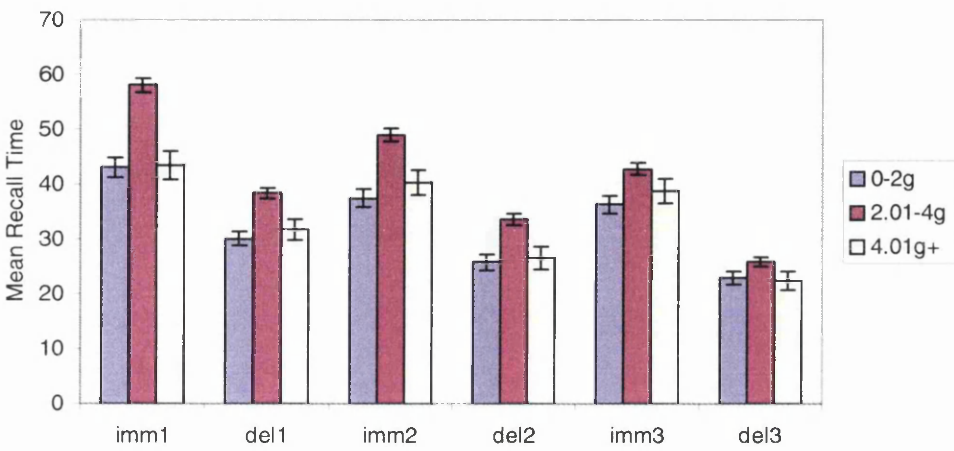
The interaction Fibre X Session reached significance with respect to the total number of words recalled [F (4,654) = 2.497, p<0.05]. SME's demonstrated significant decreases in the number of words recalled over the three test sessions for each fibre grouping (p<0.001).

The interaction Fibre X Session again reached significance with respect to concrete word recall [F (4,654) = 3.346, p=0.01]. The pattern is identical to that with total word recall.

Fibre failed to influence the recall of abstract words [F (2,327) = 1.637, p=0.20].

The three-way interaction Fibre X Recall X Session reached significance with respect to the time taken to recall the word lists [F (6,654) = 2.874, p<0.05]. Figure 7.22 illustrated the overall main effect of fibre [F (2,327) = 19.135, p<0.001], with participants who consumed 2.01-4 of fibre taking significantly more time to recall the word lists over the morning than the other groupings (p<0.001). All SSME's were significant.

Figure 7.22: Profile of the time taken to recall the word lists over Time for each Fibre grouping (means +/- s.e.m)



Fibre and the Hick Paradigm

29 participants were removed from the analysis due to negative slope values.

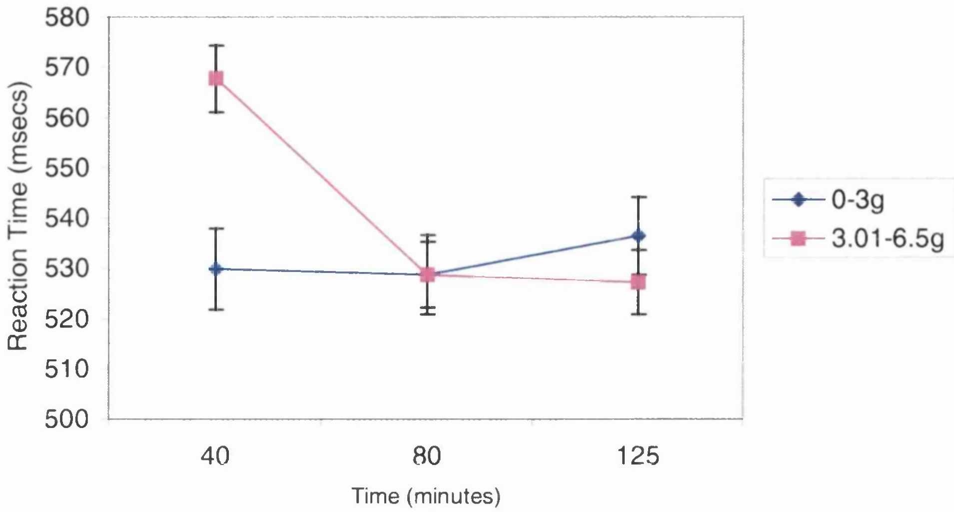
Fibre consumed failed to influence Decision Times [F (1,370) = 0.002, p=n.s.]. There was a significant effect of Fibre with respect to Movement Times [F (1,370) = 4.026, p<0.05]. Participants who consumed over 3.01g of fibre were significantly quicker, compared to those who consumed less than 3g.

Fibre also failed to influence Intercept values [F (1,370) = 0.065, p=n.s.], Slope values [F (1,370) = 0.082, p=n.s.] or Intra-Individual Variability [F (1,370) = 0.527, p=n.s.].

Fibre and the RIPT

Fibre consumed failed to influence either the number of correct responses recorded over the morning [F (1,386) = 0.375, p=n.s.], nor wrong responses [F (1,386) = 0.483, p=n.s.].

Figure 7.23: The effect of Fibre on total Reaction times on the RIPT over time (means +/- s.e.m)



The interaction Fibre X Session with respect to reaction times reached significance [F (2,772) = 9.546, p<0.001]. Figure 7.23 and SME's demonstrated that this reflects a significant decrease in reaction times over the three session for those participants who consumed 3.01-6.5g of fibre [F (2,772) = 19.82, p<0.001]. In addition participants who consumed 3.01-6.5g presented significantly longer reaction times than those who consumed less than 3g at 40 minutes [F (1,386) = 12.82, p<0.001].

Summary of the effects of Fibre consumption

- Consumption of 2.01-5g of fibre resulted in significantly enhanced mood throughout the morning compared to the other conditions. Consumption of 12g and over was detrimental to mood.
- Consumption of over 12g of fibre, compared to less than 2-7g, resulted in significantly less hunger over the morning.

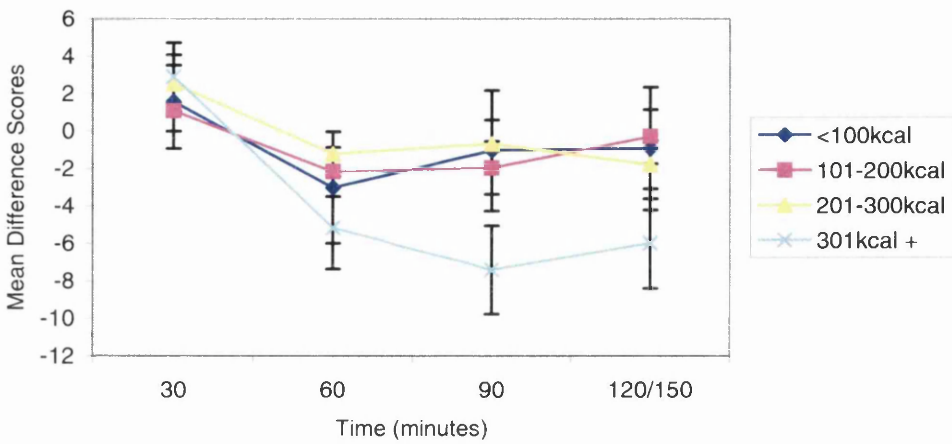
- Significant decreases on the number of total and concrete words recalled over time were observed for all conditions, however no significant differences between the conditions were found at any time point. Furthermore, participants who consumed 2.01-4g of fibre, compared to the other conditions, took significantly longer to recall the word lists.
- Consumption of 0-3g of fibre, compared to over 3.01, resulted in significantly slower movement times on the Hick Paradigm over the morning.
- Fibre consumed failed to influence either correct or wrong responses on the RIPT. Participants who consumed 3.01-6g of fibre, compared to 0-3g, significantly decreased the reaction times over the morning in this task.

7.6 EFFECT OF CALORIC INTAKE

Caloric Intake and Mood

The interaction Caloric Intake X Time reached significance with respect to ratings of Agreeability [$F(9, 1644) = 2.359$, $p<0.05$]. Figure 7.24 and SME's demonstrate that there are significant changes over time for all groups except 0-100kcal, whose reported agreeability is relatively constant over the morning [$F(3,1644) = 1.13$, p=n.s.]. At 90 minutes there was a trend towards signficance for those who consumed more than 301Kcal, compared to 201-300Kcal, to be less agreeable. A similar pattern was observed for ratings of Clearheadedness [$F(9,1644) = 1.858$, $p=0.05$].

Figure 7.24: Profile of Agreeable ratings over Time for Caloric intake (means +/- s.e.m)

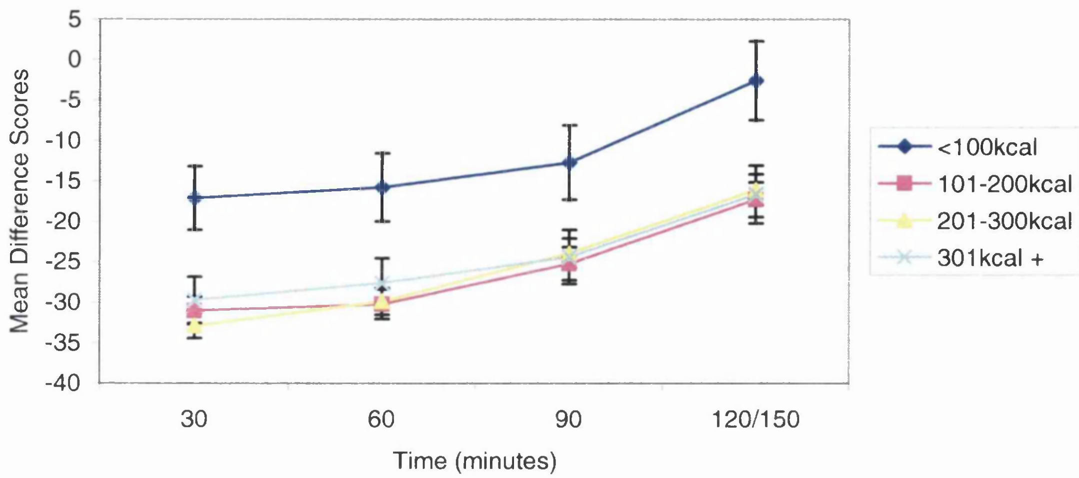


The interaction Caloric Intake X Time also reached significance with respect to Total Mood [F (3,1644) = 2.521, p<0.01]. All groups reported significant changes in mood over time (p<0.05), however there were no significant differences between the groups at any time point.

Caloric Intake and Hunger

Hunger was significantly influenced by the amount of calories consumed [F (3,548) = 3.707, p<0.05]. Figure 7.25 and further analysis showed that consumption of any meal greater than 100 kcal significantly reduced hunger when compared to a meal less than 100 kcal (p<0.05).

Figure 7.25: Profile of Hunger ratings over Time for Caloric Intake (means +/- s.e.m)



Caloric Intake and Memory

The interaction Caloric Intake X Session reached significance with respect to the total number of words recalled [F (4,654) = 2.563, p<0.05]. SME's demonstrate that there were significant differences between the groupings at 40 minutes [F (2,327) = 3.00, p=0.05], however, there was only a trend for participants who consumed 101-200 Kcal to recall more words than those who consumed over 301 Kcal (p=0.07). As with previous findings, there were significant decreases in the number of words recalled over the three test sessions (p<0.001).

The interaction Caloric Intake X Session also reached significance with respect to concrete word recall [F (4,654) = 2.357, p=0.05]. SME's demonstrated that there were significant decreases in the number of words recalled over the three sessions (p<0.001). Caloric Intake failed to influence the recall of abstract words [F (2,327) = 1.315, p=n.s.].

The interaction Caloric Intake X Recall reached significance with respect to the time taken to recall the word lists [F (2,327) = 4.448, p<0.05]. SME's performed on the data demonstrated that there were significant decreases in the time taken to recall the word lists from immediate to delayed for each Caloric Intake grouping (p<0.001).

Caloric Intake and the Hick Paradigm

Caloric intake failed to influence total Decision Times [F (2,369) = 0.445, p=n.s.], or total Movement Times [F (2,369) = 0.662, p=n.s.].

Caloric Intake also failed to influence Intercept [F (2,369) = 0.582, p=n.s.], Slope [F (2,369) = 0.000, p=n.s.] or Intra-Individual Variability [F (2,369) = 0.268, p=n.s.].

Caloric Intake and the RIPT

The interaction Caloric Intake X Session reached significance with respect to correct responses recorded [F (4,770) = 2.637, p<0.05]. Figure 7.26 and SME's demonstrate that participants who consumed 201-300kcal [F (2,770) = 13.11, p<0.001] and over 301kcal [F (2,770) = 4.90, p<0.01] increased the amount of correct responses recorded over the three sessions.

Figure 7.26: The effect of Caloric Intake on Correct responses over Time (means +/- s.e.m)

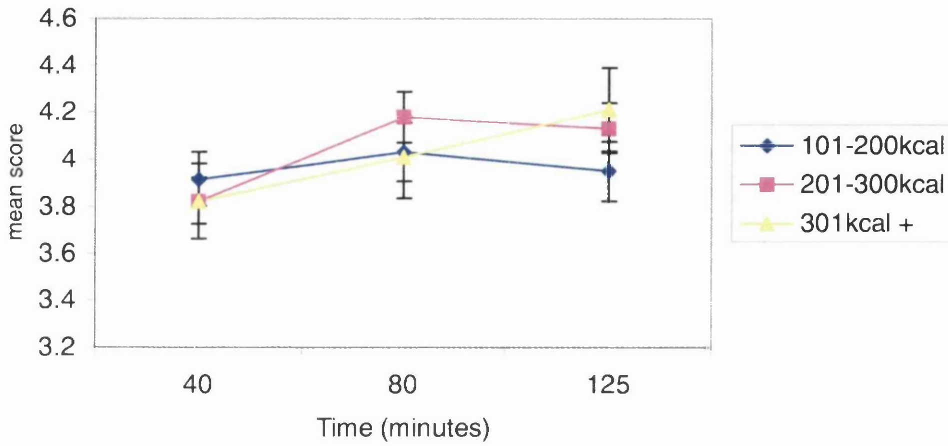
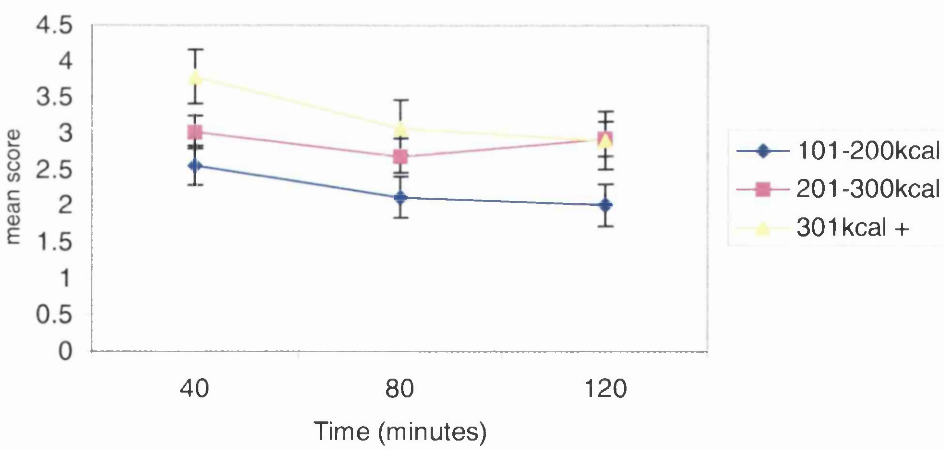


Figure 7.27: The effect of Caloric Intake on Wrong responses over Time (means +/- s.e.m)



The interaction Caloric Intake X Session reached significance with respect to Wrong responses recorded [F (4,770) = 2.736, p<0.05]. Figure 7.27 and SME's demonstrate that participants who consumed over 301kcal, compared to those who consumed 101-200kcal, recorded significantly more wrong responses at 40 minutes [F (2,385) = 3.60, p<0.05]. In addition those who consumed 201-300kcal, compared to those who consumed 101-200kcal, recorded significantly more wrong responses at 125 minutes [F (2,385) = 3.31, p<0.05]. There were also significant decreases in wrong responses over the three sessions for 101-200kcal [F (2,770) = 6.44, p<0.01], 201-300kcal [F (2,770) = 3.01, p=0.05] and over 301kcal [F (2,770) = 8.71, p<0.001].

Participants who consumed over 301kcal, compared to those who consumed 101-200kcal, also demonstrated significantly slower reaction times over the morning [F (2,385) = 4.393, p<0.05].

Summary of the effects of Caloric Intake

- Consumption of over 101kcal resulted in significant changes over time with respect to mood; larger intakes were be detrimental after 2 hours.
- Any meal over 100Kcal significantly reduced hunger, however there were no significant differences between the other conditions despite varied caloric intake.
- There was a trend for participants who consumed 101-200Kcal, compared to over 301Kcal, to recall more words (total) at 40 minutes. Significant decreases in the number of total and concrete words recalled over the morning were observed for all conditions.
- Caloric intake failed to influence any measure of Reaction Times.
- Participants who consumed over 201Kcal increased the number of correct responses over the morning. Consumption of 101-200Kcal resulted in the lowest number of

wrong responses over the morning, and significantly quicker reaction times compared to over 301Kcal.

7.6 DISCUSSION

The consumption of breakfast significantly enhanced Total Mood, Energy, Composure and just missed significance with respect to Clearheadedness, when compared to fasting. These finding suggest that the consumption of breakfast is indeed beneficial to mood enhancement, replicating previous studies (Benton et al., 2001b; Holt et al., 1999; Smith et al., 1999; 1994). Not surprisingly those who consumed breakfast were significantly less hungry over the morning.

The effects on cognitive functioning were more limited. The number of words recalled failed to be influenced by the consumption of breakfast, yet breakfast consumers took significantly longer times to recall the word lists over the morning, compared to those who fasted. Those who consumed breakfast took employed different discrimination strategies on the Hick Paradigm, and recorded more correct responses on the RIPT, compared to those who fasted.

The amount of carbohydrate consumed was demonstrated to be an important factor for both mood enhancement and cognitive functioning. It was found that 20.1-35g was optimal for the enhancement of mood, with consumption over 50.1g being detrimental after a period of 2 hours. With respect to memory, consumption of 35.1-50g was found to be associated with the shortest recall times, with both 20.1-35g and 50.1g and above having similar effects on memory. These findings with memory will be discussed further in Chapter 9.

Interestingly the consumption of 35.1-50g was beneficial for sustained performance on the RIPT. Consumption of 20.1-35g and 50.1g and above was associated with an increased number of correct responses recorded over the three sessions, yet 35.1-50g consumers recorded less wrong and quicker reaction times over the morning.

These reported findings suggest that the differences in the memory and RIPT tasks may be a function of the demands and the duration of the tasks. To gain the sustained performance that is beneficial for the RIPT an increased amount of carbohydrate was required, yet 35.1-50g was associated with poorer performance on the memory tests due to quicker recall times. Furthermore, enhanced performance on the memory tests was associated with an increased number of correct responses on the RIPT for those who consumed 20.1-35g and 50.1g and above. These ideas will be discussed further in Chapters 9 and 10.

Consumption of high protein meals (8.01-12g) were associated with enhanced Elation, Agreeability, Total Mood and Composurement of mood, compared to both lower doses and consumption of over 12.01g. With respect to hunger, the more protein contained in the meal, the greater the suppression of hunger. These findings with protein and mood are interesting as they dispute the theories of Wurtman and Wurtman (1995) who suggested that high carbohydrate foods are craved and consumed for their positive psychopharmacological effects. This ides will be discussed in depth in Chapter 8.

Protein consumed failed to influence the number of words recalled, however, participants who consumed 6.01-8g of protein took significantly less time to recall the word lists compared to other doses. Protein consumed failed to influence any measure of Reaction Times. Similarly to the effects with carbohydrate on the RIPT, consumption of 0-4g and over 8.01g of protein significantly increased the number of correct responses over the morning, yet consumption of 4.01-8g of protein was associated with more stable performance. It may be possible that the effects on the RIPT are due to another macronutrient, or possible combinations of macronutrients, rather than protein per se, as protein failed to influence performance on the Hick Paradigm, and had little influence on Memory. These ideas will be discussed further in Chapter 9.

Consumption of over 16g of fat had a beneficial effect on Composure and Total Mood compared to lower amounts, however, this effect was only observed over the first 30 minutes. Furthermore, higher amount of fat consumed were associated with a greater suppression of hunger over the morning. Consumption of less than 2g of fat was associated with enhanced memory performance. High amounts of fat were associated with poorer performance on the RIPT and Hick Paradigm.

It is possible that the feeling of satiation induced by the high fat meals could have resulted in the poorer performance on the cognitive tests. It has previously been reported that high fat meals, consumed as both a breakfast and lunch meal, have been associated with decreased alertness and vigour (Wells et al., 1997; Lloyd et al., 1994). These ideas will be discussed further in Chapter 8 and 9.

The consumption of 2.01-5g of fibre significantly enhanced reported Elation, Total Mood, Composure and Energy ratings, compared to other doses. Consumption of over 12g of fibre was detrimental to mood over the morning, yet the larger the dose of fibre consumed, the more satiated the consumer. Previous studies have similarly reported the reduction in mood following high fibre intake (Holt et al., 1999; Levine et al., 1989), yet the finding with mood is more novel, and will be discussed in greater detail in Chapter 8.
Fibre failed to have any substantial effect on cognitive functioning.

The caloric content of the meal significantly influenced ratings of Agreeability, Clearheadedness and Total Mood, with intakes of over 301Kcal being detrimental over the two hours. However, higher caloric meals were associated with decreased hunger over the morning. Memory and performance on the RIPT were enhanced following consumption of 101-200Kcal, compared to over 301Kcal. Again, suggesting that small meals when consumed as a breakfast meal are more beneficial. These findings were interesting as the mean habitual caloric intake reportedly consumed by those who participated was 347.2Kcal, suggesting that this was in general detrimental to mood, however satiating. Furthermore, most previous studies have kept test meals equicaloric, often used intakes of over 400Kcal (Fischer et al., 2002; 2001; Holt et al., 1999). The studies presented within this thesis suggest that the caloric intake consumed may be more important that initially thought. These ideas will be discussed in greater detail in Chapters 8 and 9.

It is clear from this meta-analysis chapter that a great number of issues that have been raised regarding the meals consumed, the interactions of the macronutrients, and their influence on mood and cognitive functioning. The ensuing chapters will aim to give a more in-depth interpretation and explanation of the results reported in this chapter in relation to the previous literature, and endeavour to present some conclusions as to what is the 'better' breakfast for the optimal enhancement of mood and cognitive functioning.

Table 7.1: Summary table with respect to measures of Mood for Breakfast groupings (means +/-s.e.m)

MOOD	MEAL	30mins – base	60mins – base	90mins – base	120/150 mins – base	RESULT
Composure	Fast	3.040 (1.836)	-2.687 (2.216)	-3.808 (2.263)	-3.828 (2.332)	*Meal* F (1,649) = 6.794, p<0.01
	Active	5.598 (0.777)	1.554 (0.938)	3.694 (0.958)	3.210 (0.988)	*Time* F (3,1947) = 11.868, p<0.001 *Meal X Time* F (3,1947) = 3.022, p<0.05
Agreeability	Fast	-0.495 (1.578)	-3.576 (1.827)	-5.697 (1.972)	-2.697 (1.985)	*Meal* F (1,649) = 1.538, p=0.215
	Active	2.004 (0.668)	-2.183 (0.774)	-2.022 (0.835)	-1.721 (0.841)	*Time* F (3,1947) = 11.175, p<0.001 *Meal X Time* F (3,1947) = 1.037, p=0.375
Elation	Fast	2.141 (1.329)	0.525 (1.573)	-0.364 (1.560)	-0.404 (1.642)	*Meal* F (1,649) = 0.140, p=0.708
	Active	2.496 (0.563)	0.299 (0.666)	0.806 (0.661)	0.413 (0.695)	*Time* F (3,1947) = 4.449, p<0.01 *Meal X Time* F (3,1947) = 0.375, p=0.784
Confidence	Fast	5.263 (1.506)	1.717 (1.983)	3.101 (1.874)	3.657 (2.082)	*Meal* F (1,649) = 1.375, p=0.241
	Active	6.513 (0.638)	3.935 (0.840)	5.373 (0.793)	6.205 (0.882)	*Time* F (3,1947) = 4.886, p<0.01 *Meal X Time* F (3,1947) = 0.236, p=0.871

Energy	Fast	1.990 (1.989)	-0.333 (2.398)	-6.091 (2.478)	-6.990 (2.596)	*Meal* F (1,649) = 7.568, p<0.01
	Active	9.306 (0.842)	4.187 (1.015)	1.054 (1.050)	-1.297 (1.099)	*Time* F (3,1947) = 36.143, p<0.001 *Meal X Time* F (3,1947) = 0.800, p=0.494
Clearheaded	Fast	1.949 (1.653)	-3.808 (2.046)	-1.990 (2.194)	-3.485 (2.256)	*Meal* F (1,649) = 3.554, p=0.060
	Active	6.190 (0.700)	0.422 (0.866)	0.654 (0.929)	-0.328 (0.956)	*Time* F (3,1947) = 17.057, p<0.001 *Meal X Time* F (3,1947) = 0.347, p=0.791
Total Mood	Fast	13.889 (5.939)	-8.162 (7.808)	-14.848 (7.990)	-13.747 (8.478)	*Meal* F (1,649) = 7.697, p<0.01
	Active	32.107 (2.515)	8.214 (3.306)	9.560 (3.384)	6.482 (3.590)	*Time* F (3,1947) = 27.511, p<0.001 *Meal X Time* F (3,1947) = 0.512, p=0.674
Hunger	Fast	-1.747 (2.386)	1.808 (2.572)	9.313 (2.840)	16.606 (2.998)	*Meal* F (1,649) = 140.153, p<0.001
	Active	-30.716 (1.011)	-28.737 (1.089)	-23.661 (1.203)	-15.629 (1.270)	*Time* F (3,1947) = 96.265, p<0.001 *Meal X Time* F (3,1947) = 1.399, p=0.241

Table 7.2: Summary table with respect to measures of Mood for Carbohydrate groupings (means +/-s.e.m)

MOOD	MEAL	30mins – base	60mins – base	90mins – base	120/150 mins – base	RESULT
Composure	Fast	3.040 (1.836)	-2.687 (2.216)	-3.808 (2.263)	-3.828 (2.332)	*Carbohydrate* F (3,548) = 3.161, p<0.05
	< 20g	-1.368 (2.950)	-4.447 (3.578)	-0.895 (3.645)	-1.105 (3.756)	
	20.1-35g	7.597 (1.223)	3.977 (1.484)	6.480 (1.511)	6.086 (1.557)	*Time* F (3,1644) = 6.788, p<0.001
	35.1-50g	2.607 (1.363)	-0.062 (1.653)	2.129 (1.684)	1.028 (1.735)	*Carb X Time* F (9,1644) = 1.379, p=0.192
	50.1g +	8.687 (1.696)	1.383 (2.057)	2.278 (2.095)	2.487 (2.159)	
Agreeability	Fast	-0.495 (1.578)	-3.576 (1.827)	-5.697 (1.972)	-2.697 (1.985)	*Carbohydrate* F (3,548) = 3.223, p<0.05
	< 20g	1.579 (2.502)	-3.000 (2.961)	-1.026 (3.214)	-0.921 (3.268)	
	20.1-35g	3.231 (1.037)	0.792 (1.228)	0.339 (1.333)	0.380 (1.355)	*Time* F (3,1644) = 13.640, p<0.001
	35.1-50g	1.051 (1.156)	-3.079 (1.368)	-2.219 (1.485)	-1.640 (1.510)	*Carb X Time* F (9,1644) = 1.606, p=0.108
	50.1g +	1.261 (1.438)	-6.243 (1.702)	-6.583 (1.847)	-6.148 (1.879)	
Elation	Fast	2.141 (1.329)	0.525 (1.573)	-0.364 (1.560)	-0.404 (1.642)	*Carbohydrate* F (3,548) = 1.141, p=0.332
	< 20g	0.158 (2.186)	-4.789 (2.593)	-0.184 (2.550)	-2.079 (2.679)	
	20.1-35g	2.520 (0.906)	1.195 (1.075)	1.181 (1.057)	0.801 (1.111)	*Time* F (3,1644) = 6.091, p<0.001
	35.1-50g	1.428 (1.010)	-0.657 (1.198)	0.573 (1.178)	-0.264 (1.238)	*Carb X Time* F (9,1644) = 1.048, p=0.399
	50.1g +	4.878 (1.256)	1.739 (1.490)	0.774 (1.466)	1.539 (1.540)	
Confidence	Fast	5.263 (1.506)	1.717 (1.983)	3.101 (1.874)	3.657 (2.082)	*Carbohydrate* F (3,548) = 1.002, p=0.391
	< 20g	4.658 (2.325)	-0.132 (3.057)	2.632 (2.966)	4.474 (3.355)	
	20.1-35g	6.738 (0.964)	3.222 (1.268)	6.357 (1.230)	7.783 (1.391)	*Time* F (3,1644) = 5.069, p<0.01
	35.1-50g	5.596 (1.074)	4.124 (1.413)	4.236 (1.370)	4.011 (1.550)	*Carb X Time* F (9,1644) = 1.438, p=0.166
	50.1g +	8.113 (1.336)	6.357 (1.757)	6.148 (1.705)	7.139 (1.929)	

Energy	Fast	1.990 (1.989)	-0.333 (2.398)	-6.091 (2.478)	-6.990 (2.596)	*Carbohydrate* F (3,548) = 1.763, p=0.153
	< 20g	4.737 (3.335)	-2.053 (3.975)	-5.553 (4.110)	-9.053 (4.264)	
	20.1-35g	10.113 (1.383)	40.86 (1.648)	2.380 (1.704)	0.407 (1.768)	*Time* F (3,1644) = 47.184, p<0.001
	35.1-50g	7.185 (1.541)	2.916 (1.837)	0.056 (1.899)	-1.298 (1.970)	*Carb X Time* F (9,1644) = 1.572, p=0.118
	50.1g +	12.548 (1.917)	8.409 (2.285)	2.235 (2.362)	-2.009 (2.451)	
Clearheaded	Fast	1.949 (1.653)	-3.808 (2.046)	-1.990 (2.194)	-3.485 (2.256)	*Carbohydrate* F (3,548) = 0.710, p=0.546
	< 20g	5.632 (2.765)	0.342 (3.322)	3.579 (3.571)	0.605 (3.653)	
	20.1-35g	6.140 (1.146)	-0.421 (1.378)	2.222 (1.481)	1.493 (1.515)	*Time* F (3,1644) = 21.782, p<0.001
	35.1-50g	6.399 (1.277)	1.596 (1.535)	0.736 (1.650)	-0.045 (1.688)	*Carb X Time* F (9,1644) = 2.576, p<0.01
	50.1g +	6.148 (1.589)	0.252 (1.910)	-3.452 (2.053)	-4.574 (2.100)	
Total Mood	Fast	13.889 (5.939)	-8.162 (7.808)	-14.848 (7.990)	-13.747 (8.478)	*Carbohydrate* F (3,548) = 1.958, p-0.119
	< 20g	15.395 (9.724)	-14.079 (12.735)	-1.447 (13.092)	-8.079 (13.712)	
	20.1-35g	36.339 (4.032)	12.851 (5.281)	18.959 (5.429)	16.950 (5.686)	*Time* F (3,1644) = 29.631, p<0.001
	35.1-50g	24.264 (4.493)	4.837 (5.884)	5.511 (6.049)	1.792 (6.335)	*Carb X Time* F (9,1644) = 2.186, p<0.05
	50.1g +	41.635 (5.589)	11.896 (7.321)	1.400 (7.526)	-1.565 (7.882)	
Hunger	Fast	-1.747 (2.386)	1.808 (2.572)	9.313 (2.840)	16.606 (2.998)	*Carbohydrate* F (3,548) = 9.134, p<0.001
	< 20g	-17.105 (3.881)	-15.763 (4.131)	-12.684 (4.564)	-2.579 (4.834)	
	20.1-35g	-28.765 (1.609)	-26.063 (1.713)	-20.928 (1.893)	-12.615 (2.005)	*Time* F (3,1644) = 80.017, p<0.001
	35.1-50g	-37.039 (1.793)	-35.685 (1.909)	-30.427 (2.109)	-22.596 (2.234)	*Carb X Time* F (9,1644) = 0.226, p=0.991
	50.1g +	-29.174 (2.231)	-27.409 (2.375)	-22.070 (2.624)	-14.948 (2.779)	

Table 7.3: Summary table with respect to measures of Mood for Protein groupings (means +/- s.e.m)

MOOD	MEAL	30mins – base	60mins – base	90mins – base	120/150 mins – base	RESULT
Composure	Fast	3.040 (1.836)	-2.687 (2.216)	-3.808 (2.263)	-3.828 (2.332)	*Protein* F (3,548) = 2.592, p=0.052
	0-2g	9.366 (1.891)	1.978 (2.292)	5.054 (2.336)	7.151 (2.396)	
	2.01-8g	2.717 (1.360)	0.578 (1.648)	2.339 (1.679)	1.961 (1.723)	*Time* F (3,1644) = 9.624, p<0.001
	8.01-12g	7.376 (1.227)	3.308 (1.487)	5.176 (1.515)	4.290 (1.555)	*Protein X Time*
	12.01g +	1.724 (2.395)	-2.776 (2.902)	0.069 (2.958)	-3.345 (3.035)	F (9,1644) = 1.193, p=0.295
Agreeability	Fast	-0.495 (1.578)	-3.576 (1.827)	-5.697 (1.972)	-2.697 (1.985)	*Protein* F (3,548) = 3.709, p<0.05
	0-2g	0.806 (1.583)	-4.172 (1.901)	-6.043 (2.054)	-4.882 (2.091)	
	2.01-8g	0.406 (1.138)	-2.511 (1.366)	-2.089 (1.477)	-1.533 (1.503)	*Time* F (3,1644) = 15.285, p<0.001
	8.01-12g	4.824 (1.027)	-0.018 (1.233)	0.606 (1.333)	0.457 (1.356)	*Protein X Time*
	12.01g +	-1.862 (2.004)	-6.224 (2.407)	-5.379 (2.601)	-5.534 (2.648)	F (9,1644) = 0.801, p=0.615
Elation	Fast	2.141 (1.329)	0.525 (1.573)	-0.364 (1.560)	-0.404 (1.642)	*Protein* F (3,548) = 1.202, p=0.308
	0-2g	2.753 (1.403)	0.484 (1.658)	-2.183 (1.620)	-2.323 (1.709)	
	2.01-8g	3.122 (1.008)	0.372 (1.192)	2.067 (1.164)	0.344 (1.229)	*Time* F (3,1644) = 7.461, p<0.001
	8.01-12g	2.299 (0.910)	1.330 (1.076)	1.765 (1.051)	1.661 (1.109)	*Protein X Time*
	12.01g +	0.897 (1.776)	-4.155 (2.100)	-1.966 (2.051)	0.259 (2.164)	F (9,1644) = 2.453, p<0.01
Confidence	Fast	5.263 (1.506)	1.717 (1.983)	3.101 (1.874)	3.657 (2.082)	*Protein* F (3,548) = 1.374, p=0.250
	0-2g	9.409 (1.482)	6.538 (1.957)	7.290 (1.897)	10.269 (2.143)	
	2.01-8g	5.061 (1.065)	3.128 (1.407)	4.972 (1.363)	4.561 (1.540)	*Time* F (3,1644) = 6.184, p<0.01
	8.01-12g	6.199 (0.961)	3.638 (1.270)	5.475 (1.230)	6.090 (1.390)	*Protein X Time*
	12.01g +	7.569 (1.876)	3.397 (2.479)	3.155 (2.402)	5.224 (2.713)	F (9,1644) = 0.718, p=0.692

Energy	Fast	1.990 (1.989)	-0.333 (2.398)	-6.091 (2.478)	-6.990 (2.596)	*Protein* F (3,548) =
	0-2g	11.613 (2.129)	6.892 (2.512)	2.097 (2.614)	-2.796 (2.729)	3.610, p<0.05
	2.01-8g	9.156 (1.530)	3.467 (1.806)	1.422 (1.879)	-1.283 (1.962)	*Time* F (3,1644) =
	8.01-12g	10.276 (1.381)	6.891 (1.630)	2.787 (1.696)	0.452 (1.771)	48.475, p<0.001 *Protein X Time*
	12.01g +	2.379 (2.696)	-8.224 (3.181)	-8.362 (3.310)	-5.603 (3.456)	F (9,1644) = 2.081, p=0.028
Clearheaded	Fast	1.949 (1.653)	-3.808 (2.046)	-1.990 (2.194)	-3.485 (2.256)	*Protein* F (3,548) =
	0-2g	4.946 (1.766)	-0.022 (2.121)	-3.258 (2.280)	-2.860 (2.343)	0.881, p=0.451
	2.01-8g	6.167 (1.270)	1.922 (1.524)	3.589 (1.639)	0.917 (1.684)	*Time* F (3,1644) =
	8.01-12g	6.602 (1.146)	0.213 (1.376)	0.534 (1.479)	-0.299 (1.520)	29.575, p<0.001 *Protein X Time*
	12.01g +	6.690 (2.237)	-2.724 (2.685)	-1.724 (2.888)	-0.241 (2.967)	F (9,1644) = 1.546, p=0.126
Total Mood	Fast	13.889 (5.939)	-8.162 (7.808)	-14.848 (7.990)	-13.747 (8.478)	*Protein* F (3,548) =
	0-2g	38.892 (6.227)	11.699 (8.100)	2.957 (8.353)	4.559 (8.787)	2.622, p=0.050
	2.01-8g	26.628 (4.476)	6.956 (5.822)	12.300 (6.004)	4.967 (6.316)	*Time* F (3,1644) =
	8.01-12g	37.575 (4.039)	15.362 (5.254)	16.344 (5.418)	12.652 (5.700)	37.750, p<0.001 *Protein X Time*
	12.01g +	17.397 (7.885)	-20.707 (10.256)	-14.207 (10.577)	-9.241 (11.127)	F (9,1644) = 1.373, p=0.195
Hunger	Fast	-1.747 (2.386)	1.808 (2.572)	9.313 (2.840)	16.606 (2.998)	*Protein* F (3,548) =
	0-2g	-26.022 (2.513)	-22.172 (2.670)	-15.538 (2.921)	-8.688 (3.104)	5.817, p=0.001
	2.01-8g	-29.917 (1.806)	-28.506 (1.919)	-21.933 (2.100)	-14.144 (2.231)	*Time* F (3,1644) =
	8.01-12g	-30.891 (1.630)	-29.308 (1.732)	-25.814 (1.895)	-16.733 (2.013)	96.458, p<0.001 *Protein X Time*
	12.01g +	-40.052 (3.182)	-37.810 (3.381)	-33.845 (3.699)	-27.155 (3.930)	F (9,1644) = 0.866, p=0555

Table 7.4: Summary table with respect to measures of Mood for Fat groupings (means +/- s.e.m)

MOOD	MEAL	30mins – base	60mins – base	90mins – base	120/150 mins – base	RESULT
Composure	Fast	3.040 (1.836)	-2.687 (2.216)	-3.808 (2.263)	-3.828 (2.332)	*Fat* F (2,549) = 1.464, p=0.232
	< 2.5g	4.939 (0.957)	1.295 (1.162)	4.050 (1.185)	3.713 (1.218)	
	7-12g	2.351 (1.880)	0.106 (2.283)	2.777 (2.328)	-0.479 (2.393)	*Time* F (3,1647) = 8.981, p<0.001
	16g +	11.326 (1.870)	3.979 (2.271)	3.242 (2.315)	4.937 (2.380)	*Fat X Time* F (6,1647) = 2.969, p<0.01
Agreeability	Fast	-0.495 (1.578)	-3.576 (1.827)	-5.697 (1.972)	-2.697 (1.985)	*Fat* F (2,549) = 0.421, p=0.656
	< 2.5g	1.333 (0.807)	-2.766 (0.966)	-1.972 (1.047)	-1.303 (1.064)	
	7-12g	1.532 (1.586)	-2.011 (1.899)	-2.755 (2.058)	-3.053 (2.090)	*Time* F (3,1647) = 16.680, p<0.001
	16g +	5.032 (1.578)	-0.126 (1.889)	-1.484 (2.048)	-2.000 (2.079)	*Fat X Time* F (6,1647) = 1.448, p=0.193
Elation	Fast	2.141 (1.329)	0.525 (1.573)	-0.364 (1.560)	-0.404 (1.642)	*Fat* F (2,549) = 1.105, p=0.332
	< 2.5g	1.612 (0.707)	-0.366 (0.840)	0.488 (0.822)	0.405 (0.867)	
	7-12g	4.213 (1.390)	2.936 (1.651)	3.319 (1.615)	0.713 (1.704)	*Time* F (3,1647) = 7.077, p<0.001
	16g +	4.179 (1.383)	0.232 (1.643)	-0.463 (1.607)	0.147 (1.695)	*Fat X Time* F (6,1647) = 1.729, p=0.111
Confidence	Fast	5.263 (1.506)	1.717 (1.983)	3.101 (1.874)	3.657 (2.082)	*Fat* F (2,549) = 0.893, p=0.410
	< 2.5g	6.314 (0.751)	3.972 (0.991)	5.366 (0.961)	6.631 (1.086)	
	7-12g	4.926 (1.476)	2.745 (1.948)	4.606 (1.888)	3.170 (2.134)	*Time* F (3,1647) = 4.448, p<0.01
	16g +	8.842 (1.468)	4.968 (1.938)	6.158 (1.878)	7.579 (2.122)	*Fat X Time* F (6,1647) = 0.693, p=0.655

Energy	Fast	1.990 (1.989)	-0.333 (2.398)	-6.091 (2.478)	-6.990 (2.596)	*Fat* F (2,549) = 1.150, p=0.317
	< 2.5g	8.149 (1.081)	3.077 (1.290)	0.174 (1.329)	-1.556 (1.382)	
	7-12g	11.170 (2.125)	6.947 (2.535)	5.223 (2.612)	1.191 (2.716)	*Time* F (3,1647) = 47.818, p<0.001
	16g +	11.884 (2.114)	5.695 (2.521)	0.295 (2.598)	-2.768 (2.702)	*Fat X Time* F (6,1647) = 1.300, p=0.254
Clearheaded	Fast	1.949 (1.653)	-3.808 (2.046)	-1.990 (2.194)	-3.485 (2.256)	*Fat* F (2,549) = 0.225, p=0.775
	< 2.5g	6.105 (0.894)	0.311 (1.074)	0.388 (1.159)	0.006 (1.186)	
	7-12g	6.064 (1.756)	1.479 (2.111)	3.000 (2.277)	0.340 (2.330)	*Time* F (3,1647) = 23.995, p<0.001
	16g +	6.642 (1.747)	-0.200 (2.100)	-0.653 (2.265)	-2.263 (2.318)	*Fat X Time* F (6,1647) = 0.753, p=0.607
Total Mood	Fast	13.889 (5.939)	-8.162 (7.808)	-14.848 (7.990)	-13.747 (8.478)	*Fat* F (2,549) = 0.341, p=0.711
	< 2.5g	28.452 (3.149)	5.523 (4.128)	8.493 (4.250)	7.895 (4.455)	
	7-12g	30.255 (6.188)	12.202 (8.113)	16.170 (8.351)	1.883 (8.755)	*Time* F (3,1647) = 35.796, p<0.001
	16g +	47.905 (6.155)	14.547 (8.070)	7.095 (8.307)	5.632 (8.709)	*Fat X Time* F (6,1647) = 2.793, p=0.010
Hunger	Fast	-1.747 (2.386)	1.808 (2.572)	9.313 (2.840)	16.606 (2.998)	*Fat* F (2,549) = 2.931, p=0.054
	< 2.5g	-31.449 (1.281)	-30.146 (1.359)	-25.342 (1.492)	-17.099 (1.584)	
	7-12g	-32.074 (2.517)	-29.298 (2.671)	-23.596 (2.932)	-15.543 (3.113)	*Time* F (3,1647) = 94.065, p<0.01
	16g +	-26.568 (2.504)	-22.800 (2.657)	-17.305 (2.917)	-10.095 (3.097)	*Fat X Time* F (6,1647) = 0.494, p=0.813

Table 7.5: Summary table with respect to measures of Mood for Fibre groupings (means +/- s.e.m)

MOOD	MEAL	30mins – base	60mins – base	90mins – base	120/150 mins – base	RESULT
Composure	Fast	3.040 (1.836)	-2.687 (2.216)	-3.808 (2.263)	-3.828 (2.332)	*Fibre* F (3,548) =
	0-2g	2.423 (1.343)	0.269 (1.638)	2.670 (1.672)	2.462 (1.718)	2.596, p=0.052
	2.01-5g	9.407 (1.151)	3.552 (1.403)	5.185 (1.4332)	5.254 (1.471)	*Time* F (3,1644) =
	5.01-7g	3.447 (1.966)	0.165 (2.397)	2.647 (2.446)	1.682 (2.513)	5.282, p=0.001 *Fibre X Time*
	12g +	0.622 (2.979)	-2.234 (3.634)	1.135 (3.707)	-3.297 (3.809)	F (9,1644) = 1.305, p=0.229
Agreeability	Fast	-0.495 (1.578)	-3.576 (1.827)	-5.697 (1.972)	-2.697 (1.985)	*Fibre* F (3,548) =
	0-2g	-0.566 (1.131)	-3.698 (1.358)	-2.874 (1.479)	-1.962 (1.504)	1.650, p=0.177
	2.01-5g	4.609 (0.969)	0.234 (1.163)	-0.843 (1.267)	-1.262 (1.288)	*Time* F (3,1644) =
	5.01-7g	1.094 (1.656)	-4.588 (1.986)	-3.082 (2.164)	-2.271 (2.200)	10.555, p<0.001 *Fibre X Time*
	12g +	-0.730 (2.509)	-5.405 (3.011)	-3.297 (3.280)	-2.351 (3.335)	F (9,1644) = 1.545, p=0.127
Elation	Fast	2.141 (1.329)	0.525 (1.573)	-0.364 (1.560)	-0.404 (1.642)	*Fibre* F (3,548) =
	0-2g	2.409 (0.999)	-0.066 (1.179)	1.467 (1.164)	0.137 (1.226)	1.223, p=0.300
	2.01-5g	3.782 (0.856)	2.331 (1.010)	1.040 (0.997)	0.540 (1.050)	*Time* F (3,1644) =
	5.01-7g	0.788 (1.462)	-2.424 (1.726)	-0.235 (1.703)	0.965 (1.794)	5.712, p=0.001 *Fibre X Time*
	12g +	0.001 (2.216)	-5.270 (2.615)	-1.622 (2.581)	-0.351 (2.719)	F (9,1644) = 2.125, p<0.05
Confidence	Fast	5.263 (1.506)	1.717 (1.983)	3.101 (1.874)	3.657 (2.082)	*Fibre* F (3,548) =
	0-2g	5.088 (1.059)	3.473 (1.396)	5.368 (1.351)	6.280 (1.535)	3.161, p<0.05
	2.01-5g	7.931 (0.907)	5.629 (1.196)	6.879 (1.158)	7.383 (1.351)	*Time* F (3,1644) =
	5.01-7g	4.569 (1.550)	0.576 (2.042)	1.541 (1.977)	3.376 (2.246)	6.788, p<0.001 *Fibre X Time*
	12g +	8.270 (2.349)	2.568 (3.095)	4.108 (2.997)	4.432 (3.404)	F (9,1644) = 1.379, p=0.192

Energy	Fast	1.990 (1.989)	-0.333 (2.398)	-6.091 (2.478)	-6.990 (2.596)	*Fibre* F (3,548) = 5.142, p<0.01
	0-2g	9.786 (1.515)	5.588 (1.787)	4.099 (1.861)	1.231 (1.948)	
	2.01-5g	11.512 (1.298)	7.613 (1.531)	2.169 (1.595)	-1.472 (1.669)	*Time* F (3,1644) = 32.906, p<0.001
	5.01-7g	6.082 (2.217)	-2.871 (2.615)	-3.988 (2.724)	-3.282 (2.850)	*Fibre X Time*
	12g +	-0.432 (3.360)	-9.459 (3.964)	-9.811 (4.128)	-8.000 (4.320)	F (9,1644) = 2.741, p<0.01
Clearheaded	Fast	1.949 (1.653)	-3.808 (2.046)	-1.990 (2.194)	-3.485 (2.256)	*Fibre* F (3,548) = 0.616, p=0.605
	0-2g	6.132 (1.263)	1.407 (1.517)	2.478 (1.636)	0.989 (1.670)	
	2.01-5g	6.117 (1.082)	0.306 (1.299)	-0.887 (1.402)	-2.444 (1.431)	*Time* F (3,1644) = 20.792, p<0.001
	5.01-7g	6.529 (1.849)	0.471 (2.219)	1.518 (2.394)	3.024 (2.444)	*Fibre X Time*
	12g +	6.189 (2.802)	-3.757 (3.364)	0.027 (3.629)	-0.324 (3.705)	F (9,1644) = 1.626, p=0.103
Total Mood	Fast	13.889 (5.939)	-8.162 (7.808)	-14.848 (7.990)	-13.747 (8.478)	*Fibre* F (3,548) = 2.897, p<0.05
	0-2g	24.912 (4.415)	6.973 (5.761)	13.209 (5.986)	9.137 (6.290)	
	2.01-5g	43.359 (3.782)	19.665 (4.935)	13.544 (5.128)	8.000 (5.389)	*Time* F (3,1644) = 26.414, p<0.001
	5.01-7g	22.600 (6.460)	-8.671 (8.430)	-1.600 (8.759)	3.494 (9.204)	*Fibre X Time*
	12g +	13.919 (9.762)	-23.649 (12.777)	-9.459 (13.276)	-9.892 (13.951)	F (9,1644) = 2.645, p<0.01
Hunger	Fast	-1.747 (2.386)	1.808 (2.572)	9.313 (2.840)	16.606 (2.998)	*Fibre* F (3,548) = 6.105, p<0.001
	0-2g	-33.214 (1.792)	-31.819 (1.903)	-26.473 (2.094)	-18.505 (2.219)	
	2.01-5g	-27.972 (1.535)	-26.077 (1.630)	-20.250 (1.794)	-11.972 (1.901)	*Time* F (3,1644) = 69.447, p<0.001
	5.01-7g	-28.200 (2.622)	-24.353 (2.784)	-21.788 (3.064)	-13.882 (3.247)	*Fibre X Time*
	12g +	-42.595 (3.974)	-41.486 (4.220)	-37.000 (4.644)	-30.000 (4.922)	F (9,1644) = 0.406, p=0.932

Table 7.6: Summary table with respect to measures of Mood for Energy Intake groupings (means +/- s.e.m)

MOOD	MEAL	30mins – base	60mins – base	90mins – base	120/150 mins – base	RESULT
Composure	Fast	3.040 (1.836)	-2.687 (2.216)	-3.808 (2.263)	-3.828 (2.332)	*Energy Intake* F (3,548) = 1.821, p=0.142
	< 100kcal	-1.368 (2.977)	-4.447 (3.584)	-0.895 (3.648)	-1.105 (3.758)	
	101-200kcal	5.551 (1.304)	3.066 (1.570)	5.682 (1.598)	5.793 (1.647)	*Time* F (3,1644) = 6.778, p<0.001
	201-300kcal	6.412 (1.173)	1.922 (1.412)	3.882 (1.437)	2.837 (1.480)	*EI X Time*
	301kcal +	6.648 (2.178)	-0.718 (2.622)	-0.042 (2.669)	-0.394 (2.750)	F (9,1644) = 1.580, p=0.116
Agreeability	Fast	-0.495 (1.578)	-3.576 (1.827)	-5.697 (1.972)	-2.697 (1.985)	*Energy Intake* F (3,548) = 0.960, p=0.411
	< 100kcal	1.579 (2.504)	-3.000 (2.986)	-1.026 (3.222)	-0.921 (3.279)	
	101-200kcal	1.091 (1.097)	-2.162 (1.308)	-1.949 (1.412)	-0.278 (1.437)	*Time* F (3,1644) = 15.027, p<0.001
	201-300kcal	2.547 (0.986)	-1.208 (1.176)	-0.673 (1.269)	-1.766 (1.291)	*EI X Time*
	301kcal +	2.901 (1.832)	-5.169 (2.184)	-7.408 (2.357)	-5.986 (2.399)	F (9,1644) = 2.359, p<0.05
Elation	Fast	2.141 (1.329)	0.525 (1.573)	-0.364 (1.560)	-0.404 (1.642)	*Energy Intake* F (3,548) = 1.216, p=0.303
	< 100kcal	0.158 (2.188)	-4.789 (2.594)	-0.184 (2.546)	-2.079 (2.678)	
	101-200kcal	1.303 (0.958)	-0.278 (1.136)	0.101 (1.115)	0.192 (1.173)	*Time* F (3,1644) = 6.503, p<0.001
	201-300kcal	3.363 (0.862)	1.531 (1.022)	1.808 (1.003)	1.392 (1.054)	*EI X Time*
	301kcal +	4.085 (1.601)	0.380 (1.868)	-0.155 (1.863)	-1.014 (1.959)	F (9,1644) = 1.039, p=0.406
Confidence	Fast	5.263 (1.506)	1.717 (1.983)	3.101 (1.874)	3.657 (2.082)	*Energy Intake* F (3,548) = 0.922, p=0.430
	< 100kcal	4.658 (2.327)	-0.132 (3.058)	2.632 (2.964)	4.474 (3.361)	
	101-200kcal	6.455 (1.019)	4.566 (1.339)	6.742 (1.299)	7.747 (1.472)	*Time* F (3,1644) = 4.252, p<0.01
	201-300kcal	6.318 (0.916)	3.241 (1.204)	4.327 (1.167)	5.282 (1.324)	*EI X Time*
	301kcal +	8.338 (1.702)	6.746 (2.237)	6.634 (2.169)	6.014 (2.459)	F (9,1644) = 0.861, p=0.560

Energy	Fast	1.990 (1.989)	-0.333 (2.398)	-6.091 (2.478)	-6.990 (2.596)	*Energy Intake* F (3,548) = 1.654, p=0.176
	< 100kcal	4.737 (3.339)	-2.053 (3.975)	-5.553 (4.111)	-9.053 (4.266)	
	101-200kcal	7.460 (1.463)	2.081 (1.741)	0.485 (1.801)	-0.354 (1.869)	*Time* F (3,1644) = 42.493, p<0.001
	201-300kcal	10.947 (1.315)	5.808 (1.565)	2.090 (1.619)	-0.653 (1.680)	*EI X Time*
	301kcal +	11.239 (2.443)	7.803 (2.908)	2.606 (3.008)	-2.000 (3.121	F (9,1644) = 1.291, p=0.236
Clearheaded	Fast	1.949 (1.653)	-3.808 (2.046)	-1.990 (2.194)	-3.485 (2.256)	*Energy Intake* F (3,548) = 0.421, p=0.738
	< 100kcal	5.632 (2.757)	0.342 (3.324)	3.579 (3.583)	0.605 (3.658)	
	101-200kcal	5.111 (1.208)	0.126 (1.456)	1.318 (1.569)	1.778 (1.603)	*Time* F (3,1644) = 17.854, p<0.001
	201-300kcal	7.641 (1.086)	0.816 (1.309)	0.535 (1.411)	-1.147 (1.441)	*EI X Time*
	301kcal +	4.493 (2.017)	-0.056 (2.432)	-2.352 (2.621)	-3.873 (2.676)	F (9,1644) = 1.858, p=0.054
Total Mood	Fast	13.889 (5.939)	-8.162 (7.808)	-14.848 (7.990)	-13.747 (8.478)	*Energy Intake* F (3,548) = 1.014, p=0.386
	< 100kcal	15.395 (9.752)	-14.079 (12.744)	-1.447 (13.128)	-8.079 (13.726)	
	101-200kcal	26.970 (4.272)	7.399 (5.583)	12.379 (5.751)	14.879 (6.013	*Time* F (3,1644) = 28.187, p<0.001
	201-300kcal	37.229 (3.841)	12.106 (5.019)	11.967 (5.170)	5.935 (5.406)	*EI X Time*
	301kcal +	37.704 (7.134)	8.986 (9.323)	-0.718 (9.604)	-7.254 (10.042)	F (9,1644) = 2.521, p<0.01
Hunger	Fast	-1.747 (2.386)	1.808 (2.572)	9.313 (2.840)	16.606 (2.998)	*Energy Intake* F (3,548) = 3.707, p<0.05
	< 100kcal	-17.105 (3.924)	-15.736 (4.186)	-12.684 (4.615)	-2.579 (4.884)	
	101-200kcal	-31.025 (1.719)	-30.222 (1.834)	-25.202 (2.022)	-17.263 (2.140)	*Time* F (3,1644) = 69.896, p<0.001
	201-300kcal	-32.869 (1.545)	-29.878 (1.649)	-23.914 (1.817)	-16.037 (1.923)	*EI X Time*
	301kcal +	-29.704 (2.871)	-27.606 (3.063)	-24.366 (3.376)	-16.648 (3.573)	F (9,1644) = 0.690, p=0.718

Table 7.7: Summary table with respect to the total number of words recalled on the Memory tests for Breakfast groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	10.542 (0.393)	7.958 (0.402)	9.458 (0.402)	5.000 (0.412)	9.375 (0.434)	3.792 (0.461)	*Breakfast* F (1,376) = 0.077, p=0.782 *Session* F (2,752) = 98.245, p<0.001 *Breakfast X Session* F (2,752) = 0.887, p=0.412
Active	10.524 (0.150)	7.809 (0.153)	9.761 (0.153)	5.476 (0.157)	8.912 (0.166)	4.224 (0.176)	*Recall* F (1,376) = 1315.852 p<0.001 *Breakfast X Recall* F (1,376) = 1.955, p=0.163 *Session X Recall* F (2,752) = 66.877, p<0.001 *Breakfast X Session X Recall* F (2,752) = 2.869, p=0.057

Table 7.8: Summary table with respect to the number of Concrete words recalled on the Memory tests for Breakfast groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	6.708 (0.279)	5.417 (0.298)	5.667 (0.278)	3.479 (0.284)	5.125 (0.284)	2.333 (0.279)	*Breakfast* F (1,376) = 0.069, p=0.792 *Session* F (2,752) = 120.717, p<0.001 *Breakfast X Session* F (2,752) = 0.809, p=0.446
Active	6.406 (0.107)	5.312 (0.114)	5.809 (0.106)	3.645 (0.108)	4.736 (0.108)	2.467 (0.106)	*Recall* F (1,376) = 680.325, p<0.001 *Breakfast X Recall* F (1,376) = 2.702, p=0.101 *Session X Recall* F (2,752) = 43.719, p<0.001 *Breakfast X Session X Recall* F (2,752) = 1.454, p=0.234

Table 7.9: Summary table with respect to the number of Abstract words recalled on the Memory tests for Breakfast groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	3.833 (0.239)	2.542 (0.215)	3.792 (0.224)	1.521 (0.198)	4.250 (0.244)	1.438 (0.234)	*Breakfast* F (1,376) = 0.879, p=0.349 *Session* F (2,752) = 8.521, p<0.001 *Breakfast X Session* F (2,752) = 0.152, p=0.859
Active	4.118 (0.091)	2.497 (0.082)	3.952 (0.086)	1.830 (0.075)	4.176 (0.093)	1.758 (0.089)	*Recall* F (1,376) = 1089.893 p<0.001 *Breakfast X Recall* F (1,376) = 0.319, p=0.573 *Session X Recall* F (2,752) = 32.618, p<0.001 *Breakfast X Session X Recall* F (2,752) = 3.211, p<0.05

Table 7.10: Summary table with respect to the time taken to recall the word lists on the Memory tests for Breakfast groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	45.604 (2.662)	30.146 (1.831)	38.771 (2.311)	26.979 (2.109)	37.771 (2.286)	24.354 (1.646)	*Breakfast* $F(1,376) = 3.962$, $p<0.05$ *Session* $F(2,752) = 67.606$, $p<0.001$ *Breakfast X Session* $F(2,752) = 3.910$, $p<0.05$
Active	51.688 (1.015)	35.067 (0.698)	44.467 (0.881)	30.418 (0.804)	40.394 (0.872)	24.527 (0.628)	*Recall* $F(1,376) = 499.335$, $p<0.001$ *Breakfast X Recall* $F(1,376) = 2.262$, $p=0.133$ *Session X Recall* $F(2,752) = 3.4247$, $p<0.05$ *Breakfast X Session X Recall* $F(2,752) = 0.169$, $p=0.845$

Table 7.11: Summary table with respect to the total number of words recalled on the Memory tests for Carbohydrate groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	10.542 (0.393)	7.958 (0.402)	9.458 (0.402)	5.000 (0.412)	9.375 (0.434)	3.792 (0.461)	*Carbohydrate* F (2,327) = 0.035, p=0.966 *Session* F (2,654) = 175.120, p<0.001
20.1-35g	10.516 (0.285	7.758 (0.282)	10.074 (0.287)	5916 (0.293)	8.821 (0.312)	3.884 (0.335)	*Carb X Session* F (4,654) = 2.687, p<0.05
35.1-50g	10.532 (0.234)	7.943 (0.232)	9.482 (0.235)	5.156 (0.240)	9.000 (0.256)	4.383 (0.275)	*Recall* F (1,327) = 2250.917 p<0.001 *Carb X Recall* F (2,327) = 0.166, p=0.847
50.1g +	10.521 (0.286)	7.660 (0.284)	9.862 (0.288)	5.511 (0.294)	8.872 (0.314)	4.330 (0.336)	*Session X Recall* F (2,654) = 81.668, p<0.001 *Carb X Session X Recall* F (4,654) = 0.784, p=0.535

Table 7.12: Summary table with respect to the number of Concrete words recalled on the Memory tests for Carbohydrate groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	6.708 (0.279)	5.417 (0.298)	5.667 (0.278)	3.479 (0.284)	5.125 (0.284)	2.333 (0.279)	*Carbohydrate* F (2,327) = 0.293, p=0.746 *Session* F (2,654) = 228.996, p<0.001 *Carb X Session* F (4,654) = 3.713, p<0.01 *Recall* F (1,327) = 1142.853 p<0.001 *Carb X Recall* F (2,327) = 0.256, p=0.774 *Session X Recall* F (2,654) = 73.283, p<0.001 *Carb X Session X Recall* F (4,654) = 0.832, p=0.505
20.1-35g	6.063 (0.193)	5.011 (0.207)	5.989 (0.196)	3.895 (0.202)	4.642 (0.203)	2.200 (0.202)	
35.1-50g	6.574 (0.159)	5.546 (0.170)	5.645 (0.161)	3.447 (0.166)	4.794 (0.166)	2.624 (0.166)	
50.1g +	6.500 (0.194)	5.266 (0.208)	5.872 (0.197)	3.961 (0.203)	4.745 (0.204)	2.500 (0.203)	

Table 7.13: Summary table with respect to the number of Abstract words recalled on the Memory tests for Carbohydrate groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	3.833 (0.239)	2.542 (0.215)	3.792 (0.224)	1.521 (0.198)	4.250 (0.244)	1.438 (0.234)	*Carbohydrate* F (2,327) = 1.126, p=0.326 *Session*
20.1-35g	4.453 (0.172)	2.747 (0.150)	4.084 (0.159)	2.021 (0.139)	4.179 (0.175)	1.684 (0.171)	F (2,654) = 13.900, p<0.001 *Carb X Session* F (4,654) = 1.646, p=0.161 *Recall*
35.1-50g	3.957 (0.141)	2.397 (0.123)	3.837 (0.131)	1.709 (0.114)	4.206 (0.144)	1.759 (0.140	F (1,327) = 1977.986 p<0.001 *Carb X Recall* F (2,327) = 0.122, p=0.885
50.1g +	4.021 (0.173	2.394 (0.151)	3.989 (0.160)	1.819 (0.140)	4.128 (0.176)	1.830 (0.171)	*Session X Recall* F (2,654) = 28.223, p<0.001 *Carb X Session X Recall* F (4,654) = 0.466, p=0.760

Table 7.14: Summary table with respect to the time taken to recall the word lists on the Memory tests for Carbohydrate groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	45.604 (2.662)	30.146 (1.831)	38.771 (2.311)	26.979 (2.109)	37.771 (2.286)	24.354 (1.646)	*Carbohydrate* F (2,327) = 19.910, p<0.001 *Session* F (2,654) = 220.837, p<0.001 *Carb X Session* F (4,654) = 12.072, p<0.001 *Recall* F (1,327) = 1205.423 p<0.001 *Carb X Recall* F (2,327) = 12.872, p<0.001 *Session X Recall* F (2,654) = 5.906, p<0.01 *Carb X Session X Recall* F (4,654) = 3.261, p<0.05
20.1-35g	57.716 (1.794)	38.105 (1.282)	46.779 (1.593)	33.789 (1.454)	39.916 (1.611)	24.579 (1.187)	
35.1-50g	43.156 (1.472)	30.617 (1.052)	38.447 (1.308)	26.028 (1.193)	37.163 (1.322)	22.723 (0.975)	
50.1g +	58.394 (1.803)	38.670 (1.289)	51.160 (1.602)	33.596 (1.461)	45.723 (1.620)	27.181 (1.194)	

Table 7.15: Summary table with respect to the total number of words recalled on the Memory tests for Protein groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	10.542 (0.393)	7.958 (0.402)	9.458 (0.402)	5.000 (0.412)	9.375 (0.434)	3.792 (0.461)	*Protein* F (2,327) = 1.019, p=0.362 *Session*
0-4g	10.839 (0.287)	8.151 (0.284)	10.108 (0.290)	5.925 (0.296)	9.011 (0.315)	4.387 (0.339)	F (2,654) = 167.773, p<0.001 *Protein X Session* F (4,654) = 1.307, p=0.266 *Recall*
4.01-8g	10.662 (0.328)	7.901 (0.326)	9.366 (0.331)	5.099 (0.339)	8.732 (0.361)	4.254 (0.388)	F (1,327) = 2031.647 p<0.001 *Protein X Recall* F (2,327) = 0.297, p=0.743
8.01g +	10.289 (0.215)	7.578 (0.213)	9.735 (0.217)	5.386 (0.222)	8.934 (0.236)	4.120 (0.254)	*Session X Recall* F (2,654) = 72.259, p<0.001 *Protein X Session X Recall* F (4,654) = 0.249, p=0.911

Table 7.16: Summary table with respect to the number of Concrete words recalled on the Memory tests for Protein groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	6.708 (0.279)	5.417 (0.298)	5.667 (0.278)	3.479 (0.284)	5.125 (0.284)	2.333 (0.279)	*Protein* F (2,327) = 1.112, p=0.330 *Session* F (2,654) = 220.485, p<0.001 *Protein X Session* F (4,654) = 1.692, p=0.150 *Recall* F (1,327) = 1025.955 p<0.001 *Protein X Recall* F (2,327) = 0.196, p=0.822 *Session X Recall* F (2,654) = 66.610, p<0.001 *Protein X Session X Recall* F (4,654) = 0.365, p=0.834
0-4g	6.527 (0.196)	5.484 (0.209)	5.968 (0.198)	3.925 (0.204)	4.871 (0.205)	2.548 (0.205)	
4.01-8g	6.718 (0.224)	5.620 (0.239)	5.648 (0.227)	3.437 (0.233)	4.718 (0.234)	2.577 (0.234)	
8.01g +	6.205 (0.146)	5.084 (0.156)	5.789 (0.148)	3.578 (0.153)	4.669 (0.153)	2.373 (0.153)	

Table 7.17: Summary table with respect to the number of Abstract words recalled on the Memory tests for Protein groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	3.833 (0.239)	2.542 (0.215)	3.792 (0.224)	1.521 (0.198)	4.250 (0.244)	1.438 (0.234)	*Protein* F (2,327) = 1.484, p=0.228 *Session* F (2,654) = 12.298, p<0.001 *Protein X Session* F (4,654) = 0.453, p=0.770 *Recall* F (1,327) = 1791.616 p<0.001 *Protein X Recall* F (2,327) = 0.207, p=0.813 *Session X Recall* F (2,654) = 24.055, p<0.001 *Protein X Session X Recall* F (4,654) = 0.462, p=0.764
0-4g	40312 (0.175)	2.667 (0.152)	4.140 (0.161)	2.000 (0.141)	1.140 (0.176)	1.839 (0.172)	
4.01-8g	3.944 (0.200)	2.282 (0.174)	3.718 (0.184)	1.662 (0.161)	4.014 (0.202)	1.676 (0.197)	
8.01g +	4.084 (0.131)	2.494 (0.114)	3.946 (0.120)	1.807 (0.105)	4.265 (0.132)	1.747 (0.129)	

Table 7.18: Summary table with respect to the time taken to recall the word lists on the Memory tests for Protein groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	45.604 (2.662)	30.146 (1.831)	38.771 (2.311)	26.979 (2.109)	37.771 (2.286)	24.354 (1.646)	*Protein* F (2,327) = 11.077, p<0.001 *Session*
0-4g	56.763 (1.905)	39.355 (1.319)	48.419 (1.643)	33.935 (1.491)	43.473 (1.641)	26.075 (1.208)	F (2,654) = 167.101, p<0.001 *Protein X Session* F (4,654) = 3.225, p<0.05 *Recall*
4.01-8g	43.324 (2.181)	30.761 (1.509)	36.211 (1.880)	25.592 (1.706)	35.127 (1.878)	22.408 (1.383)	F (1,327) = 952.110, p<0.001 *Protein X Recall* F (2,327) = 8.294, p<0.001
8.01g +	52.422 (1.426)	34.506 (0.987)	45.783 (1.230)	30.512 (1.116)	40.922 (1.228)	24.566 (0.904)	*Session X Recall* F (2,654) = 4.217, p<0.05 *Protein X Session X Recall* F (4,654) = 0.316, p=0.867

Table 7.19: Summary table with respect to the total number of words recalled on the Memory tests for Fat groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	10.542 (0.393)	7.958 (0.402)	9.458 (0.402)	5.000 (0.412)	9.375 (0.434)	3.792 (0.461)	*Fat* F (1,328) = 2.491, p=0.115 *Session* F (2,656) = 159.544 p<0.001
0-2g	10.778 (0.189)	8.047 (0.188)	9.854 (0.192)	5.481 (0.197)	9.085 (0.208)	4.344 (0.224)	*Fat X Session* F (2,656) = 1.832, p=0.161 *Recall* F (1,328) = 2120.084 p<0.001
10g +	10.068 (0.253)	7.381 (0.251)	9.593 (0.258)	5.466 (0.264)	8.602 (0.279)	4.088 (0.300)	*Fat X Recall* F (1,328) = 0.751, p=0.387 *Session X Recall* F (2,656) = 77.359, p<0.001 *Fat X Session X Recall* F (2,656) = 0.183, p=0.833

Table 7.20: Summary table with respect to the number of Concrete words recalled on the Memory tests for Fat groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	6.708 (0.279)	5.417 (0.298)	5.667 (0.278)	3.479 (0.284)	5.125 (0.284)	2.333 (0.279)	*Fat* F (1,328) = 1.273, p=0.260 *Session* F (2,656) = 207.655 p<0.001 *Fat X Session* F (2,656) = 3.442, p<0.05 *Recall* F (1,328) = 1089.754 p<0.001 *Fat X Recall* F (1,328) = 0.179, p=0.672 *Session X Recall* F (2,656) = 70.036, p<0.001 *Fat X Session X Recall* F (2,656) = 0.388, p=0.678
0-2g	6.575 (0.129)	5.505 (0.138)	5.807 (0.131)	3.263 (0.135)	4.745 (0.135)	2.523 (0.135)	
10g +	6.102 (0.173)	4.966 (0.185)	5.814 (0.176)	3.686 (0.182)	4.720 (0.182)	2.364 (0.182)	

Table 7.21: Summary table with respect to the number of Abstract words recalled on the Memory tests for Fat groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	3.833 (0.239)	2.542 (0.215)	3.792 (0.224)	1.521 (0.198)	4.250 (0.244)	1.438 (0.234)	*Fat* F (1,328) = 3.127, p=0.078 *Session* F (2,656) = 12.943, p<0.001
0-2g	4.203 (0.116)	2.542 (0.101)	4.047 (0.106)	1.858 (0.094)	4.340 (0.116)	1.821 (0.114)	*Fat X Session* F (2,656) = 0.416, p=0.660 *Recall* F (1,328) = 1858.470 p<0.001
10g +	3.966 (0.155)	2.415 (0.135)	3.780 (0.142)	1.780 (0.125)	3.881 (0.155)	1.644 (0.153)	*Fat X Recall* F (1,328) = 4.228, p<0.05 *Session X Recall* F (2,656) = 26.306, p<0.001 *Fat X Session X Recall* F (2,655) = 0.319, p=0.727

Table 7.22: Summary table with respect to the time taken to recall the word lists on the Memory tests for Fat groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	45.604 (2.662)	30.146 (1.831)	38.771 (2.311)	26.979 (2.109)	37.771 (2.286)	24.354 (1.646)	*Fat* F (1,328) = 2.756, p=0.098 *Session* F (2,656) = 184.485, p<0.001
0-g	51.368 (1.302)	36.288 (0.890)	45.307 (1.127)	31.708 (0.999)	41.585 (1.099)	25.495 (0.799)	*Fat X Session* F (2,656) = 1.485, p=0.227 *Recall* F (1,328) = 1054.888, p<0.001
10g +	52.263 (1.745)	32.873 (1.193)	42.958 (1.510)	28.102 (1.339)	38.254 (1.473)	22.788 (1.071	*Fat X Recall* F (1,328) = 2.887, p=0.090 *Session X Recall* F (2,656) = 5.674, p<0.01 *Fat X Session X Recall* F (2,656) = 3.887, p<0.05

Table 7.23: Summary table with respect to the total number of words recalled on the Memory tests for Fibre groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	10.542 (0.393)	7.958 (0.402)	9.458 (0.402)	5.000 (0.412)	9.375 (0.434)	3.792 (0.461)	*Fibre* F (2,327) = 0.685, p=0.505 *Session*
0-2g	10.351 (0.286)	7.596 (0.282)	9.362 (0.288)	5.074 (0.295)	8.809 (0.313)	4.372 (0.337)	F (2,654) = 139.502, p<0.001 *Fibre X Session* F (4,654) = 2.497, p<0.05 *Recall*
2.01-4g	10.519 (0.202)	7.709 (0.199)	9.968 (0.203)	5.714 (0.208)	8.847 (0.221)	4.106 (0.238)	F (1,327) = 1688.396 p<0.001 *Fibre X Recall* F (2,327) = 0.175, p=0.840
4.01g +	10.894 (0.404)	8.638 (0.399)	9.723 (0.407)	5.319 (0.417)	9.383 (0.443)	4.404 (0.476)	*Session X Recall* F (2,654) = 73.205, p<0.001 *Fibre X Session X Recall* F (4,654) = 1.253, p=0.287

Table 7.24: Summary table with respect to the number of Concrete words recalled on the Memory tests for Fibre groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	6.708 (0.279)	5.417 (0.298)	5.667 (0.278)	3.479 (0.284)	5.125 (0.284)	2.333 (0.279)	*Fibre* F (2,327) = 0.354, p=0.702 *Session* F (2,654) = 191.322, p<0.001 *Fibre X Session* F (4,654) = 3.346, p=0.01 *Recall* F (1,327) = 832.899 p<0.001 *Fibre X Recall* F (2,327) = 0.497, p=0.609 *Session X Recall* F (2,654) = 60.007, p<0.001 *Fibre X Session X Recall* F (4,654) = 0.523, p=0.719
0-2g	6.468 (0.195)	5.430 (0.207)	5.628 (0.197)	3.415 (0.203)	4.798 (0.204)	2.617 (0.203)	
2.01-4g	6.280 (0.137)	5.138 (0.146)	5.931 (0.139)	3.794 (0.143)	4.693 (0.144)	2.349 (0.143)	
4.01g +	3.787 (0.276)	5.957 (0.293)	5.681 (0.278)	3.511 (0.287)	4.787 (0.288)	2.638 (0.288)	

Table 7.25: Summary table with respect to the number of Abstract words recalled on the Memory tests for Fibre groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	3.833 (0.239)	2.542 (0.215)	3.792 (0.224)	1.521 (0.198)	4.250 (0.244)	1.438 (0.234)	*Fibre* F (2,327) = 1.637, p=0.196 *Session*
0-2g	3.883 (0.174)	2.255 (0.151)	3.734 (0.160)	1.660 (0.140)	4.011 (0.175)	1.755 (0.172)	F (2,654) = 9.386, p<0.001 *Fibre X Session* F (4,654) = 0.707, p=0.587 *Recall*
2.01-4g	4.238 (0.123)	2.571 (0.106)	4.037 (0.113)	1.921 (0.099)	4.153 (0.123)	1.757 (0.121)	F (1,327) = 1529.681 p<0.001 *Fibre X Recall* F (2,327) = 0.741, p=0.478
4.01g +	4.106 (0.246)	2.681 (0.213)	4.043 (0.226)	1.809 (0.198)	4.596 (0.247)	1.766 (0.243)	*Session X Recall* F (2,654) = 29.816, p<0.001 *Fibre X Session X Recall* F (4,654) = 1.504, p=0.199

Table 7.26: Summary table with respect to the time taken to recall the word lists on the Memory tests for Fibre groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	45.604 (2.662)	30.146 (1.831)	38.771 (2.311)	26.979 (2.109)	37.771 (2.286)	24.354 (1.646)	*Fibre* F (2,327) = 19.135, p<0.001 *Session* F (2,654) = 107.261, p<0.001
0-2g	43.021 (1.803)	30.064 (1.288)	37.489 (1.608)	25.798 (1.461)	36.351 (1.634)	22.883 (1.198)	*Fibre X Session* F (4,654) = 10.452, p<0.001 *Recall*
2.01-4g	58.053 (1.272)	38.386 (0.908)	48.958 (1.134)	33.693 (1.030)	42.804 (1.152)	25.873 (0.845)	F (1,327) = 767.847 p<0.001 *Fibre X Recall* F (2,327) = 10.676, p<0.001
4.01g +	43.426 (2.550)	31.723 (1.822)	40.362 (2.274)	26.489 (2.066)	38.787 (2.311)	22.404 (1.694)	*Session X Recall* F (2,654) = 1.996, p=0.137 *Fibre X Session X Recall* F (4,654) = 2.874, p<0.05

Table 7.27: Summary table with respect to the total number of words recalled on the Memory tests for Energy Intake groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	10.542 (0.393)	7.958 (0.402)	9.458 (0.402)	5.000 (0.412)	9.375 (0.434)	3.792 (0.461)	*Energy Intake* F (2,327) = 1.216, p=0.298 *Session*
101-200kcal	10.909 (0.230)	8.196 (0.229)	9.888 (0.234)	5.476 (0.240)	9.140 (0.254)	4.406 (0.272)	F (2,654) = 153.500, p<0.001 *EI X Session* F (4,654) = 2.563, p<0.05 *Recall*
201-300kcal	10.336 (0.256)	7.578 (0.254)	9.672 (0.260)	5.517 (0.267)	8.586 (0.282)	3.750 (0.302)	F (1,327) = 2110.598 p<0.001 *EI X Recall* F (2,327) = 0.490, p=0.613
301kcal +	10.056 (0.327)	7.408 (0.324)	9.648 (0.333)	5.408 (0.341)	8.986 (0.360)	4 .634 (0.386)	*Session X Recall* F (2,654) = 76.551, p<0.001 *EI X Session X Recall* F (4,654) = 0.570, p=0.684

Table 7.28: Summary table with respect to the number of Concrete words recalled on the Memory tests for Energy Intake groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	6.708 (0.279)	5.417 (0.298)	5.667 (0.278)	3.479 (0.284)	5.125 (0.284)	2.333 (0.279)	*Energy Intake* F (2,327) = 0.845, p=0.430 *Session* F (2,654) = 205.439 p<0.001 *EI X Session* F (4,654) = 2.357, p=0.052 *Recall* F (1,327) = 1083.230 p<0.001 *EI X Recall* F (2,327) = 0.160, p=0.852 *Session X Recall* F (2,654) = 68.684, p<0.001 *EI X Session X Recall* F (4,654) = 0.734, p=0.569
101-200kcal	6.559 (0.158)	5.573 (0.168)	5.846 (0.160)	3.615 (0.165)	4.811 (0.164)	2.601 (0.164)	
201-300kcal	6.345 (0.176)	5.138 (0.187)	5.776 (0.178)	3.707 (0.183)	4.491 (0.183)	2.138 (0.182)	
301kcal +	6.197 (0.225)	5.070 (0.239)	5.789 (0.227)	3.606 (0.234)	4.986 (0.233)	2.732 (0.233)	

Table 7.29: Summary table with respect to the number of Abstract words recalled on the Memory tests for Energy Intake groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	3.833 (0.239)	2.542 (0.215)	3.792 (0.224)	1.521 (0.198)	4.250 (0.244)	1.438 (0.234)	*Energy Intake* F (2,327) = 1.315, p=0.270 *Session* F (2,654) = 10.704, p<0.001
101-200kcal	4.350 (0.142)	2.622 (0.123)	4.042 (0.130)	1.860 (0.114)	4.329 (0.142)	1.804 (0.139)	*EI X Session* F (4,654) = 0.596, p=0.666 *Recall* F (1,327) = 1852.863 p<0.001
201-300kcal	3.991 (0.156)	2.440 (0.136)	3.897 (0.144)	1.810 (0.127)	4.095 (0.158)	1.612 (0.154)	*EI X Recall* F (2,327) = 2.277, p=0.104 *Session X Recall* F (2,654) = 26.295, p<0.001
301kcal +	3.859 (0.199)	2.338 (0.174)	3.859 (0.184)	1.803 (0.162)	4.000 (0.202)	1.901 (0.197)	*EI X Session X Recall* F (4,654) = 0.572, p=0.683

Table 7.30: Summary table with respect to the time taken to recall the word lists on the Memory tests for Energy Intake groupings (+/-s.e.m)

	Imm 1	Del 1	Imm 2	Del 2	Imm 3	Del 3	RESULT
Fast	45.604 (2.662)	30.146 (1.831)	38.771 (2.311)	26.979 (2.109)	37.771 (2.286)	24.354 (1.646)	*Energy Intake* F (2,327) = 0.020, p=0.981 *Session* F (2,654) = 170.688, p<0.001 *EI X Session* F (4,654) = 1.575, p=0.179 *Recall* F (1,327) = 1084.786 p<0.001 *EI X Recall* F (2,327) = 4.448, p<0.05 *Session X Recall* F (2,654) = 3.901, p<0.05 *EI X Session X Recall* F (4,654) = 1.032, p=0.390
101-200kcal	50.371 (1.584)	36.028 (1.092)	43.322 (1.374)	30.846 (1.225)	40.168 (1.343)	25.035 (0.978)	
201-300kcal	53.103 (1.759)	34.431 (1.212)	45.328 (1.526)	30.862 (1.360)	39.422 (1.492)	23.534 (1.086)	
301kcal +	52.028 (2.249)	34.169 (1.549	45.366 (1.951)	28.831 (1.738)	42.347 (1.907)	25.127 (1.388)	

Table 7.31: Summary table for Decision Times on the Hick Paradigm for Breakfast groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	309.122 (4.321)	332.622 (4.413)	356.596 (5.147)	396.667 (7.815)	*Meal* F (1,488) = 0.604, p=0.438
	Active	304.019 (1.979)	325.663 (2.021)	353.120 (2.357)	398.961 (3.578)	*Session* F (2,896) = 2.121,
Sess 2	Fast	308.365 (4.321)	330.699 (4.506)	356.718 (5.373)	388.128 (7.723)	p=0.121 *Meal X Session* F (12,896) = 0.083,
	Active	298.173 (1.978)	323.157 (2.063)	349.472 (2.460)	395.192 (3.536)	p=0.921 *Lamps* F (3,1344) = 618.477,
Sess 3	Fast	310.910 (4.096)	327 .936 (4.254)	353.788 (5.314)	389.160 (8.730)	p<0.001 *Meal X Lamps* F (3,1344) = 4.675,
	Active	297.469 (1.876)	323.017 (1.948)	351.464 (2.433)	397.438 (3.997)	p<0.01 *Session X Lamps* F (6,2688) = 0.380, p=0.892 *Meal X Session X Lamps* F (6,2688) = 0.929, p=0.473

Table 7.32: Summary table for Movement Times on the Hick Paradigm for Breakfast groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	188.596 (5.080)	193.221 (5.297)	205.449 (5.544)	211.532 (5.774)	*Meal* F (1,488) = 2.593, p=0.108
	Active	183.449 (2.326)	186.489 (2.426)	194.429 (2.539)	204.090 (2.644)	*Session* F (2,896) = 2.671,
Sess 2	Fast	196.462 (6.071)	200.231 (6.152)	206.436 (5.940)	215.904 (6.160)	p=0.070 *Meal X Session* F (12,896) = 0.147,
	Active	186.046 (2.780)	190.801 (2.817)	197.524 (2.720)	207.563 (2.821)	p=0.863 *Lamps* F (3,1344) = 119.055,
Sess 3	Fast	197.827 (2.326)	186.489 (2.426)	194.429 (2.539)	204.090 (2.644)	p<0.001 *Meal X Lamps* F (3,1344) = 0.616, p-0.605
	Active	188.288 (2.780)	187.590 (2.637)	196.345 (2.654)	207.384 (2.593)	*Session X Lamps* F (6,2688) = 1.292, p=0.257 *Meal X Session X Lamps* F (6,2688) = 0.549, p=0.771

Table 7.33: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm fro Carbohydrate groupings (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3	RESULT
Intercept	Fast	305.749 (4.447)	306.177 (4.299)	306.359 (4.099)	*Meal* F (1,488) = 7.510, p<0.01 *Session* F (2,896) = 0.625, p=0.536 *Meal X Session* F (2,896) = 0.998, p=0.369
	Active	298.060 (2.036)	293.897 (1.968)	293.118 (1.877)	
Slope	Fast	28.663 (2.231)	26.536 (2.157)	26.062 (2.524)	*Meal* F (1,488) = 5.854, p<0.05 *Session* F (2,896) = 0.186, p=0.830 *Meal X Session* F (2,896) = 1.227, p=0.294
	Active	31.243 (1.022)	31.737 (0.988)	32.832 (1.156)	
Intra-Individual Variability	Fast	189.833 (11.583)	167.220 (12.215)	172.146 (13.089)	*Meal* F (1,488) = 1.314, p=0.252 *Session* F (2,896) = 1.432, p=0.239 *Meal X Session* F (2,896) = 1.420, p=0.242
	Active	187.786 (5.303)	185.694 (5.593)	192.141 (5.994)	

Table 7.34: Summary table for Decision Times on the Hick Paradigm for Carbohydrate groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	309.122 (4.321)	332.622 (4.413)	356.596 (5.147)	396.667 (7.815)	*Meal* F (2,369) = 0.849, p=0.429 *Session* F (2,738) = 3.929, p<0.05 *Meal X Session* F (4,738) = 0.338, p=0.852 *Lamps* F (3,1107) = 937.598, p<0.001 *Meal X Lamps* F (6,1107) = 0.556, p=0.765 *Session X Lamps* F (6,2214) = 0.669, p=0.675 *Meal X Session X Lamps* F (12,2214) = 0.834, p=0.615
	20.1-35g	306.141 (2.966)	328.160 (3.033)	355.760 (3.622)	401.673 (5.728)	
	35.1-50g	304.837 (3.224)	323.765 (3.297)	350.186 (3.937)	392.633 (6.227)	
	50.1g +	298.792 (4.042)	324.006 (4.133)	352.827 (4.936)	403.869 (7.805)	
Sess 2	Fast	308.365 (4.321)	330.699 (4.506)	356.718 (5.373)	388.128 (7.723)	
	20.1-35g	299.554 (2.977)	323.897 (3.116)	352.997 (3.707)	400.837 (5.606)	
	35.1-50g	296.996 (3.237)	322.773 (3.387)	346.746 (4.029)	389.564 (6.094)	
	50.1g +	297.458 (4.057)	322.387 (4.246)	347.208 (5.501)	393.554 (7.640)	
Sess 3	Fast	310.910 (4.096)	327 .936 (4.254)	353.788 (5.314)	389.160 (8.730)	
	20.1-35g	301.292 (2.833)	326.176 (3.061)	355.904 (3.839)	400.785 (6.455)	
	35.1-50g	296.792 (3.080)	320.955 (3.328)	347.178 (4.174)	396.489 (7.017)	
	50.1g +	291.435 (3.861)	320.631 (4.171)	349.952 (5.232)	392.714 (8.797)	

Table 7.35: Summary table for Movement Times on the Hick Paradigm for Carbohydrate groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	188.596 (5.080)	193.221 (5.297)	205.449 (5.544)	211.532 (5.774)	*Meal* F (2,369) = 2.235, p=0.108
	20.1-35g	187.298 (3.483)	190.378 (3.626)	197.340 (3.846)	209.721 (3.961)	
	35.1-50g	182.924 (3.786)	185.633 (3.942)	193.026 (4.181)	199.814 (4.306)	*Session* F (2,738) = 1.737, p=0.177
	50.1g +	177.125 (4.746)	180.613 (4.941)	191.232 (5.241)	200.351 (5.397)	*Meal X Session* F (4,738) = 0.725, p=0.575
Sess 2	Fast	196.462 (6.071)	200.231 (6.152)	206.436 (5.940)	215.904 (6.160)	*Lamps* F (3,1107) = 176.222, p<0.001
	20.1-35g	189.385 (4.174)	197.247 (4.155)	205.003 (4.014)	217.622 (4.069)	
	35.1-50g	186.902 (4.537)	188.591 (4.517)	194.117 (4.364)	201.610 (4.423)	*Meal X Lamps* F (6,1107) = 1.358, p=0.229
	50.1g +	178.500 (5.688)	182.304 (5.662)	188.988 (5.470)	198.238 (5.545)	*Session X Lamps* F (6,2214) = 1.612, p=0.140
Sess 3	Fast	197.827 (2.326)	186.489 (2.426)	194.429 (2.539)	204.090 (2.644)	*Meal X Session X Lamps* F (12,2214) = 2.312, p<0.01
	20.1-35g	194.910 (4.154)	192.183 (4.038)	201.615 (4.062)	210.516 (3.974)	
	35.1-50g	183.417 (4.516)	186.788 (4.390)	194.364 (4.415)	204.136 (4.320)	
	50.1g +	183.381 (5.661)	180.321 (5.503)	189.673 (5.535)	206.673 (5.416)	

Table 7.36: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm fro Carbohydrate groupings (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3	RESULT
Intercept	Fast	305.749 (4.447)	306.177 (4.299)	306.359 (4.099)	*Meal* F (2,369) = 1.105, p=0.332
	20.1-35g	300.803 (3.061)	294.685 (2.946)	296.810 (2.920)	*Session* F (2,738) = 3.617, p<0.05
	35.1-50g	299.386 (3.327)	293.776 (3.203)	291.559 (3.174)	*Meal X Session* F (4,738) = 1.438, p=0.220
	50.1g +	290.885 (4.171)	293.182 (4.015)	288.710 (3.979)	
Slope	Fast	28.663 (2.231)	26.536 (2.157)	26.062 (2.524)	*Meal* F (2,369) = 0.721, p=0.487
	20.1-35g	31.419 (1.615)	33.294 (1.576)	32.824 (1.879)	*Session* F (2,738) = 0.746, p=0.475
	35.1-50g	28.989 (1.755)	30.172 (1.713)	32.534 (2.043)	*Meal X Session* F (4,738) = 1.065, p=0.373
	50.1g +	34.457 (2.200)	31.305 (2.147)	33.314 (2.561)	
Intra-Individual Variability	Fast	189.833 (11.583)	167.220 (12.215)	172.146 (13.089)	*Meal* F (2,369) = 0.636, p=0.530
	20.1-35g	187.636 (8.212)	189.757 (8.982)	195.665 (9.510)	*Session* F (2,738) = 0.561, p=0.571
	35.1-50g	180.246 (8.927)	179.903 (9.764)	185.451 (10.339)	*Meal X Session* F (4,738) = 0.246, p=0.912
	50.1g +	199.912 (11.191)	187.249 (12.240)	196.11 (12.960)	

Table 7.37: Summary table for Decision Times on the Hick Paradigm for Protein groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	309.122 (4.321)	332.622 (4.413)	356.596 (5.147)	396.667 (7.815)	*Meal* F (2,369) = 0.002, p=0.998
	< 4g	304.269 (3.406)	325.685 (3.478)	352.639 (4.152)	399.542 (6.572)	
	4.01-8g	303.909 (3.734)	324.753 (3.813)	352.010 (4.552)	399.030 (7.206)	*Session* F (2,738) = 3.567,
	8.01g +	303.896 (2.994)	326.231 (3.057)	354.205 (3.650)	398.468 (5.777)	p<0.05 *Meal X Session* F (4,738) = 0.871,
Sess 2	Fast	308.365 (4.321)	330.699 (4.506)	356.718 (5.373)	388.128 (7.723)	p=0.481 *Lamps*
	< 4g	297.693 (3.409)	321.647 (3.5565)	346.908 (4.250)	393.613 (6.432)	F (3,1107) = 958.572, p<0.001
	4.01-8g	297.025 (3.728)	325.177 (3.909)	350.096 (4.659)	392.722 (7.051)	*Meal X Lamps* F (6,1107) = 0.208,
	8.01g +	299.282 (2.997)	323.026 (3.134)	351.052 (3.736)	398.000 (5.654)	p=0.974 *Session X Lamps* F (6,2214) = 0.686,
Sess 3	Fast	310.910 (4.096)	327 .936 (4.254)	353.788 (5.314)	389.160 (8.730)	p=0.661 *Meal X Session X*
	< 4g	299.382 (3.255)	326.013 (3.500)	352.046 (4.409)	396.950 (7.396)	*Lamps* F (12,2214) = 0.297,
	4.01-8g	299.591 (3.569)	325.596 (3.837)	352.591 (4.834)	397.308 (8.109)	p=0.990
	8.01g +	294.627 (2.861)	319.175 (3.077)	350.289 (3.876)	397.899 (6.502)	

Table 7.38: Summary table for Movement Times on the Hick Paradigm for Protein groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	188.596 (5.080)	193.221 (5.297)	205.449 (5.544)	211.532 (5.774)	*Meal* F (2,369) = 0.521, p=0.594 *Session* F (2,738) = 2.127, p=0.120 *Meal X Session* F (4,738) = 0.273, p=0.895 *Lamps* F (3,1107) = 284.377, p<0.001 *Meal X Lamps* F (6,1107) = 1.138, p=0.338 *Session X Lamps* F (6,2214) = 1.517, p=0.169 *Meal X Session X Lamps* F (12,2214) = 0.803, p=0.647
	< 4g	182.206 (3.994)	188.265 (4.161)	197.080 (4.400)	207.693 (4.544)	
	4.01-8g	188.510 (4.379)	188.561 (4.562)	197.232 (4.824)	206.384 (4.982)	
	8.01g +	181.156 (3.511)	183.786 (3.657)	190.786 (3.867)	199.831 (3.994)	
Sess 2	Fast	196.462 (6.071)	200.231 (6.152)	206.436 (5.940)	215.904 (6.160)	
	< 4g	184.975 (4.794)	190.647 (4.787)	197.996 (4.631)	210.248 (4.719)	
	4.01-8g	186.808 (5.256)	193.146 (5.248)	200.889 (5.077)	209.535 (5.173)	
	8.01g +	186.383 (4.214)	189.412 (4.208)	194.997 (4.071)	204.221 (4.148)	
Sess 3	Fast	197.827 (2.326)	186.489 (2.426)	194.429 (2.539)	204.090 (2.644)	
	< 4g	189.550 (4.782)	186.328 (4.639)	195.046 (4.660)	208.261 (4.547)	
	4.01-8g	190.197 (5.242)	191.076 (5.086)	202.051 (5.109)	211.929 (4.985)	
	8.01g +	185.942 (4.203)	186.325 (4.078)	193.682 (4.097)	203.786 (3.997)	

Table 7.39: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm for Protein groupings (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3	RESULT
Intercept	Fast	305.749 (4.447)	306.177 (4.299)	306.359 (4.099)	*Meal* F (2,369) = 0.111, p=0.895
	< 4g	296.934 (3.522)	293.016 (3.373)	295.789 (3.344)	*Session* F (2,738) = 3.879, p<0.05
	4.01-8g	298.031 (3.862)	294.456 (3.698)	295.749 (3.667)	*Meal X Session* F (4,738) = 1.567, p=0.181
	8.01g +	298.950 (3.096)	294.219 (2.965)	289.362 (2.940)	
Slope	Fast	28.663 (2.231)	26.536 (2.157)	26.062 (2.524)	*Meal* F (2,369) = 0.190, p=0.827
	< 4g	31.274 (1.858)	31.300 (1.808)	31.875 (2.150)	*Session* F (2,738) = 0.744, p=0.476
	4.01-8g	31.270 (2.037)	31.206 (1.982)	32.016 (2.357)	*Meal X Session* F (4,738) = 0.219, p=0.928
	8.01g +	31.201 (1.633)	32.416 (1.589)	34.095 (1.890)	
Intra-Individual Variability	Fast	189.833 (11.583)	167.220 (12.215)	172.146 (13.089)	*Meal* F (2,369) = 0.272, p=0.762
	< 4g	193.911 (9.415)	186.409 (10.288)	185.435 (10.882)	*Session* F (2,738) = 0.456, p=0.634
	4.01-8g	180.773 (10.322)	181.357 (11.280)	188.219 (11.930)	*Meal X Session* F (4,738) = 0.545, p=0.702
	8.01g +	187.561 (8.276)	187.931 (9.044)	199.845 (9.566)	

Table 7.40: Summary table for Decision Times on the Hick Paradigm for Fat groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	309.122 (4.321)	332.622 (4.413)	356.596 (5.147)	396.667 (7.815)	*Meal* F (2,369) = 0.015,
	<2.5g	302.779 (2.631)	324.666 (2.688)	351.035 (3.208)	399.588 (5.080)	p=0.986
	7-12g	307.006 (4.003)	326.860 (4.090)	355.773 (4.879)	401.227 (7.728)	*Session* F (2,738) = 4.075,
	16g +	303.902 (3.980)	326.759 (4.066)	355.264 (4.851)	395.287 (7.683)	p<0.05 *Meal X Session*
Sess 2	Fast	308.365 (4.321)	330.699 (4.506)	356.718 (5.373)	388.128 (7.723)	F (4,738) = 0.299, p=0.878
	<2.5g	297.296 (2.636)	324.415 (2.757)	348.802 (3.288)	396.163 (4.976)	*Lamps* F (3,1107) = 850.411,
	7-12g	298.738 (4.010)	321.453 (4.194)	350.936 (5.002)	394.174 (7.569)	p<0.001 *Meal X Lamps*
	16g +	299.621 (3.987)	321.966 (4.170)	349.557 (4.973)	393.977 (7.526)	F (6,1107) = 0.361, p=0.903
Sess 3	Fast	310.910 (4.096)	327 .936 (4.254)	353.788 (5.314)	389.160 (8.730)	*Session X Lamps* F (6,2214) = 0.674,
	<2.5g	297.653 (2.523)	323.719 (2.715)	351.025 (3.410)	397.666 (5.718)	p=0.670 *Meal X Session X*
	7-12g	296.919 (3.838)	320.483 (4.130)	351.122 (5.187)	399.831 (8.698)	*Lamps* F (12,2214) = 0.222,
	16g +	297.592 (3.815)	324.149 (4.106)	352.805 (5.158)	394.552 (8.648)	p=0.997

Table 7.41: Summary table for Movement Times on the Hick Paradigm for Fat groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	188.596 (5.080)	193.221 (5.297)	205.449 (5.544)	211.532 (5.774)	*Meal* F (2,369) = 3.552, $p<0.05$
	<2.5g	180.907 (3.083)	183.259 (3.202)	190.319 (3.384)	196.960 (3.478)	
	7-12g	190.837 (4.689)	195.442 (4.871)	204.994 (5.147)	215.134 (5.291)	*Session* F (2,738) = 2.756, $p=0.064$
	16g +	181.960 (4.662)	185.029 (4.843)	193.385 (5.118)	209.483 (5.260)	*Meal X Session*
Sess 2	Fast	196.462 (6.071)	200.231 (6.152)	206.436 (5.940)	215.904 (6.160)	F (4,738) = 0.985, $p=0.415$
	<2.5g	181.043 (3.663)	184.618 (3.663)	191.636 (3.544)	200.663 (3.612)	*Lamps* F (3,1107) = 174.721,
	7-12g	200.610 (5.572)	203.483 (5.572)	210.587 (5.391)	219.017 (5.495)	$p<0.001$ *Meal X Lamps*
	16g +	183.092 (5.540)	192.408 (5.540)	198.080 (5.360)	212.023 (5.463)	F (6,1107) = 2.637, $p<0.05$
Sess 3	Fast	197.827 (2.326)	186.489 (2.426)	194.429 (2.539)	204.090 (2.644)	*Session X Lamps* F (6,2214) = 2.264,
	<2.5g	183.651 (3.682)	185.658 (3.577)	193.575 (3.587)	203.663 (3.512)	$p<0.05$ *Meal X Session X*
	7-12g	195.610 (5.601)	195.453 (5.441)	207.302 (5.456)	213.140 (5.343)	*Lamps* F (12,2214) = 1.836,
	16g +	191.402 (5.569)	184.236 (5.409)	191.581 (5.424)	210.207 (5.312)	$p<0.05$

Table 7.42: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm for Fat groupings (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3	RESULT
Intercept	Fast	305.749 (4.447)	306.177 (4.299)	306.359 (4.099)	*Meal* F (2,369) = 0.125, p=0.882
	<2.5g	295.993 (2.720)	293.527 (2.608)	293.416 (2.595)	*Session* F (2,738) = 5.886, p<0.01
	7-12g	300.979 (4.137)	293.960 (3.968)	291.187 (3.947)	*Meal X Session* F (4,738) = 0.784, p=0.556
	16g +	299.903 (4.113)	294.683 (3.945)	294.344 (3.924)	
Slope	Fast	28.663 (2.231)	26.536 (2.157)	26.062 (2.524)	*Meal* F (2,369) = 0.140, p=0.870
	<2.5g	31.684 (1.436)	32.100 (1.398)	32.737 (1.663)	*Session* F (2,738) = 1.092, p=0.336
	7-12g	31.158 (2.185)	31.580 (2.127)	33.942 (2.530)	*Meal X Session* F (4,738) = 0.120, p=0.975
	16g +	30.317 (2.172)	31.062 (2.115)	31.952 (2.516)	
Intra-Individual Variability	Fast	189.833 (11.583)	167.220 (12.215)	172.146 (13.089)	*Meal* F (2,369) = 0.196, p=0.822
	<2.5g	187.083 (7.288)	186.604 (7.958)	199.018 (8.409)	*Session* F (2,738) = 0.181, p=0.835
	7-12g	191.438 (11.086)	183.313 (12.105)	188.444 (12.791)	*Meal X Session* F (4,738) = 0.580, p=0.677
	16g +	185.793 (11.022)	185.968 (12.035)	180.067 (12.718)	

Table 7.43: Summary table for Decision Times on the Hick Paradigm for Fibre groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	309.122 (4.321)	332.622 (4.413)	356.596 (5.147)	396.667 (7.815)	*Meal* F (1,370) = 0.002, p=0.960
	<3g	304.614 (3.000)	325.556 (3.063)	353.134 (3.658)	398.788 (5.789)	
	3.01-6.5g	303.603 (2.507)	325.737 (2.560)	353.110 (3.057)	399.082 (4.838)	*Session* F (2,740) = 3.718, p<0.05
Sess 2	Fast	308.365 (4.321)	330.699 (4.506)	356.718 (5.373)	388.128 (7.723)	*Meal X Session* F (2,740) = 0.061, p=0.941
	<3g	298.141 (3.004)	323.026 (3.142)	349.794 (3.746)	393.098 (5.66)	*Lamps* F (3,1110) = 963.661, p<0.001
	3.01-6.5g	298.196 (2.511)	323.249 (2.626)	349.247 (3.131)	396.655 (4.736)	*Meal X Lamps* F (3,1110) = 0.061, p=0.980
Sess 3	Fast	310.910 (4.096)	327 .936 (4.254)	353.788 (5.314)	389.160 (8.730)	*Session X Lamps* F (6,2220) = 0.723, p=0.631
	<3g	297.984 (2.873)	323.101 (3.094)	350.627 (3.884)	297.935 (6.514)	
	3.01-6.5g	297.110 (2.401)	323.050 (2.586)	352.048 (3.246)	397.094 (5.445)	*Meal X Session X Lamps* F (6,2220) = 0.196, p=0.978

Table 7.44: Summary table for Movement Times on the Hick Paradigm for Fibre groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	188.596 (5.080)	193.221 (5.297)	205.449 (5.544)	211.532 (5.774)	*Meal* F (1,370) = 4.026,
	<3g	187.859 (3.514)	191.833 (3.651)	200.748 (3.860)	209.098 (3.998)	p<0.05
	3.01-6.5g	180.368 (2.937)	182.756 (3.052)	190.014 (3.226)	200.591 (3.342)	*Session* F (2,740) = 2.405, p=0.091
Sess 2	Fast	196.462 (6.071)	200.231 (6.152)	206.436 (5.940)	215.904 (6.160)	*Meal X Session* F (2,740) = 0.259,
	<3g	193.621 (4.191)	197.098 (4.196)	204.042 (4.059)	211.324 (4.154)	p=0.772 *Lamps*
	3.01-6.5g	180.753 (3.503)	186.402 (3.507)	192.970 (3.393)	204.936 (3.472)	F (3,1110) = 177.573, p<0.001 *Meal X Lamps*
Sess 3	Fast	197.827 (2.326)	186.489 (2.426)	194.429 (2.539)	204.090 (2.644)	F (3,1110) = 1.336, p=0.261
	<3g	191.627 (4.208)	192.493 (4.075)	202.807 (4.091)	211.144 (4.006)	*Session X Lamps* F (6,2220) = 1.242,
	3.01-6.5g	185.854 (3.517)	184.164 (3.406)	191.831 (3.419)	204.758 (3.348)	p=0.282 *Meal X Session X Lamps* F (6,2220) = 0.951, p=0.457

Table 7.45: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm for Fibre groupings (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3	RESULT
Intercept	Fast	305.749 (4.447)	306.177 (4.299)	306.359 (4.099)	*Meal* F (1,370) = 0.065, p=0.799
	<3g	299.007 (3.102)	294.273 (2.971)	293.308 (2.956)	*Session* F (2,740) = 4.816, p<0.01
	3.01-6.5g	297.400 (2.593)	293.635 (2.483)	292.985 (2.471)	*Meal X Session* F (2,740) = 0.073, p=0.930
Slope	Fast	28.663 (2.231)	26.536 (2.157)	26.062 (2.524)	*Meal* F (1,370) = 0.082, p=0.775
	<3g	31.014 (1.636)	31.169 (1.592)	32.741 (1.895)	*Session* F (2,740) = 0.968, p=0.380
	3.01-6.5g	31.402 (1.368)	32.134 (1.331)	32.895 (1.584)	*Meal X Session* F (2,740) = 0.061, p=0.941
Intra-Individual Variability	Fast	189.833 (11.583)	167.220 (12.215)	172.146 (13.089)	*Meal* F (1,370) = 0.527, p=0.468
	<3g	185.489 (8.300)	183.042 (9.062)	185.277 (9.587)	*Session* F (2,740) = 0.438, p=0.645
	3.01-6.5g	189.390 (6.938)	187.548 (7.575)	196.937 (8.013)	*Meal X Session* F (2,740) = 0.236, p=0.790

Table 7.46: Summary table for Decision Times on the Hick Paradigm for Energy Intake groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	309.122 (4.321)	332.622 (4.413)	356.596 (5.147)	396.667 (7.815)	*Meal* F (2,369) = 0.445, p=0.641 *Session* F (2,738) = 5.338, p<0.01 *Meal X Session* F (4,738) = 0.986, p=0.415 *Lamps* F (3,1107) = 836.312, p<0.001 *Meal X Lamps* F (6,1107) = 0.075, p=0.998 *Session X Lamps* F (6,2214) = 0.879, p=0.510 *Meal X Session X Lamps* F (12,2214) = 0.594, p=0.848
	101-200kcal	304.836 (3.174)	325.927 (3.241)	353.347 (3.870)	399.726 (6.125)	
	201-300kcal	303.863 (2.841)	325.538 (2.901)	352.170 (3.464)	399.041 (5.482)	
	301kcal +	302.688 (4.644)	325.430 (4.742)	355.172 (5.661)	397.109 (8.961)	
Sess 2	Fast	308.365 (4.321)	330.699 (4.506)	356.718 (5.373)	388.128 (7.723)	
	101-200kcal	298.040 (3.177)	325.223 (3.314)	350.307 (3.958)	395.974 (5.986)	
	201-300kcal	399.015 (2.844)	324.050 (2.966)	350.801 (3.543)	398.058 (5.358)	
	301kcal +	296.211 (4.649)	316.352 (4.849)	344.133 (5.791)	385.859 (8.758)	
Sess 3	Fast	310.910 (4.096)	327 .936 (4.254)	353.788 (5.314)	389.160 (8.730)	
	101-200kcal	299.883 (3.025)	325.142 (3.259)	351.033 (4.103)	399.993 (6.891)	
	201-300kcal	298.468 (2.707)	324.401 (2.917)	353.982 (3.672)	396.202 (6.168)	
	301kcal +	289.633 (4.425)	315.086 (4.768)	345.656 (6.002)	395.273 (10.083)	

Table 7.47: Summary table for Movement Times on the Hick Paradigm for Energy Intake groupings (+/- s.e.m)

	MEAL	Lamp 1	Lamp 2	Lamp 4	Lamp 8	RESULT
Sess 1	Fast	188.596 (5.080)	193.221 (5.297)	205.449 (5.544)	211.532 (5.774)	*Meal* F (2,369) = 0.662,
	101-200kcal	182.602 (3.728)	184.861 (3.880)	192.405 (4.107)	199.073 (4.232)	p=0.517
	201-300kcal	185.368 (3.337)	188.395 (3.473)	195.199 (3.676)	206.102 (3.788)	*Session* F (2,738) = 1.593,
	301kcal +	180.133 (5.454)	184.883 (5.676)	196.703 (6.010)	209.453 (6.192)	p=0.204 *Meal X Session*
Sess 2	Fast	196.462 (6.071)	200.231 (6.152)	206.436 (5.940)	215.904 (6.160)	F (4,738) = 0.523, p=0.717
	101-200kcal	181.704 (4.459)	187.577 (4.458)	192.661 (4.301)	203.266 (4.392)	*Lamps* F (3,1107) = 163.703,
	201-300kcal	188.137 (3.991)	192.591 (3.990)	202.784 (3.850)	211.561 (3.931)	p<0.001 *Meal X Lamps*
	301kcal +	189.750 (6.524)	192.922 (6.522)	193.883 (6.293)	206.078 (6.426)	F (6,1107) = 1.336, p=0.238
Sess 3	Fast	197.827 (2.326)	186.489 (2.426)	194.429 (2.539)	204.090 (2.644)	*Session X Lamps* F (6,2214) = 1.845,
	101-200kcal	184.544 (4.447)	187.164 (4.324)	193.675 (4.336)	204.719 (4.244)	p=0.087 *Meal X Session X*
	201-300kcal	192.488 (3.980)	189.307 (3.870)	200.994 (3.881)	208.716 (3.799)	*Lamps* F (12,2214) = 2.182,
	301kcal +	184.734 (6.506)	183.914 (6.326)	189.641 (6.345)	209.531 (6.209)	p=0.010

Table 7.48: Summary table for Intercept, Slope and Intra-Individual Variability on the Hick Paradigm for Energy Intake groupings (+/- s.e.m)

	MEAL	Session 1	Session 2	Session 3	RESULT
Intercept	Fast	305.749 (4.447)	306.177 (4.299)	306.359 (4.099)	*Meal* F (2,369) = 0.582, p=0.559 *Session* F (2,738) = 6.858, p<0.001 *Meal X Session* F (4,738) = 1.534, p=0.191
	101-200kcal	299.147 (3.283)	294.560 (3.142)	295.080 (3.109)	
	201-300kcal	297.156 (2.938)	294.403 (2.812)	294.849 (2.783)	
	301kcal +	298.150 (4.803)	291.128 (4.597)	284.291 (4.549)	
Slope	Fast	28.663 (2.231)	26.536 (2.157)	26.062 (2.524)	*Meal* F (2,369) = 0.000, p=1.000 *Session* F (2,738) = 1.502, p=0.223 *Meal X Session* F (4,738) = 0.623, p=0.646
	101-200kcal	31.217 (1.732)	31.893 (1.683)	32.623 (2.004)	
	201-300kcal	31.213 (1.550)	32.385 (1.507)	32.282 (1.794)	
	301kcal +	31.377 (2.534)	29.672 (2.463)	34.745 (2.932)	
Intra-Individual Variability	Fast	189.833 (11.583)	167.220 (12.215)	172.146 (13.089)	*Meal* F (2,369) = 0.268, p=0.765 *Session* F (2,738) = 0.416, p=0.660 *Meal X Session* F (4,738) = 0.487, p=0.746
	101-200kcal	181.471 (8.774)	185.871 (9.586)	196.626 (10.147)	
	201-300kcal	192.964 (7.853)	188.590 (8.580)	192.642 (9.083)	
	301kcal +	187.470 (12.837)	177.579 (10.025)	181.204 (14.846)	

Table 7.49: Summary table for Correct responses on the RIPT for Breakfast (fast/active) groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Cor 1	Fast	4.638 (0.213)	4.013 (0.209)	3.125 (0.199)	3.363 (0.203)	2.713 (0.182)	*Breakfast* F (1,466) = 3.715, p=0.055 *Session* F (2,932) = 9.060, p<0.001 *Breakfast X Session* F (2,932) = 0.445, p=0.641 *Minute* F (4,1864) = 163.017, p<0.001 *Breakfast X Minute* F (4,1864) = 0.353, p=0.842 *Session X Minute* F (8,3728) = 2.207, p=0.024 *Carb X Session X Minute* F (8,3728) = 0.794, p=0.608
	Active	4.704 (0.097)	4.209 (0.095)	3.611 (0.090)	3.835 (0.092)	2.925 (0.083)	
Cor 2	Fast	4.625 (0.227)	4.200 (0.212)	3.475 (0.208)	3.988 (0.217)	2.975 (0.183)	
	Active	4.866 (0.103)	4.479 (0.096)	3.863 (0.094)	4.168 (0.099)	3.124 (0.083)	
Cor 3	Fast	4.450 (0.226)	4.025 (0.207)	3.575 (0.221)	3.950 (0.217)	2.600 (0.176)	
	Active	4.820 (0.103)	4.456 (0.094)	3.894 (0.100)	4.194 (0.098)	3.067 (0.080)	

Table 7.50: Summary table for Wrong responses on the RIPT for Breakfast (fast/active) groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrg 1	Fast	3.575 (0.420)	2.763 (0.395)	3.175 (0.413)	2.925 (0.402)	2.913 (0.403)	*Breakfast* F (1,466) = 0.044, p=0.834
	Active	3.356 (0.191)	2.923 (0.179)	2.892 (0.187)	3.041 (0.183)	2.786 (0.183)	*Session* F (2,932) = 7.925, p<0.001
Wrg 2	Fast	2.738 (0.377)	2.188 (0.400)	2.575 (0.399)	2.763 (0.411)	3.275 (0.431)	*Breakfast X Session* F (2,932) = 0.143, p=0.867 *Minute*
	Active	2.482 (0.171)	2.456 (0.181)	2.549 (0.181)	2.624 (0.187)	2.706 (0.196)	F (4,1864) = 4.583, p<0.001 *Breakfast X Minute* F (4,1864) = 0.729, p=0.572
Wrg 3	Fast	2.288 (0.389)	2.450 (0.407)	2.650 (0.404)	2.750 (0.406)	3.000 (0.474)	*Session X Minute* F (8,3728) = 4.766, p<0.001 *Carb X Session X*
	Active	2.345 (0.177)	2.399 (0.185)	2.544 (0.183)	2.637 (0.184)	3.121 (0.215)	*Minute* F (8,3728) = 0.822, p=0.531

Table 7.51: Summary table for Reaction Times on the RIPT for Breakfast (fast/active) groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	Fast	520.750 (18.249)	518.588 (19.318)	554.188 (22.436)	526.538 (20.372)	521.913 (23.833)	*Breakfast* F (1,466) = 0.033, p=0.855
	Active	517.894 (8.286)	551.054 (8.772)	560.505 (10.187)	551.023 (9.250)	581.028 (10.822)	*Session* F (2,932) = 0.486, p=0.615 *Breakfast X Session* F (2,932) = 4.029, p<0.05 *Minute* F (4,1864) = 5.263, p<0.001 *Breakfast X Minute* F (8,1864) = 0.447, p=0774 *Session X Minute* F (8,3728) = 0.979, p=0.450 *Carb X Session X Minute* F (8,3728) = 1.084, p=0.371
RT 2	Fast	531.413 (16.566)	546.875 (17.427)	525.913 (19.085)	551.775 (20.373)	549.313 (21.476)	
	Active	499.881 (7.522)	526.098 (7.913)	528.049 (8.666)	546.070(9.251)	543.588 (9.752)	
RT 3	Fast	504.850 (15.216)	527.213 (16.753)	529.038 (19.764)	571.325 (21.556)	554.525 (20.735)	
	Active	514.683 (6.909)	522.784 (7.607)	533.820 (8.974)	542.763 (9.788)	540.740 (9.415)	

Table 7.52: Summary table for Correct responses on the RIPT for Carbohydrate groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Corr 1	Fast	4.638 (0.213)	4.013 (0.209)	3.125 (0.199)	3.363 (0.203)	2.713 (0.182)	*Carbohydrate* F (2,385) = 0.311,
	20.1-35g	4.642 (0.149)	4.145 (0.146)	3.600 (0.138)	3.745 (0.141)	2.800 (0.129)	p=0.733
	35.1-50g	4.862 (0.168)	4.346 (0.164)	3.792 (0.156)	4.115 (0.159)	3.108 (0.145)	*Session* F (2,770) = 13.707,
	50.1g +	4.591 (0.198)	4.129 (0.194)	3.376 (0.184)	3.602 (0.188)	2.892 (0.172)	p<0.001 *Carb X Session*
Corr 2	Fast	4.625 (0.227)	4.200 (0.212)	3.475 (0.208)	3.988 (0.217)	2.975 (0.183)	F (4,770) = 2.892, p<0.05
	20.1-35g	4.927 (0.162)	4.521 (0.148)	3.873 (0.148)	4.085 (0.154)	3.152 (0.130)	*Minute* F (4,1540) = 212.777,
	35.1-50g	4.846 (0.182)	4.415 (0.167)	3.985 (0.166)	4.400 (0.173)	3.108 (0.147)	p<0.001 *Carb X Minute*
	50.1g +	4.785 (0.216)	4.495 (0.197)	3.677 (0.197)	3.989 (0.205)	3.097 (0.174)	F (8,1540) = 0.342, p=0.950
Corr 3	Fast	4.450 (0.226)	4.025 (0.207)	3.575 (0.221)	3.950 (0.217)	2.600 (0.176)	*Session X Minute* F (8,3080) = 0.708,
	20.1-35g	4.770 (0.159)	4.279 (0.143)	3.879 (0.154)	4.273 (0.152)	3.073 (0.126)	p=0.684 *Carb X Session X*
	35.1-50g	4.815 (0.179)	4.952 (0.161)	3.785 (0.174)	4.062 (0.171)	3.062 (0.142)	*Minute* F (16,3080) = 1.004,
	50.1g +	4.9174 (0.211)	4.581 (0.190)	4.075 (0.205)	4.226 (0.202)	3.065 (0.168)	p=0.449

Table 7.53: Summary table for Wrong responses on the RIPT for Carbohydrate groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrg 1	Fast	3.575 (0.420)	2.763 (0.395)	3.175 (0.413)	2.925 (0.402)	2.913 (0.403)	*Carbohydrate* F (2,385) = 4.375, p<0.05
	20.1-35g	3.703 (0.282)	3.267 (0.271)	3.303 (0.276)	3.388 (0.286)	3.121 (0.282)	
	35.1-50g	2.538 (0.318)	2.285 (0.306)	2.077 (0.311)	2.369 (0.322)	2.331 (0.318)	*Session* F (2,770) = 12.249, p<0.001
	50.1g +	3.882 (0.376)	3.204 (0.362)	3.301 (0.368)	3.366 (0.381)	2.828 (0.376)	*Carb X Session* F (4,770) = 0.306, p=0.874
Wrg 2	Fast	2.738 (0.377)	2.188 (0.400)	2.575 (0.399)	2.763 (0.411)	3.275 (0.431)	*Minute* F (4,1540) = 3.196, p<0.05
	20.1-35g	2.988 (0.266)	2.606 (0.284)	2.800 (0.284)	2.976 (0.287)	3.073 (0.301)	*Carb X Minute* F (8,1540) = 0.669, p=0.720
	35.1-50g	1.708 (0.300)	2.092 (0.320)	1.846 (0.320)	1.977 (0.324)	2.023 (0.339)	*Session X Minute* F (8,3080) = 6.887, p<0.001
	50.1g +	2.667 (0.354)	2.699 (0.378)	3.086 (0.379)	2.903 (0.383)	3.011 (0.401)	*Carb X Session X Minute* F (16,3080) = 1.191, p=0.267
Wrg 3	Fast	2.288 (0.389)	2.450 (0.407)	2.650 (0.404)	2.750 (0.406)	3.000 (0.474)	
	20.1-35g	2.606 (0.281)	3.006 (0.286)	2.994 (0.279)	2.994 (0.288)	3.406 (0.331)	
	35.1-50g	1.915 (0.317)	1.762 (0.322)	1.800 (0.314)	2.023 (0.324)	2.492 (0.373)	
	50.1g +	2.484 (0.374)	2.215 (0.380)	2.785 (0.372)	2.860 (0.383)	3.495 (0.440)	

Table 7.54: Summary table for Reaction Times on the RIPT for Carbohydrate groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	Fast	520.750 (18.249)	518.588 (19.318)	554.188 (22.436)	526.538 (20.372)	521.913 (23.833)	*Carbohydrate* F (2,385) = 4.433,
	20.1-35g	522.782 (13.168)	554.661 (13.586)	558.345 (15.838)	562.309 (13.770)	584.091 (16.631)	p<0.05
	35.1-50g	504.262 (14.835)	530.154 (15.306)	544.615 (17.843)	526.515 (15.514)	553.454 (18.737)	*Session* F (2,770) = 11.242,
	50.1g +	528.280 (17.540)	573.871 (18.097)	586.548 (21.096)	565.258 (18.342	614.140 (22.153)	p<0.001 *Carb X Session*
RT 2	Fast	531.413 (16.566)	546.875 (17.427)	525.913 (19.085)	551.775 (20.373)	549.313(21.476)	F (4,770) = 1.044, p=0.384
	20.1-35g	501.115 (11.172)	529.242 (11.379)	530.285 (12.814)	542.873 (14.032)	552.400 (14.900)	*Minute* F (4,1540) =
	35.1-50g	493.177 (12.587)	508.515 (12.819)	536.246 (14.436)	522.900 (15.808)	537.354 (16.786)	10.912, p<0.001 *Carb X Minute*
	50.1g +	507.065 (14.882)	545.097 (15.156)	512.624 (17.068)	584.129 (18.690)	536.667 (19.846)	F (8,1540) = 0.985, p=0.446
RT 3	Fast	504.850 (15.216)	527.213 (16.753)	529.038 (19.764)	571.325 (21.556)	554.525 (20.735)	*Session X Minute* F (8,3080) = 1.544,
	20.1-35g	525.097 (10.041)	519.285 (11.184)	546.776 (13.250)	569.842 (14.692)	543.715 (14.255)	p=0.137 *Carb X Session X*
	35.1-50g	487.431 (11.312)	515.008 (12.599)	530.977 (14.927)	509.385 (16.552)	524.685 (16.060)	*Minute* F (16,3080) =
	50.1g +	534.301 (13.374)	539.860 (14.896)	514.806 (17.649)	541.376 (19.569)	557.903 (18.988)	0.984, p=0.471

Table 7.55: Summary table for Correct responses on the RIPT for Protein groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Corr 1	Fast	4.638 (0.213)	4.013 (0.209)	3.125 (0.199)	3.363 (0.203)	2.713 (0.182)	*Protein* F (2,385) = 0.060, p=0.942
	<4g	4.492 (0.169)	4.133 (0.166)	3.492 (0.1457)	3.672 (0.161)	2.703 (0.146)	
	4.01-8g	4.901 (0.190)	4.238 (0.187)	3.644 (0.177)	4.050 (0.181)	3.119 (0.165)	*Session* F (2,770) = 12.348, p<0.001
	8.01-12g	4.748 (0.151)	4.252 (0.149)	3.686 (0.141)	3.830 (0.144)	2.891 (0.131)	*Protein X Session*
Corr 2	Fast	4.625 (0.227)	4.200 (0.212)	3.475 (0.208)	3.988 (0.217)	2.975 (0.183)	F (4,770) = 3.491, p<0.01
	<4g	4.805 (0.184)	4.539 (0.168)	3.891 (0.168)	3.992 (0.175)	3.141 (0.148)	*Minute* F (4,1540) =
	4.01-8g	4.762 (0.207)	4.356 (0.189)	4.020 (0.189)	4.376 (0.197)	3.188 (0.166)	214.889, p<0.001 *Protein X Minute*
	8.01-12g	4.981 (0.165)	4.509 (0.151)	3.742 (0.150)	4.176 (0.157)	3.069 (0.133)	F (8,1540) = 0.358, p=0.943
Corr 3	Fast	4.450 (0.226)	4.025 (0.207)	3.575 (0.221)	3.950 (0.217)	2.600 (0.176)	*Session X Minute* F (8,3080) = 0.654,
	<4g	4.984 (0.180)	4.453 (0.163)	3.898 (0.175)	4.359 (0.172)	3.172 (0.143)	p=0.732 *Protein X Session X*
	4.01-8g	4.634 (0.202)	4.505 (0.183)	3.644 (0.197)	4.099 (0.194)	2.950 (0.161)	*Minute* F (16,3080) =
	8.01-12g	4.805 (0.161)	4.428 (0.146	4.050 (0.157)	4.113 (0.154)	3.057 (0.128)	1.221, p=0.243

Table 7.56: Summary table for Wrong responses on the RIPT for Protein groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrg 1	Fast	3.575 (0.420)	2.763 (0.395)	3.175 (0.413)	2.925 (0.402)	2.913 (0.403)	*Protein* F (2,385) = 0.445,
	<4g	3.961 (0.322)	3.227 (0.310)	2.992 (0.317)	3.148 (0.327)	2.977 (0.322)	p=0.641
	4.01-8g	2.950 (0.363)	2.624 (0.349)	2.723 (0.357)	2.832 (0.368)	2.980 (0.362)	*Session* F (2,770) =
	8.01-12g	3.126 (0.289)	2.868 (0.278)	2.918 (0.285)	3.088 (0.294)	2.509 (0.288)	12.420, p<0.001 *Protein X Session*
Wrg 2	Fast	2.738 (0.377)	2.188 (0.400)	2.575 (0.399)	2.763 (0.411)	3.275 (0.431)	F (4,770) = 0.303, p=0.876
	<4g	2.703 (0.306)	2.313 (0.323)	2.891 (0.325)	2.836 (0.329)	2.672 (0.344)	*Minute* F (4,1540) =
	4.01-8g	2.297 (0.344)	2.455 (0.364)	2.228 (0.366)	2.594 (0.370)	2.515 (0.387)	3.191, p<0.05 *Protein X Minute*
	8.01-12g	2.267 (0.360)	2.356 (0.368)	2.218 (0.360)	2.376 (0.370)	2.861 (0.425)	F (8,1540) = 0.362, p=0.940
Wrg 3	Fast	2.288 (0.389)	2.450 (0.407)	2.650 (0.404)	2.750 (0.406)	3.000 (0.474)	*Session X Minute* F (8,3080) =
	<4g	2.305 (0.320)	2.797 (0.327)	2.719 (0.320)	2.883 (0.329)	3.406 (0.377)	5.715, p<0.001 *Protein X Session*
	4.01-8g	2.421 (0.274)	2.572 (0.290)	2.478 (0.292)	2.472 (0.295)	2.855 (0.309	*X Minute* F (16,3080) =
	8.01-12g	2.428 (0.287)	2.107 (0.293)	2.610 (0.287)	2.604 (0.295)	3.057 (0.338)	2.015, p=0.010

Table 7.57: Summary table for Reaction Times on the RIPT for Protein groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	Fast	520.750 (18.249)	518.588 (19.318)	554.188 (22.436)	526.538 (20.372)	521.913 (23.833)	*Protein* F (2,385) = 1.687, p=0.186
	<4g	524.492 (14.961)	544.219 (15.377)	548.281 (17.920)	552.922 (15.679)	592.258 (18.974)	
	4.01-8g	505.099 (16.842)	522.149 (17.311)	533.752 (20.174)	533.139 (17.651)	568.396 (21.360)	*Session* F (2,770) = 8.698, p<0.001
	8.01-12g	520.711 (13.423)	574.918 (13.797)	587.340 (16.079)	560.855 (14.068)	580.013 (17.024)	*Protein X Session*
RT 2	Fast	531.413 (16.566)	546.875 (17.427)	525.913 (19.085)	551.775 (20.373)	549.313 (21.476)	F (4,770) = 0.970, p=0.423
	<4g	508.000 (12.683)	541.320 (12.917)	500.953 (14.455)	547.320 (16.062)	539.164 (16.927)	*Minute* F (4,1540) =
	4.01-8g	498.228 (14.278)	504.327 (14.542)	528.901 (16.272)	546.436 (18.081)	543.871 (19.056)	11.070, p<0.001 *Protein X Minute*
	8.01-12g	494.396 (11.379)	527.673 (11.590)	549.321 (12.969)	544.830 (14.411)	546.969 (15.188)	F (8,1540) = 1.703, p=0.093
RT 3	Fast	504.850 (15.216)	527.213 (16.753)	529.038 (19.764)	571.325 (21.556)	554.525 (20.735)	*Session X Minute* F (8,3080) = 1.207,
	<4g	525.602 (11.507)	517.875 (12.723)	504.875 (14.976)	541.797 (16.811)	536.680 (16.216)	p=0.291 *Protein X Session X*
	4.01-8g	503.139 (12.954)	525.119 (14.323)	544.228 (16.859)	525.733 (18.925)	535.228 (18.256)	*Minute* F (16,3080) =
	8.01-12g	513.226 (10.325)	525.252 (11.416)	550.509 (13.437)	554.358 (15.084)	547.509 (14.550)	0.559, p=0.915

Table 7.58: Summary table for Correct responses on the RIPT for Fat groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Corr 1	Fast	4.638 (0.213)	4.013 (0.209)	3.125 (0.199)	3.363 (0.203)	2.713 (0.182)	*Fat* F (2,385) = 1.784, p=0.169 *Session* F (2,770) = 14.564, p<0.001 *Fat X Session* F (4,770) = 1.243, p=0.291 *Minute* F (4,1540) = 187.227, p<0.001 *Fat X Minute* F (8,1540) = 1.442, p=0.174 *Session X Minute* F (8,3080) = 0.897, p=0.518 *Fat X Session X Minute* F (16,3080) = 1.013, p=0.439
	<2.5g	4.796 (0.135)	4.303 (0.132)	3.617 (0.125)	3.975 (0.128)	2.965 (0.117)	
	7-12g	4.761 (0.199)	4.228 (0.195)	3.783 (0.185)	3.783 (0.189)	2.848 (0.173)	
	16g +	4.453 (0.196)	3.989 (0.192)	3.432 (0.182)	3.589 (0.186)	2.916 (0.171)	
Corr 2	Fast	4.625 (0.227)	4.200 (0.212)	3.475 (0.208)	3.988 (0.217)	2.975 (0.183)	
	<2.5g	4.891 (0.146)	4.517 (0.134)	3.806 (0.133)	4.333 (0.139)	3.045 (0.117)	
	7-12g	5.065 (0.216)	4.511 (0.198)	4.207 (0.197)	4.261 (0.205)	3.511 (0.173)	
	16g +	4.621 (0.216)	4.368 (0.195)	3.653 (0.194)	3.726 (0.202)	2.916 (0.170)	
Corr 3	Fast	4.450 (0.226)	4.025 (0.207)	3.575 (0.221)	3.950 (0.217)	2.600 (0.176)	
	<2.5g	4.925 (0.143)	4.577 (0.130)	3.811 (0.139)	4.114 (0.137)	3.020 (0.113)	
	7-12g	4.935 (0.212)	4.402 (0.192)	4.207 (0.206)	4.413 (0.203)	3.380 (0.168)	
	16g +	4.484 (0.208)	4.253 (0.188)	3.768 (0.203)	4.137 (0.200)	2.863 (0.165)	

Table 7.59: Summary table for Wrong responses on the RIPT for Fat groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrg 1	Fast	3.575 (0.420)	2.763 (0.395)	3.175 (0.413)	2.925 (0.402)	2.913 (0.403)	*Fat* F (2,385) = 5.565,
	<2.5g	2.866 (0.257)	2.453 (0.245)	2.413 (0.251)	2.453 (0.258)	2.239 (0.253)	p<0.01
	7-12g	3.870 (0.379)	3.652 (0.363)	3.576 (0.371)	3.707 (0.381)	3.793 (0.374)	*Session* F (2,770) =
	16g +	3.895 (0.373)	3.211 (0.357)	3.242 (0.365)	3.642 (0.375)	2.968 (0.368)	13.347, p<0.001 *Fat X Session*
Wrg 2	Fast	2.738 (0.377)	2.188 (0.400)	2.575 (0.399)	2.763 (0.411)	3.275 (0.431)	F (4,770) = 1.967, p=0.098
	<2.5g	2.209 (0.243)	2.194 (0.256)	2.194 (0.259)	2.025 (0.258)	2.229 (0.271)	*Minute* F (4,1540) =
	7-12g	3.120 (0.359)	3.141 (0.379)	3087 (0.383)	3.554 (0.382)	3.728 (0.401)	3.227, p<0.05 *Fat X Minute*
	16g +	2.442 (0.353)	2.347 (0.373)	2.779 (0.377)	2.989 (0.376)	2.726 (0.395)	F (8,1540) = 1.419, p=0.183
Wrg 3	Fast	2.288 (0.389)	2.450 (0.407)	2.650 (0.404)	2.750 (0.406)	3.000 (0.474)	*Session X Minute* F (8,3080) =
	<2.5g	2.005 (0.253)	1.846 (0.257)	2.055 (0.252)	2.244 (0.260)	2.796 (0.299)	5.385, p<0.001 *Fat X Session X*
	7-12g	3.261 (0.374)	3.598 (0.380)	3.489 (0.373)	3.424 (0.385)	4.065 (0.442)	*Minute* F (16,3080) =
	16g +	2.179 (0.368)	2.411 (0.374)	2.663 (0.367)	2.705 (0.379)	2.895 (0.435)	0.859, p=0.618

Table 7.60: Summary table for Reaction Times on the RIPT for Fat groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	Fast	520.750 (18.249)	518.588 (19.318)	554.188 (22.436)	526.538 (20.372)	521.913 (23.833)	*Fat* F (2,385) = 3.827,
	<2.5g	510.612 (11.918)	549.537 (12.269)	551.851 (14.369)	544.289 (12.438)	580.970 (15.138)	p<0.05
	7-12g	510.880 (17.616)	520.750 (18.134)	558.478(21.238)	527.391 (18.385)	566.217 (22.376)	*Session* F (2,770) = 7.447,
	16g +	540.095 (17.336)	583.611 (17.846)	580.779 (20.900)	588.158 (18.092)	595.495 (22.019)	p=0.001 *Fat X Session*
RT 2	Fast	531.413 (16.566)	546.875 (17.427)	525.913 (19.085)	551.775 (20.373)	549.313 (21.476)	F (4,770) = 4.453, p=0.001
	<2.5g	487.483 (10.085)	505.891 (10.247)	531.801 (11.624)	536.692 (12.779)	544.000 (13.510)	*Minute* F (4,1540) =
	7-12g	507 .620 (14.907)	553.152 (15.146)	526.033 (17.181)	541.467 (18.889)	541.467 (19.969)	9.601, p<0.001 *Fat X Minute*
	16g +	518.621 (14.669)	542.653 (14.905)	522.063(16.908)	570.368 (18.588)	544.768 (19.651)	F (8,1540) = 0.772, p=0.673
RT 3	Fast	504.850 (15.216)	527.213 (16.753)	529.038 (19.764)	571.325 (21.556)	554.525 (20.735)	*Session X Minute* F (8,3080) =
	<2.5g	497.010 (9.111)	512.995 (10.131)	520.318 (11.966)	527.861 (13.395)	513.373 (12.732)	1.196, p=0.297 *Fat X Session X*
	7-12g	532.348 (13.467)	533.685 (14.974)	566.174 (17.687)	558.022 (19.800)	595.424 (18.819)	*Minute* F (16,3080) =
	16g +	534.968 (13.253)	532.937 (14.736)	531.053 (17.406)	559.516 (19.484)	545.684 (18.519)	0.836, p=0.645

Table 7.61: Summary table for Correct responses on the RIPT for Fibre groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Corr 1	Fast	4.638 (0.213)	4.013 (0.209)	3.125 (0.199)	3.363 (0.203)	2.713 (0.182)	*Fibre* $F (1,386) = 0.375$, $p=0.540$ *Session* $F (2,772) = 12.851$, $p<0.001$ *Fibre X Session* $F (2,772) = 1.043$, $p=0.353$ *Minute* $F (4,1544) = 213.015$, $p<0.001$ *Fibre X Minute* $F (4,1544) = 0.925$, $p=0.448$ *Session X Minute* $F (8,3088) = 0.586$, $p=0.790$ *Fibre X Session X Minute* $F (8,3088) = 0.669$, $p=0.719$
	<3g	4.747 (0.152)	4.215 (0.149)	3.728 (0.141)	3.918 (0.145)	2.975 (0.132)	
	3.01-6.5g	4.674 (0.126)	4.204 (0.124)	5.530 (0.117)	3.778 (0.120)	2.891 (0.109)	
Corr 2	Fast	4.625 (0.227)	4.200 (0.212)	3.475 (0.208)	3.988 (0.217)	2.975 (0.183)	
	<3g	4.861 (0.165)	4.430 (0.151)	4.057 (0.157)	4.316 (0.157)	3.272 (0.133)	
	3.01-6.5g	4.870 (0.137)	4.513 (0.125)	3.730 (0.125)	4.065 (0.130)	3.022 (0.110)	
Corr 3	Fast	4.450 (0.226)	4.025 (0.207)	3.575 (0.221)	3.950 (0.217)	2.600 (0.176)	
	<3g	4.759 (0.162)	4.475 (0.146)	3.842 (0.157)	4.209 (0.155)	3.133 (0.129)	
	3.01-6.5g	4.861 (0.134)	4.443 (0.121)	3.930 (0.130)	4.178 (0.128)	3.022 (0.107)	

Table 7.62: Summary table for Wrong responses on the RIPT for Fibre groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrg 1	Fast	3.575 (0.420)	2.763 (0.395)	3.175 (0.413)	2.925 (0.402)	2.913 (0.403)	*Fibre* F (1,386) = 0.483, p=0.487
	<3g	3.323 (0.292)	2.962 (0.279)	2.899 (0.285)	3.101 (0.294)	3.203 (0.288)	
	3.01-6.5g	3.378 (0.242)	2.896 (0.232)	2.887 (0.237)	3.000 (0.244)	2.500 (0.239)	*Session* F (2,772) = 11.719, p<0.001
Wrg 2	Fast	2.738 (0.377)	2.188 (0.400)	2.575 (0.399)	2.763 (0.411)	3.275 (0.431)	*Fibre X Session* F (2,772) = 0.212, p=0.809
	<3g	2.25 (0.275)	2.639 (0.290)	2.481 (0.293)	2.880 (0.295)	2.905 (0.309)	
	3.01-6.5g	2.452 (0.228)	2.330 (0.241)	2.596 (0.243)	2.448 (0.245)	2.570 (0.256)	*Minute* F (4,1544) = 3.437, p<0.01
Wrg 3	Fast	2.288 (0.389)	2.450 (0.407)	2.650 (0.404)	2.750 (0.406)	3.000 (0.474)	*Fibre X Minute* F (4,1544) = 1.673, p=0.154
	<3g	2.608 (0.287)	2.766 (0.294)	2.620 (0.288)	2.677 (0.296)	3.234 (0.339)	
	3.01-6.5g	2.165 (0.238)	2.148 (0.243)	2.491 (0.239)	2.609 (0.245)	3.043 (0.281)	*Session X Minute* F (8,3088) = 5.330, p<0.001 *Fibre X Session X Minute* F (8,3088) = 1.585, p=0.124

Table 7.63: Summary table for Reaction Times on the RIPT for Fibre groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	Fast	520.750 (18.249)	518.588 (19.318)	554.188 (22.436)	526.538 (20.372)	521.913 (23.833)	*Fibre* F (1,386) = 1.440,
	<3g	506.741 (13.442)	525.532 (13.827)	537.342 (16.140)	525.367 (14.020)	554.437 (16.980)	p=0.231
	3.01-6.5g	525.557 (11.141)	568.587 (11.460)	576.417 (13.378)	568.648 (11.620)	599.296 (14.076)	*Session* F (2,772) = 7.124,
RT 2	Fast	531.413 (16.566)	546.875 (17.427)	525.913 (19.085)	551.775 (20.373)	549.313 (21.476)	p=0.001 *Fibre X Session*
	<3g	499.722 (11.410)	531.905 (11.660)	529.418 (13.097)	542.854 (14.437)	540.203 (15.217)	F (2,772) = 9.546, p<0.001
	3.01-6.5g	499.991 (9.457)	522.109 (9.664)	527.109 (10.855)	548.278 (11.965)	545.913 (12.612)	*Minute* F (4,1544) =
RT 3	Fast	504.850 (15.216)	527.213 (16.753)	529.038 (19.764)	571.325 (21.556)	554.525 (20.735)	11.003, p<0.001 *Fibre X Minute*
	<3g	513.108 (10.366)	524.424 (11.440)	552.348 (13.505)	538.468 (15.136)	554.063 (14.557)	F (4,1544) = 0.365, p=0.883
	3.01-6.5g	515.765 (8.592)	521.657 (9.482)	521.091 (11.193)	545.713 (12.546)	531.587 (12.066)	*Session X Minute* F (8,3088) = 1.068 p=0.383 *Fibre X Session X Minute* F (8,3088) = 0.646, p=0.740

Table 7.64: Summary table for Correct responses on the RIPT for Energy Intake groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Corr 1	Fast	4.638 (0.213)	4.013 (0.209)	3.125 (0.199)	3.363 (0.203)	2.713 (0.182)	*Energy Intake* F (2,385) = 0.148,
	101-200kcal	4.799 (0.165)	4.276 (0.162)	3.664 (0.154)	3.925 (0.157)	2.925 (0.144)	p=0.863
	201-300kcal	4.676 (0.141)	4.211 (0.138)	3.514 (0.131)	3.832 (0.134)	2.892 (0.122)	*Session* F (2,770) =
	301kcal +	4.594 (0.231)	4.072 (0.226)	3.768 (0.214)	3.667 (0.219)	3.014 (0.200)	11.227, p<0.001 *EI X Session*
Corr 2	Fast	4.625 (0.227)	4.200 (0.212)	3.475 (0.208)	3.988 (0.217)	2.975 (0.183)	F (4,770) = 2.637, p<0.05
	101-200kcal	4.769 (0.179)	4.403 (0.164)	3.784 (0.164)	4.246 (0.171)	2.963 (0.144)	*Minute* F (4,1540) =
	201-300kcal	4.973 (0.153)	4.573 (0.140)	3.919 (0.140)	4.216 (0.146)	3.227 (0.123)	185.885, p<0.001 *EI X Minute*
	301kcal +	4.678 (0.250)	4.377 (0.229)	3.870 (0.228)	3.884 (0.238)	3.159 (0.201)	F (8,1540) = 1.138, p=0.334
Corr 3	Fast	4.450 (0.226)	4.025 (0.207)	3.575 (0.221)	3.950 (0.217)	2.600 (0.176)	*Session X Minute* F (8,3080) =
	101-200kcal	4.701 (0.176)	4.493 (0.159)	3.642 (0.170)	4.405 (0.168)	2.881 (0.139)	0.801, p=0.602 *EI X Session X*
	201-300kcal	4.908 (0.150)	4.368 (0.135)	3.924 (0.145)	4.281 (0.143)	3.195 (0.119)	*Minute* F (16,3080) =
	301kcal +	4.812 (0.245)	4.623 (0.211)	4.304 (0.237)	4.232 (0.234)	3087 (0.194)	0.611, p=0.887

Table 7.65: Summary table for Wrong responses on the RIPT for Energy Intake groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
Wrg 1	Fast	3.575 (0.420)	2.763 (0.395)	3.175 (0.413)	2.925 (0.402)	2.913 (0.403)	*Energy Intake* $F (2,385) = 3.045$,
	101-200kcal	2.963 (0.315)	2.485 (0.302)	2.515 (0.308)	2.560 (0.317)	2.284 (0.313)	$p<0.05$
	201-300kcal	3.297 (0.268)	3.022 (0.257)	2.805 (0.262)	3.016 (0.270)	2.962 (0.266)	*Session* $F (2,770) =$
	301kcal +	4.275 (0.439)	3.507 (0.421)	3.855 (0.429)	4.043 (0.442)	3.290 (0.436)	15.752, $p<0.001$ *EI X Session*
Wrg 2	Fast	2.738 (0.377)	2.188 (0.400)	2.575 (0.399)	2.763 (0.411)	3.275 (0.431)	$F (4,770) = 2.736$, $p<0.05$
	101-200kcal	2.306 (0.299)	2.179 (0.315)	2.030 (0.317)	1.993 (0.319)	2.104 (0.334)	*Minute* $F (4,1540) =$
	201-300kcal	2.524 (0.254)	2.454 (0.268)	2.697 (0.270)	2.849 (0.271)	2.941 (0.284)	2.703, $p<0.05$ *EI X Minute*
	301kcal +	2.710 (0.416)	3.000 (0.439)	3.159 (0.441)	3.246 (0.444)	3.246 (0.466)	$F (8,1540) =$ 1.765, $p=0.080$
Wrg 3	Fast	2.288 (0.389)	2.450 (0.407)	2.650 (0.404)	2.750 (0.406)	3.000 (0.474)	*Session X Minute* $F (8,3080) =$
	101-200kcal	1.955 (0.312)	1.761 (0.318)	1.866 (0.310)	2.119 (0.320)	2.358 (0.366)	5.873, $p<0.001$ *EI X Session X*
	201-300kcal	2.481 (0.265)	2.865 (0.270)	2.865 (0.264)	2.843 (0.272)	3.595 (0.311)	*Minute* $F (16,3080) =$
	301kcal +	2.739 (0.435)	2.391 (0.443)	3.000 (0.432)	3.087 (0.446)	3.333 (0.510)	0.764, $p=0.729$

Table 7.66: Summary table for Reaction Times on the RIPT for Energy Intake groupings (+/- s.e.m)

		Min 1	Min 2	Min 3	Min 4	Min 5	RESULT
RT 1	Fast	520.750 (18.249)	518.588 (19.318)	554.188 (22.436)	526.538 (20.372)	521.913 (23.833)	*Energy Intake* F (2,385) =
	101-200kcal	511.716 (14.621)	550.679 (15.123)	550.776 (17.515)	538.299 (15.332)	562.590 (18.516)	1.784 4.393, p<0.05
	201-300kcal	516.114 (12.443)	544.119 (12.871)	549.184 (14.907)	559.984 (13.048)	585.676 (15.758)	*Session*
	301kcal +	534.667 (20.375)	570.377 (21.075)	609.754 (24.409)	551.710 (21.366)	604.377 (25.803)	F (2,770) = 8.908, p<0.001
RT 2	Fast	531.413 (16.566)	546.875 (17.427)	525.913 (19.085)	551.775 (20.373)	549.313 (21.476)	*EI X Session* F (4,770) =
	101-200kcal	492.388 (12.337)	502.687 (12.545)	542.313 (14.212)	528.284 (15.628)	548.784 (16.543)	0.524, p=0.718 *Minute*
	201-300kcal	493.200 (10.500)	528.389 (10.677)	519.924 (12.096)	546.935 (13.300)	541.265 (14.079)	F (4,1540) = 8.800, p<0.001
	301kcal +	532.348 (17.192)	565.420 (17.483)	522.130 (19.806)	578.290 (21.778)	539.725 (23.054)	*EI X Minute* F (8,1540) =
RT 3	Fast	504.850 (15.216)	527.213 (16.753)	529.038 (19.764)	571.325 (21.556)	554.525 (20.735)	0.868, p=0.543 *Session X*
	101-200kcal	494.970 (11.151)	507.336 (12.383)	533.313 (14.716)	537.888 (14.458)	496.806 (15.573)	*Minute* F (8,3080) =
	201-300kcal	515.719 (9.490)	525.124 (10.539)	526.189 (12.524)	545.276 (14.007)	554.103 (13.253)	1.601, p=0.119 *EI X Session X*
	301kcal +	550.188 (15.540)	546.507 (17.256)	555.261 (20.507)	545.493 (22.935)	590.232 (21.702)	*Minute* F (16,3080) = 1.381, p=0.141

Chapter 8: Further Analysis and Discussion of Mood and Hunger

8.1 MOOD

Consumption of breakfast within each individual experiment significantly enhanced mood when compared to fasting (section 3.4.1; 4.4.1; 5.4.1; 6.4.1). However, the effects observed with mood following the different breakfast meals were often specific to that meal, relationships between the macronutrients and mood were not demonstrated in the different studies (Chapters 3-6)

Following the meta-analysis (section 7.4) the following relationships between macronutrients and mood were observed.

- Consumption of 20.1-35g of carbohydrate was beneficial with respect Total Mood, Agreeability, Composure and Clearheadedness over the morning compared to the other carbohydrate groupings (section 7.4.1; Figures 7.2-7.5).
- Consumption of 50.1g of carbohydrate and above was detrimental with respect to Agreeability and Clearheadedness after 2 hours, despite enhanced Total Mood and Composure in the first 30 minutes (section 7.4.1; Figure 7.2-7.5).

- Consumption of 8.1-12g of protein, compared to consumption of over 12g, was beneficial with respect to Total Mood, Agreeability, Composure and Elation over the morning (section 7.4.2; Figures 7.10, 7.12, 7.13).
- Consumption of over 12g of protein significantly reduced energy over the morning compared to the consumption of less that 12g (section 7.4.2; Figure 7.11)
- Consumption of 16g of fat, when compared to less than 16g, was beneficial with respect to Total Mood and Composure between 0-30 minutes, however significant decreases in Total Mood and Composure were observed over the morning for each fat condition (section 7.4.3; Figure 7.17).
- Consumption of 2.1-5g of fibre, compared to over 5g, was beneficial with respect to Total Mood, Composure and Elation over the morning (section 7.4.5; Figure 7.20).
- Consumption of over 12g of fibre, compared to less than 12g, significantly reduced Energy over the morning (section 7.4.5; Figure 7.21).
- Consumption of over 101kcal resulted in significant changes over time with respect to ratings of Agreeability, Clearheadedness and Total Mood; larger intakes were detrimental after 2 hours (section 7.4.6; Figure 7.24).

The finding that the consumption of breakfast, as opposed to fasting, is beneficial with respect to aspects of mood has been demonstrated previously (Benton et al., 2001b; Kissileff et al., 2000; Holt et al., 1999; Smith et al 1999; 1994a; Lloyd et al., 1996; section 1.8.3). However there are inconsistencies between the studies with respect to the influence of breakfast on mood. Smith et al., (1994a) reported that a cooked breakfast of eggs and bacon, compared to cereal and toast or no breakfast, increased sociability and contentedness. However, Holt et al., (1999) demonstrated that a high fibre breakfast increased alertness when compared to a cooked, continental, or cereal breakfast. The most extensive study analysed the effects of eight breakfasts differing in the Glycaemic Index (GI) of the food, each giving 50g of available carbohydrate (Benton et al., 2001b). The authors reported that the consumption of breakfast, irrespective of its macronutrient nature, was associated with improved mood.

8.1.1 EFFECT OF CARBOHYDRATE

In the present studies the consumption of different amounts of carbohydrate was found to significantly influence mood over the morning. Participants who consumed 50.1g and above reported a substantial decline in Clearheadedness over the morning compared to other groupings, despite having comparable mood at the start of testing (Figure 7.2). Participants who consumed 50.1g and above tended to report better Total mood immediately following breakfast compared to those who consumed less than 20g ($p=0.09$) or 35.1-50g ($p=0.07$), however, a rapid decline in mood followed (Figure 7.3). Carbohydrate consumption significantly influenced ratings of Composure over the morning. Trends were observed for those who consumed 20.1-35g, compared to consumption of less than 20g ($p=0.07$) and between 35.1-50g ($p=0.07$), to be more Composed over the morning (Figure 7.4). Participants who consumed 20.1- 35g of carbohydrate were significantly more Agreeable over the morning than those who consumed over 50.1g ($p=0.01$) (Figure 7.5).

Are the effects observed with 20-35g of carbohydrate a function of the type of carbohydrate consumed, and the resulting Glycaemic Load (GL)? Carbohydrate intake correlated very highly with GL (r (552) = 0.903, p<0.001, Table 8.1), GL is the GI of the food in question, multiplied by the number of grams of carbohydrate of that food, so as carbohydrate in the meal increases, so does the GL. The GL of the meals increased as the amount of carbohydrate consumed increased, therefore, the effects on mood reflect the GL and vice versa.

Table 8.1: Correlations between the Macronutrients

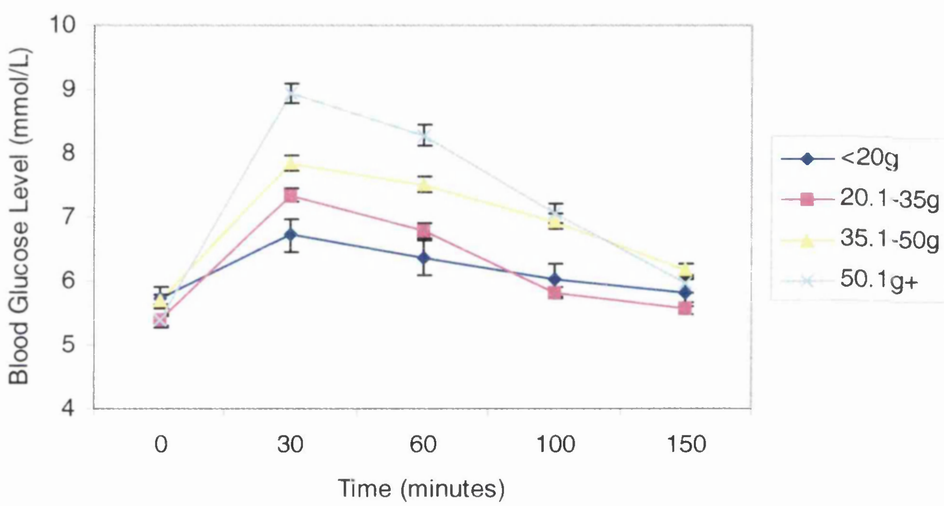
	Carbohydrate	Fat	Protein	Fibre	Caloric Intake	Glucose Load
Carbohydrate	----------------	-----------	-----------	-----------	-----------	-----------
Fat	r = 0.14 **	-----------	-----------	-----------	-----------	-----------
Protein	r = 0.15 **	r = -0.28 ***	-----------	-----------	-----------	-----------
Fibre	r = 0.04 p=n.s.	r = -0.15 **	r = 0.50 ***	-----------	-----------	-----------
Caloric Intake	r = 0.76 ***	r = 0.72 ***	r = 0.11 *	r = 0.02 p=n.s.	-----------	-----------
Glucose Load	r = 0.90 ***	r = 0.26 ***	r = -0.04 p=n.s.	r = -0.22 ***	r = 0.73 ***	-----------

*** p<0.001; ** p=0.001; * p<0.05

8.1.2 EFFECT OF BLOOD GLUCOSE LEVELS

If GL is not an important factor, are the observed effects with mood a function of blood glucose levels? It is clear that the larger the amount of carbohydrate consumed, the greater the increase in blood glucose levels (Figure 8.1).

Figure 8.1: Mean Blood Glucose Levels over time for the Carbohydrate groupings (means +/- s.e.m.)



Correlations (Pearson's r) and Stepwise Regression equations were performed on the data set, with blood glucose levels at each time point, and change in blood glucose levels (subtract the former from the latter, e.g. blood glucose levels at 30mins – baseline blood glucose levels) as the independent variables and the dimensions Agreeable/Hostile, Composed/Anxious, Clearheaded/Confused and Total mood as the dependent variables. Rapidly rising blood glucose levels over the first 30 minutes were associated with increased Total mood over the first hour.

Thus consumption of over 50.1g of carbohydrate was beneficial to overall mood in the first hour. No other relationships were observed between blood glucose levels and mood. In addition to concluding that 20.1-35g is the optimal dose with respect to enhanced mood, one can state that the consumption of 50.1g has an overall negative effect on mood later in the morning. Benton et al., (2001a) previously demonstrated that high carbohydrate intake (51g) was beneficial in the short term, however, a subsequent rapid decline ensued after 90 minutes.

In addition, the profile of blood glucose levels following the consumption of 20.1-35g of carbohydrate was much flatter when compared to 50.1g and above. One can suggest that the relative stability in blood glucose levels following 20.1-35g may account for the positive effects with mood. Fischer et al., (2001) reported that overall cognitive performance was better following consumption of a pure fat meal compared to a pure carbohydrate or pure protein meal. Marked changes in glucagon and insulin were observed following the carbohydrate and protein, but not the fat meals (Fischer et al., 2001), as glucagon and insulin concentrations are controlled by carbohydrate and protein contents in the diet (Tiedgen and Seitz, 1980). Therefore, consumption of a high quantity of carbohydrate, which in turn liberates glucose and hence a high amount of insulin, could possibly produce metabolic instability resulting in negative mood. The consumption of up to 35g of carbohydrate benefited mood without the negative consequences.

Benton and Owen (1993b) suggested that enhancement of mood may be a function of changes in blood glucose levels. Following a series of experiments, the authors demonstrated that higher blood glucose levels were associated with decreased reported tension 15-30 minutes after consumption of a 50g glucose drink. The subsequent fall associated with the glucose-induced release of insulin (a hypoglycaemic rebound), therefore, may lower mood. Consequently, the time scale over which mood is tested may be an important factor. If mood is measured approximately two-hours following a meal or glucose drink, the positive effects associated with increased blood glucose levels will be missed. When mood has been assessed prior to two-hours, carbohydrate intake has been found to decrease tension (Benton and Owens, 1993b) and increase energy (Benton and Owens, 1993b; Blouin et al., 1991). In addition Gonder-Frederick et al., (1989) have demonstrated with insulin-dependent diabetics that positive moods are associated with high blood glucose levels.

Donohoe and Benton (1999c) and Benton et al., (1982) have demonstrated that individual differences in the ability to control blood glucose levels influence mood; there was a relationship between blood glucose levels and aggression in healthy adults. Previously Virkkunen and colleagues had demonstrated that abnormally high rises in blood glucose levels with subsequent rapid falls, from which participants were slow to recover, were associated with violence and aggression (Virkkunen et al., 1996; 1995; Virkkunen, 1986; 1984; 1982). Similarly, Bolton (1979; 1973) reported associations between low blood glucose levels on a glucose tolerance test and increased violence and aggression in the Quolla Indians. However, one must note that the studies documented above report correlations that are not necessarily causal; low blood glucose levels may not cause violence and aggression. In fact, it may be a function of insulin release associated with increased blood glucose levels, on the levels of brain serotonin (Virkkunen, 1983; Virkkunen et al, 1996).

8.1.3 THE INTERACTION BETWEEN CARBOHYDRATE AND PROTEIN: THE WURTMAN HYPOTHESIS

Can the effects observed with 20.1-35g of carbohydrate be explained by the relationship between carbohydrate and the other macronutrients? Supplementary analysis demonstrated that there was significantly more fat ($p<0.001$) and less protein ($p<0.001$) in the meals associated with 20.1-35g of carbohydrate. However, regression equations performed on the data found no significant relationships between carbohydrate and the other macronutrients in the meals with 20.1-35g carbohydrate.

Wurtman and Wurtman (1995) suggested that some individuals consume high carbohydrate foods for positive psychopharmacological effects, rather than as a response to hunger or for their pleasant taste. The consumption of high carbohydrate food has been demonstrated to increase the uptake of tryptophan into the brain, which stimulates the synthesis and release of serotonin that is involved in mood and appetite regulation (Spring et al., 1987). However, Benton and Donohoe (1999) extensively reviewed the relationship between carbohydrate, protein and mood. In reviewing over 30 studies, the authors concluded that consumption of meals that contain between 2-4% of caloric energy as protein is sufficient to block the increases in plasma tryptophan associated with consumption of high carbohydrate meals. Protein typically accounts for $13 \pm 2\%$ of daily calories; the ratio of carbohydrate to protein within food typically varies from 4/5:1 (Krauchi et al., 1988; De Castro, 1987). Therefore, problems arise with respect to the Wurtman's explanation of the association between the choice of high carbohydrate food as part of the normal diet and enhanced mood.

Further analysis of the data demonstrated that the interaction Percentage of total caloric energy from protein X Time (repeated measure), with Total mood as the dependent variable, was significant [F (18,1683) = 2.35, p=0.001]. SME's demonstrated that between 30 and 60 minutes, participants who consumed 0% calories from protein reported significantly poorer Total Mood compared to those who consumed between 5-10% [F (6,561) = 2.35, p<0.05]. These data suggest that the consumption of an exclusively carbohydrate meal does not enhance mood, but rather suppressed it, again questioning the hypothesis of Wurtman and Wurtman (1995).

As the quantities of protein consumed by those consuming 20.1-35g of carbohydrate ranged between 1.67-14.06g it is unlikely that the observed effects with mood are a function of increased tryptophan uptake. In addition, a lack of chronic protein intake in the diet would decrease the overall tryptophan availability, as tryptophan cannot be synthesised by the human body (Fernstrom and Wurtman, 1972). One must also consider the possibility that humans do not respond in an analogous way to rodents. Grimes et al., (2000) demonstrated that high rather than low levels of protein intake were associated with increased serotonin synthesis, and unlike rodents, there was no acute meal effect, rather differences in the synthesis of serotonin were observed over days and weeks.

8.1.4 CONCLUSIONS WITH CARBOHYDRATE AND MOOD

Thus, one can conclude that consumption of over 50.1g of carbohydrate, although comparable with other carbohydrate doses in the short term (0-60 minutes), is later detrimental with respect to mood. High blood glucose levels over the first 60 minutes were associated with enhanced overall mood, however, significant declines in both mood and blood glucose levels were reported later on in the morning. No other associations were found.

It was suggested that the enhanced mood associated with consumption of 20.1-35g may be associated with metabolic stability, as poorer mood has previously been associated with increased insulin secretion (Virkkunen et al., 1996). No evidence was found to support the Wurtman hypothesis (Wurtman and Wurtman, 1995), as participants who consumed 0% calories from protein, compared to 5-10%, reported significantly poorer mood over the morning.

8.1.5 EFFECT OF OTHER MACRONUTERIENTS

Effect of Protein

Participants who consumed of 8.1-12g of protein were more consistent in their reported ratings of Elation over the morning compared to the other groupings (Figure 7.10). Participants who consumed 0-12g were significantly more Energetic than those who ate over 12.1g (Figure 7.11). Consumption of 8.1-12g, compared to consumption of 0-2g and over 12.1g, significantly enhanced Agreeablity (Figure 7.12) and Composure over the morning. Similarly, participants who consumed 8.1-12g of protein, compared to the consumption of over 12g, reported significantly enhanced Total mood over the morning (Figure 7.13).

Is the consumption of 8.1-12g of protein and its effects on mood a genuine phenomenon, or just an artefact of the amount of other macronutrients within the meal? Protein intake correlated negatively with fat [(r (552) = -0.28, $p<0.001$] and positively with carbohydrate [r (552) = 0.15, $p<0.01$], energy intake [r (552) = 0.11, $p<0.05$] and fibre [r (552) = 0.50, $p<0.001$]. Regression equations using protein and fibre as the only independent variables due to high correlation, with Total Mood and Energy as the dependent variables, found high fibre rather than protein within the meal predicted poorer mood.

Both All Bran and Cornflakes (Kelloggs, Manchester) have high quantities of protein (13g/100g; 8g/100g) as well as high amounts of fibre, therefore the inclusion of the medium-high carbohydrate/medium-high fibre meals from Chapter 3 may have influenced the results found with protein. However, high fibre is associated with poorer mood. Chapter 5 reported a study where protein, fat and carbohydrate were manipulated when the levels of fibre were kept constant (3.2-3.32g). The results demonstrated that high protein breakfasts (approximately 10g) were associated with increased Agreeability, Elation and Total Mood (section 5.4). One must note, however, that the highest amount of protein used within this study (9.91g; low/high carbohydrate high-fat high-protein) fell into the 8.1-12g protein grouping, which was associated with enhanced mood.

Therefore, it can be cautiously suggested that consumption of 8.1-12g of protein can significantly improve mood, however, one must take care to dissociate protein from possible interactions with fibre within the meal.

Effect of Fat

Consumption of 16g of fat, compared to lower doses, improved ratings of Composure and Total Mood over the first 30 minutes (section 7.4.3; Figure 7.17). In addition, consumption of 16g of fat resulted in significantly more calories ($p<0.001$), and more carbohydrate ($p<0.01$) compared to those who ate less than 16g.

Smith et al., (1994a) has similarly found that following consumption of a cooked breakfast of eggs and bacon (estimated value of fat from Nutritional tables – 51g fat), participants reported increased sociability and contentedness.

Although there have been relatively few studies that examined the effects of fat consumed for breakfast, the effects following a high-fat lunches are well documented. Typically the consumption of high-fat compared to high-carbohydrate meals has led to decreased vigour, alertness and increased fatigue beyond 2.5 hours post-consumption (Wells et al., 1997; Wells and Read, 1996; Lloyd et al., 1994). However, one must be careful to dissociate the natural circadian dip from meal effects.

One can suggest, therefore, that consumption of high fat meals are associated with increased contentedness 30 minutes post-consumption, however, these effects are short lived, possibly due to the feeling of fullness and contentedness after a high-fat/high-energy intake.

Effect of Fibre

Participants who consumed 2.1-5g of fibre, compared to the other fibre groupings, reported significantly increased Composure and Total Mood over the first 30 minutes. Consumption of 2.1-5g, compared to over 5.1g, significantly enhanced Elation and Total Mood between 30 and 60 minutes (section 7.4.5, Figure 7.20). Participants who consumed over 12g, compared to consumption of 0-5g, were significantly less Energetic over the morning (section 7.4.5, Figure 7.21).

Stepwise regressions were calculated, that indicated identical associations as reported above. Low fibre consumption was associated with better mood for each aspect. However, why was mood better following consumption of 2.1-5g of fibre? Was it a reflection of the associated macronutrients? Significantly more fat [$F(3,548) = 54.41$, $p<0.001$] .was consumed by those who ate 2.1-5g of fibre compared to the other groupings. Higher quantities of fat have already been shown to significantly enhance mood, especially over the first 30 minutes (Figure 7.17).

Holt et al., (1999) found that consumption of 19.1g of fibre significantly increased alertness compared to a cooked (2.9g fibre), continental (1.5g) or a high-carbohydrate breakfast of Cornflakes (1.0g). However, previous studies have focussed on the effects of fibre on hunger, rather than mood.

It could be suggested that the decrease in subjective energy reported by those who consumed over 12g of fibre could be a function of decreased hunger and increased fullness. It is well documented that consumption of meals can induce increased lassitude, irrespective of macronutrient composition and circadian rhythms (Wells et al., 1998; Smith and Miles, 1986). Regression equations were calculated with the macronutrients and caloric intake as the independent variables, and reported energy as the dependent variables. At each point high fibre predicted decreased energy.

One can suggest that the association of 2.1-5g of fibre with enhanced reported mood over the first hour may have reflected the increased fat consumed within the meal. High fibre intake was associated with decreased energy over the morning.

Effect of Caloric Intake

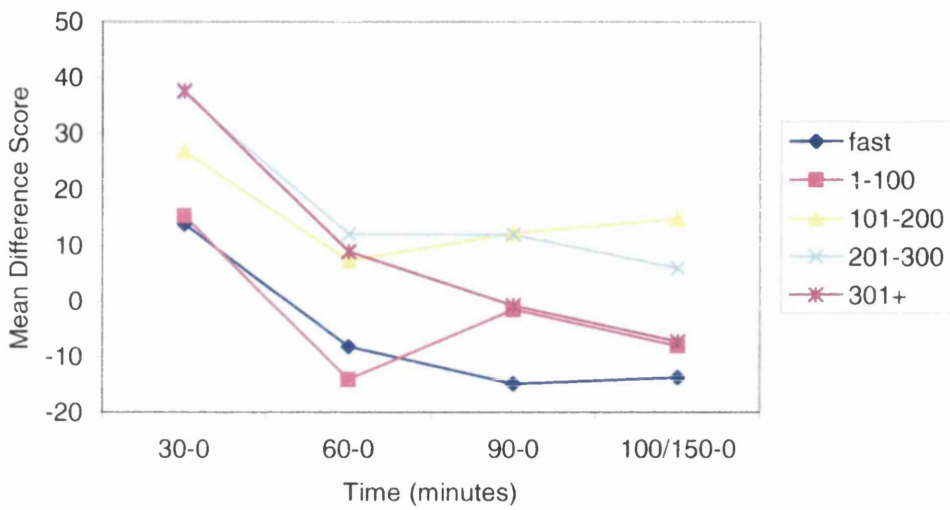
Significant variability over the morning was demonstrated on the dimensions Agreeable/Hostile and Clearheaded/Confused and Total Mood following consumption of over 100 Kcal. Participants who consumed over 301 Kcal reported increased hostility towards the end of the morning, however, there were no significant differences between the caloric groupings at any time point (section 7.4.6; Figure 7.24). A similar pattern was observed with Clearheadedness. Therefore, it can be concluded that the larger the meal, and therefore caloric intake, the greater the decline in mood over time.

Benton et al., (2001a) have similarly demonstrated that consumption of a larger breakfast (253 Kcal) was associated with poorer mood later in the morning, compared to fasting or consumption of a small meal (51 Kcal). Interestingly, Benton et al., (2001a) found that consumption of a 25g Cornflakes snack (127 Kcal) prevented this decline in mood with the large breakfast, however, no effects were observed with the other groups.

Studies reporting the effects of different energy contents on mood have generally failed to demonstrate enhancement of mood following manipulation of energy intake (Kissileff et al., 2001; Michaud et al., 1991; Cromer et al., 1990). Lloyd et al., (1996) demonstrated that macronutrients were more important than energy intake with respect to mood; consumption of a high-carbohydrate (98.7g)/low-fat breakfast (18.4g) significantly improved fatigue/dysphoria compared with equicaloric (600 Kcal) low-carbohydrate (56.2g)/high-fat (38.5g) and medium-carbohydrate/(74.8g) medium-fat (29.3g) breakfasts. In addition, Smith et al., (1994a) reported that participants who consumed a cooked breakfast (bacon, egg, toast, 451 Kcal), compared to an equicaloric cereal/toast breakfast or fasting, were significantly more sociable, interested, contented and outward-going, two-hours after breakfast consumption, although no effect was observed before two-hours. The authors concluded that the effects of mood depended on the nature of the breakfast meal not the energy content consumed.

Using equicaloric meals, however, does not allow the separation of the effects of energy and macronutrient content. It is clear from the experimental manipulations within this thesis that systematically varying the energy content over 100Kcal has little effect with respect to mood. However, as with Benton et al., (2001a) there is a trend for larger meals, when consumed as a breakfast, to be associated with a greater decline in mood later on in the morning.

Figure 8.2: Mean difference scores for each Caloric Intake grouping for Total Mood over time (Difference scores as calculated in 7.3.1)



Is the observed enhancement of mood following breakfast therefore simply a function of eating? Including the participants who fasted into a two-way ANOVA, Kcal grouping (0, 1-100, 101-200, 201-300, 301+) X Time (repeated measure) helped to answer this question (Figure 8.2). SME's demonstrated that participants who consumed 201-300 Kcal reported significantly better Total mood following over the morning compared to those who fasted ($p<0.001$). In addition, consumption of 101-200 and 201-300 Kcal was associated with significantly better mood from 60-150 minutes when compared to the fasting condition ($p<0.05$). Figure 8.2 illustrates that participants who fasted, or consumed over 301 Kcal reported a decline in mood over the morning. Consumption of 101-200 and 201-300Kcal appeared to be optimal with respect to better mood.

8.1.6 CONCLUSIONS OF MACRONUTRIENTS AND MOOD

Consumption of breakfast, as opposed to fasting, significantly enhanced mood over the course of the morning. High carbohydrate breakfasts (50.1g and above) had an overall negative effect over the morning. The present studies found that consumption of up to 35g of carbohydrate can benefit mood without the negative consequences of poorer mood later on in the morning, however, one must take into account the individuals' glucose tolerance.

Consumption of 8.1-12g of protein significantly enhanced mood, however, regression equations failed to demonstrate an association. High fibre intake was associated poorer Total mood and Energy throughout the morning. High fat breakfasts (16.41-16.48g) were associated with increased contentedness over the first 30 minutes. The consumption of 101-300Kcal appeared to be beneficial for enhanced mood. Consumption of 301Kcal and above was associated with poorer mood later on in the morning.

One can suggest, with respect to mood, that light meals when consumed at breakfast were beneficial over the course of the morning, when compared to fasting or large meals. Furthermore, the balance of carbohydrate to the other macronutrients is also an important factor.

8.2 HUNGER

As expected, participants who consumed breakfast were significantly less hungry throughout the morning than those who fasted (section 3.4.1, Figure 3.8; section 4.4.1, Figure 4.4; section 5.4.1, Figure 5.8; section 6.4.1, Figure 6.3). In individual experiments the macronutrient content of the meal had varying effects on hunger (Chapters 3-6). However, following the meta-analysis (section 7.4), relationships between macronutrients and hunger were observed.

- Participants who consumed less than 20g of carbohydrate were the hungriest, with those who consumed 35.1-50g reporting the least hunger (section 7.4.2, Figure 7.6). Interestingly, no difference in hunger was observed between those who consumed 20.1-35g and over 50.1g and above.
- Consumption of over 12g of protein, compared to less than 8.1g, significantly reduced hunger ratings (section 7.4.3, Figure 7.14).
- Consumption of 16g of fat, compared to less that 2.5g, significantly reduced hunger (section 7.4.4, Figure 7.18).
- Consumption of over 12g of fibre, compared to 2.1-7g, significantly reduced hunger (section 7.4.5).
- Consumption of any meal over 100kcal significantly reduced hunger ratings compared to less than the consumption of 100kcal (section 7.4.6, Figure 7.25.).

It is clear from the summary that the larger the meal, both in size and energy content, the greater the reduction in hunger.

8.2.1 EFFECT OF CARBOHYDRATE

It is of interest that participants who consumed 35.1-50g of carbohydrate reported the greatest reduction in hunger ratings. One possibility why an intermediate level of carbohydrate was most effective may be a function of Glycaemic Load (GL). As the carbohydrate content of the food increased, so did the GL [r (552) = 0.90, $p<0.001$]. The GL of those consuming 35.1-50g was less than those consuming over 50.1g of carbohydrate. Thus the decreased hunger was not a reflection of the GL of the meal.

Is it the amount of carbohydrate, therefore, that is important with respect to hunger, rather than the associated macronutrients within the meal. Chapter 2 reported the effects of sucrose consumption over two and a half hours. Consumption of over 50g of sucrose significantly reduced hunger ratings compared to those who consumed 30g or less, with carbohydrate intake and hunger following a positive linear relationship. The present finding of 35.1-50g of carbohydrate reducing hunger more than higher amounts suggests an interaction with other macronutrients.

Table 8.2 illustrates that there are different quantities of fat, protein and fibre within the meals that fall into the four carbohydrate groupings. Supplementary analysis of the data set found that there is significantly less fat [$F(3,548) = 36.11$, $p<0.001$] and more protein [$F(3,548) = 27.95$, $p<0.001$] in the meals that contained 35.1-50g of carbohydrate, compared to those with 20.1-35g or over 50.1g of carbohydrate ($p<0.001$).

Table 8.2: Mean amounts of Fat, Protein, Fibre (grams) and Kilocalories for each Carbohydrate grouping (means +/-s.e.m.)

Carbohydrate	Fat	Protein	Fibre	Kcal	GL
Less than 20g	0.66 (0.05)	5.36 (0.12)	3.90 (0.38)	86.48 (0.73)	565.32 (45.78)
20.1-35g	6.66 (0.40)	6.41 (0.25)	3.52 (0.21)	199.34 (3.37)	1675.09 (36.25)
35.1-50g	2.31 (0.28)	9.17 (0.17)	3.34 (0.29)	222.11 (3.45)	2487.52 (35.29)
50g and above	7.51 (0.71)	6.98 (0.41)	3.78 (0.10)	313.37 (6.36)	4785.74 (76.64)

Regression equations were used to explore the association between protein, carbohydrate and hunger. Stepwise linear regressions were performed, with the macronutrients, fibre and Kcal entered as independent variables, and hunger as the dependent variable. At each point hunger was predicted by the amount of protein and carbohydrate within the meal, high amounts of protein and carbohydrate were associated with decreased hunger. It is credible, therefore, that the interaction between the macronutrients can explain the effects observed with 35.1-50g of carbohydrate and its effects on hunger. In those who consumed 35.1-50g of carbohydrate consumption of a large quantity of protein helped to reduce hunger.

8.2.2 EFFECT OF BLOOD GLUCOSE LEVELS

A related question is whether the reduced hunger ratings were due to blood glucose levels? Regression equations were calculated, with blood glucose levels and changes in blood glucose levels as independent variables, and the difference scores for hunger as the dependent variables. In those participants who consumed breakfast, high blood glucose levels at 30 minutes were associated with decreased hunger over the first 30 minutes [$R^2 = 0.01$, $F(1,550) = 4.27$, $p<0.05$]. In addition, high blood glucose levels at 120/150 minutes predicted decreased hunger between 90/100 to 120/150 minutes [$R^2 = 0.01$, $F(1,550) = 5.50$, $p<0.05$].

At 30 minutes participants who consumed 50.1g and above of carbohydrate had significantly higher blood glucose levels compared to the other groupings [$F(3,548) = 30.576$, $p<0.001$], yet these participants were still hungrier following breakfast compared to those who consumed 35.1-50g of carbohydrate ($p<0.05$)[$F(3,548)= 8.62$, $p<0.001$]. At 120/150 minutes participants who consumed 35.1-50g had significantly higher blood glucose levels compared to the consumption of 20.1-35g carbohydrate ($p<0.001$). Changes in blood glucose levels over time failed to predict hunger at any point.

Hence, high blood glucose levels at 30 minutes and at the end of the study were associated with decreased hunger, however consumption of 50.1g and above resulted in the highest blood glucose levels, not 35.1-50g of carbohydrate of carbohydrate. Therefore, the effect of carbohydrate on hunger does not appear to reflect changes in blood glucose levels.

8.2.3 EFFECTS OF OTHER MACRONUTRIENTS

Effects of Protein

Consumption of over 12.g of protein compared to less than 8.01g, significantly reduced hunger over the morning. Section 8.2.1 demonstrated that high amounts of protein coupled with high amounts of carbohydrate, predicted less hunger throughout the morning.

Foods high in protein have been found consistently to sustain the feeling of fullness, and reduce subsequent food intake, when compared to foods high in sucrose or fat (Rolls et al., 1988; Hill and Blundell, 1986). In addition, Marmonier et al., (2000), and Poppitt et al., (1998), have demonstrated that the consumption of protein rich meals (40g and 67.6g respectively) significantly reduced subsequent energy intake. However, the type and form of the protein has different effects on subsequent hunger. Holt et al., (1995) demonstrated that Ling fish fillets (56.3g) significantly reduced hunger when compared to isoenergetic (240Kcal) amounts of lentils (19.4g) and steak (42.0g). Uhe et al., (1992) also reported that white fish reduced hunger more than equivalent amounts of lean chicken or beef.

Studies specifically examining the effects of protein when consumed as a breakfast have reported significant reductions in hunger ratings compared to pure macronutrients, or fat-rich or carbohydrate-rich equivalent meals. Fischer et al., (2001) demonstrated that 105.2g of protein consumed as a spoonable cream significantly reduced hunger when compared to the same amounts of carbohydrate or fat. Stubbs et al., (1996) reported significant reductions in hunger following the consumption of a high protein breakfast (182.94g) consisting of steak, potatoes, sweetcorn, mushrooms and gravy with a fruit and yoghurtbased dessert. However the foods consumed in these studies are not what most would identify as a breakfast meal. In addition, the amounts of protein used in previous studies are substantially larger than those consumed within this thesis (1.67-14.06g of protein). However, within the present range protein was still found to effect hunger.

In conclusion, the consumption of larger amounts of protein reduced hunger over the morning.

Effects of Fat

Consumption of 16g of fat within a breakfast was found to significantly reduce hunger ratings compared to consumption of 0-2.5g ($p<0.05$)(section 7.4.4, Figure 7.18). Significantly more carbohydrate [$F(2,549) = 6.24$, $p<0.01$] and calories [$F(2,549) = 249.34$, $p<0.001$] were consumed by those who ate 16g of fat compared to lower intakes. Participants who consumed 0-2.5g of fat consumed significantly more protein compared to those who ate higher amounts [$F(2,549) = 43.60$, $p<0.001$].

However, foods high in fat content have previously been shown to have little effect on hunger ratings when compared to carbohydrate and protein rich meals (Fischer et al., 2001; Holt et al., 1999; Stubbs et al., 1996). There is, however, great variation between studies in the amount of fat consumed, Fischer et al., (2001) used 61.5g of fat, whereas Holt et al., (1999) used approximately 28g. Subjects generally reported less fullness after a high fat breakfast (Holt et al., 1999), compared to an equicaloric (486Kcal) carbohydrate meal. However, fat is energy dense, therefore a larger quantity of carbohydrate must be consumed, compared to fat, to obtain the same caloric intake. The larger the energy content of food consumed the greater the reduction in hunger.

Hence it can be suggested that the large intake of fat, coupled with increased carbohydrate consumption may be a determining factor of the decreased hunger observed by those who consumed 16g of fat.

Effects of Fibre

Participants who consumed over 12g of fibre were significantly less hungry over the morning compared to those consuming 0-7g. In constructing the composition of the meals within this thesis, it was difficult to find foods high in natural fibre. However, participants consumed no more than the recommended portion size of fibre as stated by the manufacturers, approximately 13g, which was sufficient to decrease reported hunger (see section 7.4.5). Consumption of a greater quantity of fibre could have resulted in discomfort and possible digestion problems, which in turn could lead to disruption of mood and cognitive functioning.

The manipulation of fibre and carbohydrate in Chapter 3 was the first study to systematically vary the amount of fibre consumed as a breakfast meal. Varying the fibre given, between 1.5g to 13g, failed to influence hunger ([$F(2,107) = 1.307$, $p=0.28$] (section 4.4.1), however, following the meta-analysis, consumption of 13g was found to significantly reduced hunger. Previously Holt et al., (1999) demonstrated that a high-fibre/carbohydrate-rich meal (19.1g fibre) was significantly more satiating than either a low-fibre/high-carbohydrate (1g fibre) breakfast or high-fat meals (1.5-2.9g fibre), however, substantially more fibre was consumed compared to the present studies.

Fibre supplementation (Delargy et al., 1997; 1995; Stevens et al., 1987; Porikos and Hagamen, 1986) as well as consumption of foods high in natural fibre (Holt et al., 1999; Levine et al., 1989) has previously been shown to reduce hunger ratings and subsequent food intake. It is suggested that reduced hunger is a function of the slower rate of carbohydrate ingestion and absorption that is associated with increased fibre intake (Holt et al., 1996). Supplementation studies have typically given 20-30g of fibre. Studies using foods high in natural fibre have also given large quantities; Holt et al., (1999) gave 19.1g of fibre as 74g of All-Bran, and Levine et al., (1989) 22.2g as 57g of Fiber One. In both instances consumption of these meals can be regarded as an unnaturally high intake of fibre. Intakes of such levels are highly unlikely to be consumed in a naturalistic setting. A feature of the present studies is to address the importance of fibre over a range usually consumed.

The consumption of over 12g of fibre, compared to lower doses, significantly reduced hunger ratings over the morning. It can be suggested that the slower carbohydrate ingestion and absorption associated with increased fibre intake may be responsible for the decreased hunger observed.

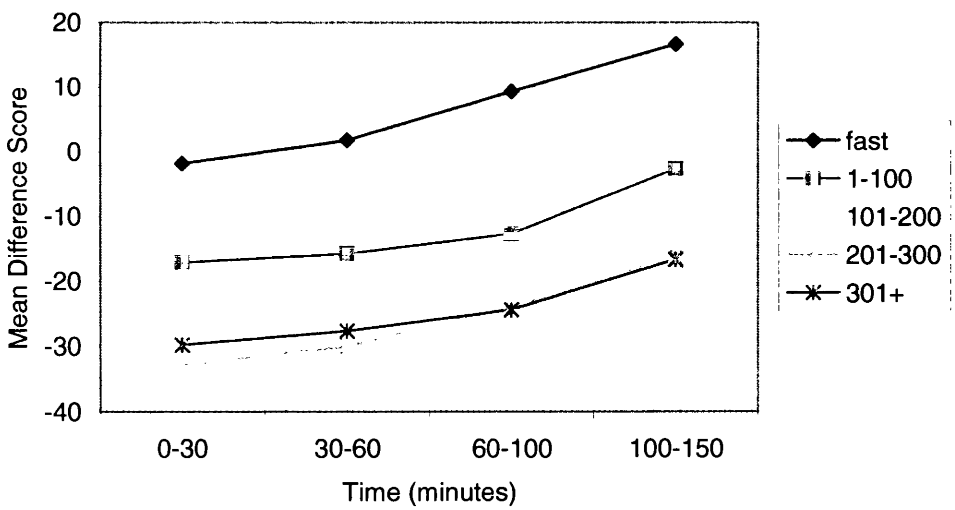
Effect of Caloric Intake

Participants who consumed over 100Kcal, compared to those who consumed less than 100Kcal, reported significantly reduced hunger (section 7.4.6; Figure 7.25). No significant differences between hunger ratings for 101-200Kcal, 201-300Kcal and over 301Kcal were reported. From dietary recall data, it was found that a typical breakfast (in many cases cereal and toast, with tea/coffee) resulted in a habitual energy intake of 347.2 Kcal (see section 6.4.4) compared with the average amount of energy received from the test meals of 222.7 Kcal. The participants, therefore, were consuming less than they would normally. However, the results showed no differences in the hunger response after consumption of 100 Kcal. Thus it can be suggested that the present findings are likely to generalise to normal meals.

Previously, studies have kept energy intake constant, typically 400 Kcal, when determining the effects of different macronutrients consumed as a breakfast meal (Fischer et al., 2002; 2001; Holt et al., 1999). This has resulted in unusually large quantities of food being eaten. To match the fat, large amounts of carbohydrate have to be consumed to receive 400 Kcal. For example Holt et al., (1999) had participants consume 74g All Bran with 250ml milk with a banana (66g weight) and toast (30g) with margarine (5g) to receive 486 Kcal, compared to 2 croissants (98g) with margarine (10g) and jam (27g). The present results suggest that rather than the energy content of the meal, the macronutrient composition of the meal is the important factor with respect to hunger.

Are the effects observed with hunger, therefore, a function of the act of eating, or the macronutrient content of the meal? Inclusion of the participants who fasted into a two-way ANOVA, Kcal grouping (0, 1-100, 101-200, 201-300, 301+) X Time (repeated measure) helped to answer this question (Figure 8.3). Participants who fasted were significantly hungrier than those who consumed a small breakfast (between 1-100 Kcal, $p<0.001$), who were significantly hungrier than those who consumed over 101 Kcal ($p<0.05$). Taken together with the macronutrient data, it can be argued that macronutrient intake, and the proportion of carbohydrate to fat and protein is more important than energy consumed.

Figure 8.3: Mean difference scores for each Caloric Intake grouping with respect to Hunger over time (Difference scores as calculated in 7.3.1)



8.2.4 CONCLUSIONS OF MACRONUTRIENTS AND HUNGER

The consumption of breakfast significantly reduced hunger when compared to fasting. In addition, the consumption of 35.1-50g of carbohydrate resulted in the largest reduction in hunger ratings. Participants who consumed 35.1-50g of carbohydrate demonstrated more stable blood glucose levels over the morning, with higher blood glucose levels at 120/150 minutes compared to the other groupings.

It was demonstrated that those who ate 35.1-50g of carbohydrate consumed significantly more protein and less fat. Regression equations confirmed that decreased reported hunger was associated with larger quantities of protein and carbohydrate being consumed within the meal. Furthermore, high intakes of fat, fibre and calories significantly decreased hunger ratings compared to the consumption of lower amounts.

It was concluded that macronutrient composition, in particular the association between carbohydrate and protein, was important in reducing hunger.

Chapter 9: Further Analysis and Discussion of Cognitive Tests

9.1 MEMORY

The experimental manipulations of sucrose (Chapter 2), and various amounts of carbohydrate and fibre (Chapter 3), failed to have substantial effects on memory. In addition the consumption of breakfast generally failed to influence measures of memory when compared to fasting (Chapters 2-7).

However, following the meta-analysis of comparable data (Chapters 5 and 6; section 7.4) the following relationships between macronutrients, fibre and caloric intake, and measures of memory were observed.

- Consumption of breakfast failed to influence the number of words recalled, however, participants who ate took significantly longer to recall the lists at 40 and 80 minutes ($p<0.05$) than those who fasted (section 7.4.1).
- The amount of carbohydrate consumed failed to influence the number of words recalled. Participants who consumed 35.1-50g of carbohydrate, compared to either 20.1-35g or 50.1g and above ($p<0.001$), took significantly less time to recall the word lists (section 7.4.2; Figure 7.8).

- Protein consumed failed to influence the number of words recalled, however, participants who consumed of 6.01-8g of protein, compared to either 0-2g or 8.1-10g ($p<0.01$), took significantly less time to recall the word lists (section 7.4.3; Figure 7.15).
- Participants who consumed 0-2g of fat, compared to consumption of over 11g ($p<0.05$), recalled significantly more words at 40 minutes (section 7.4.4). In addition, consumption of 0-2g, compared to over 11g ($p<0.05$), resulted in significantly more time being taken to recall the delayed word lists (section 7.4.4).
- Fibre consumed failed to influence the number of words recalled, however, participants who consumed 2.01-4g of fibre, compared to the other groupings, took significantly longer to recall the word lists over the morning ($p<0.001$) (section 7.4.5; Figure 7.22).
- Memory failed to be influenced by energy intake.

9.1.1 EFFECT OF CARBOHYDRATE

Within the meta-analysis, the amount of carbohydrate consumed failed to influence the number of words recalled, however, significant decreases over time were observed for each of the carbohydrate groupings (section 7.4.2, Figure 7.7).

Consumption of 35.1-50g of carbohydrate, rather than either 20.1-35g or 50.1g and above ($p<0.001$), resulted in significantly less time being taken to recall the word lists. Further analysis of the data revealed that there was significantly less fat [$F(2,327) = 38.02$,

$p<0.001$], fibre [$F(2,327) = 23.76$, $p<0.001$] and more protein [$F(2,327) = 25.45$, $p<0.001$] in the meals that fell into the 35.1-50g carbohydrate grouping.

A subsequent question is whether the effects observed with memory were a function of the amount of carbohydrate consumed, or a correlate of another macronutrient? Bivariate correlations (Pearson's R) show that carbohydrate correlated positively and highly with G-load [$r(330) = 0.94$, $p<0.001$] and caloric intake [$r(330) = 0.67$, $p<0.001$]. In addition, G-load and Caloric intake also correlated positively with each other [$r(330) = 0.69$, $p<0.001$]. Hence, the more carbohydrate that was consumed the greater the G-load and caloric intake.

However, one must take into consideration that the relationship between carbohydrate and memory was not linear; consumption of 35.1-50g of carbohydrate resulted in significantly quicker recall times. Therefore, stepwise regression equations were performed on the data set, for each individual carbohydrate grouping, with the remaining macronutrients, fibre and caloric intake as the independent variables, and measures of memory as the dependent variables.

Following consumption of 20.1-35g of carbohydrate, high fibre intake was associated with increased word recall at 80 and 125 minutes, with high fat and energy intake being associated with quicker recall times throughout the morning. In those who consumed 35.1-50g of carbohydrate, high fat intake was associated with quicker recall times at 40 minutes. In those who consumed over 50.1g of carbohydrate, high fibre intake was associated with associated with increased delayed word recall at 40 minutes, and high fat and energy intake were associated with quicker recall times at 80 minutes.

Further analysis demonstrated that when caloric intake was negatively associated with memory, it was a function of the percentage of carbohydrate consumed as calories; the greater the percentage of calories consumed as carbohydrate the better the memory, expressed as increased time being taken to recall the word lists.

It can be concluded that, in general, consumption of higher quantities of fibre were associated with the recall of an increased number of words. The higher the intake of carbohydrate expressed as a percentage of caloric intake (Kcals), the greater the time spent trying to recall the word lists. Consumption of 35.1-50g of carbohydrate was associated with lower fibre intake and poorer memory performance. Furthermore, high fat intake was detrimental to memory.

9.1.2 EFFECTS OF BLOOD GLUCOSE LEVELS

Were the effects observed with memory a function of changes in blood glucose levels? Bivariate correlations (Pearson'r R) and stepwise regressions were performed, with blood glucose levels, and changes in blood glucose levels as the independent variables, and immediate and delayed recall and recall times as the dependent variables.

Low blood glucose levels at 150 minutes were associated with increased word recall at 40 minutes, for both immediate [$R^2 = 0.01$, $F (1,328) = 5.51$, $p<0.05$] and delayed recall [$R^2 =$

0.02, F (1,328) = 7.01, $p<0.01$]. Low blood glucose levels at 60 minutes tended to be associated with increased word recall at 80 minutes for both immediate [r (330) = -0.105, p=0.06] and delayed recall [R^2 = 0.01, F (1,328) = 4.42, $p<0.05$]. Low blood glucose levels at 30 minutes were associated with increased word recall at 125 minutes for both immediate [R^2 = 0.01, F (1,328) = 5.76, $p<0.05$] and delayed recall [R^2 = 0.01, F (1,328) = 3.96, $p<0.05$].

With respect to the time taken to recall the word lists, low blood glucose levels at 150 minutes, and falling levels between 60-90/100 minutes, were associated with increased immediate recall times at 40 minutes [R^2 = 0.03, F (2,327) = 6.85, p=0.001]. With delayed recall times at 40 minutes, low levels at 150 minutes and stable levels (limited rises or falls) between 90/100-150 minutes were associated with increased recall times [R^2 = 0.08, F (2,327) = 14.60, $p<0.001$]. Low blood glucose levels at 150 minutes were associated with increased immediate recall times at 80 minutes [R^2 = 0.05, F (1,328) = 19.02, $p<0.001$], with the addition of falling blood glucose levels between 60-90/100 minutes predicting increased delayed recall times at 80 minutes [R^2 = 0.05, F (2,327) = 10.42, $p<0.001$]. Again low blood glucose levels at 90/100 and 150 minutes were associated with increased immediate recall times at 125 minutes [R^2 = 0.06, F (2,327) = 11.12, $p<0.001$], with low blood glucose levels at 90/100 minutes predicting increased delayed recall time [R^2 = 0.03, F (1,328) = 11.98, p=0.001].

One could suggest, therefore, that low blood glucose levels throughout the morning were associated with increased word recall. Furthermore, low blood glucose levels towards the end of the morning were associated with increased recall times throughout the morning representing enhanced memory. These findings lend a possible explanation for the effects observed following consumption of 35.1-50g, in that blood glucose levels failed to fall as rapidly, or to such a low level, towards the end of the study (Figure 8.1, section 8.1.2), and this was associated with quicker recall times.

A subsequent question was asked. Were the low blood glucose levels associated with enhanced memory a function of the rate of fall in blood glucose levels following the consumption of the meal, rather than a reflection of a failure of blood glucose levels to rise following carbohydrate ingestion? The fact that lower blood glucose levels early on in the morning were associated with enhanced performance on memory tests later on in the morning (previous page), suggested that the consumption of meals that elicit a low glycaemic response may benefit memory.

9.1.3 TYPE OF CARBOHYDRATE

Rather than the amount, can the type of carbohydrate significantly influence the number of words recalled from the lists? Chapter 7 specifically examined this question and found that:

- Participants who consumed the Slowly Available Glucose (SAG) breakfast recalled significantly more total and concrete words at 160 minutes ($p<0.05$) and 220 minutes ($p<0.01$) compared to the Rapidly Available Glucose (RAG) meal (section 6.4.1; Figure 6.4).

- Furthermore, consumption of SAG, compared to RAG, significantly increased the recall of the more difficult abstract words over the morning ($p<0.05$) (section 6.4.1; Figure 6.5).
- Similarly, participants who consumed the SAG meal, rather than RAG, took significantly longer to recall the word lists ($p<0.05$) (section 6.4.1; Figure 6.6).

Consumption of SAG, with a low GI (42; GL 1365.25) compared to RAG (GI 66; GL 2637.18), significantly increased the number of words recalled, and the time taken to recall the word lists, despite both groups consuming similar amounts of carbohydrate. The beneficial effects of a low GI carbohydrate on memory have previously been demonstrated using a healthy elderly adult sample. Kaplan et al., (2000) reported that memory was significantly enhanced following consumption of a low GI carbohydrate, barley (GI = 25), rather than high GI carbohydrates, glucose (GI = 100) and instant mashed potato (GI = 83), with 50g of carbohydrate available from each meal. Hence, it can be suggested that the glycaemic nature of the carbohydrate has a significant beneficial effect on memory.

In participants who consumed the RAG breakfast, rising blood glucose levels over the first hour were associated with increased word recall on the first two tests, while falling blood glucose levels between 150-210 minutes predicted increased word recall on the second and third tests. Although memory performance following the RAG breakfast was significantly poorer compared to the SAG meal, the ability to effectively utilise the glucose load, that is good glucose tolerance, was associated with better memory. In those who consumed the SAG breakfast, stable blood glucose levels between 60-90 minutes, which were distinguished as rising or slowly falling levels, predicted better memory throughout the morning.

Kaplan et al., (2000) similarly demonstrated improvements in memory following the consumption of 3 different kinds of dietary carbohydrates (glucose, instant mashed potato and barley – 50g available carbohydrate) when compared to a placebo in an elderly sample. Effects were independent of changes in blood glucose levels, and memory improvement was strongest following the consumption of the low GI barley meal. Likewise, Chapter 7 demonstrated that consumption of the low G-load SAG meal significantly enhanced the number of words recalled.

9.1.4 CONCLUSIONS WITH CARBOHYDRATE AND MEMORY

In can be concluded that consumption of carbohydrates that maintain low blood glucose levels throughout the morning significantly improved memory. It is was not the amount of carbohydrate that appeared to be beneficial. Rather the type of carbohydrate consumed, i.e. SAG as opposed to RAG, and how the carbohydrate consumed interacted with individual differences in the ability to regulate blood glucose levels (glucose tolerance) was critical.

Consumption of 35.1-50g of carbohydrate resulted in the less time being taken recalling the word lists, however no significant differences were observed in the number of words recalled. The result could be explained by one of two theories. Firstly, consumption of 35.1-50g of carbohydrate may result in greater efficiency, that is participants recorded the same number of words but more quickly. Alternatively participants who consumed 20.1-

35g and over 50.1 of carbohydrate may be more motivated, demonstrated by the increased recall times. Benton et al., (2001a) similarly reported increased recall times following breakfast that they explained as a reflection of increased motivation and therefore better memory. This explanation will be discussed in greater detail following analysis of macronutrients and memory.

Raising blood glucose levels, through the consumption of a glucose drink, has been demonstrated to enhance memory in rodents, healthy young and aged adults (section 1.3). Similar to the present conclusions, Manning et al., (1990) and Hall et al., (1989) have suggested that cognitive function is dependent on the control of blood glucose levels.

Poor glucose tolerance, where blood glucose levels remain higher over time, have been associated with poor cognitive performance in aged rodents (Korol and Gold, 1998; Stone et al., 1990), the healthy elderly (Manning et al, 1990; Hall et al., 1989; Gonder-Frederick et al., 1987), patients with Alzheimer's disease (Craft et al., 1993; 1992), patients with Diabetes (Meneilly et al., 1993; Holmes et al., 1983) and healthy young adults (Martin and Benton, 1999; Parker and Benton, 1995; Benton et al., 1994).

Donohoe and Benton (1999b) and Benton et al., (1994) found greater increases in blood glucose levels to be associated with poor performance on memory and sustained attention measures in healthy young adults. Recently, using a sample of university students similar to those used in this thesis, Benton et al., (2001a) reported that low blood glucose levels were significantly correlated with better word recall. Furthermore, following increased cognitive demand, falling blood glucose levels have been associated with better memory (Donohoe and Benton, 1999a). Similarly, with respect to the RAG meal, it was demonstrated that falling blood glucose levels towards the end of the study were indicative of better word recall (Chapter 6; section 6.4.3).

In the healthy elderly, negative correlations have also been reported between memory measures and increases in blood glucose levels from baseline to the peak of the curve (Manning et al., 1990; Hall et al., 1989). Individuals with poor glucose tolerance, whose blood glucose reaches high levels and then falls slowly, have been found to score lower on memory measures than those with good glucose tolerance. Similarly, the quicker blood glucose levels returned to baseline the better the memory has been reported in the elderly (Craft et al., 1994; 1992).

Good glucose tolerance is associated with increased insulin release and/or enhanced insulin sensitivity, which in turn may also influence the brain. The level of blood glucose cannot be dissociated from the level of blood insulin. The transport of insulin from the blood into cerebrospinal fluid (CSF) has been documented in several species and situations, with uptake occurring via an active transendothelial transport across the blood-brain barrier, specific to insulin (Banks and Kastin, 1998; Banks et al., 1997a; Schwartz et al., 1990). High levels of insulin receptors are located in the hippocampus (Unger et al., 1991); insulin may play a beneficial role in memory. Impaired insulin receptor activity has been demonstrated in patients with Alzheimer's disease (Frolich et al., 1998), in addition they also show poor glucoregulation (Hoyer et al, 1991). Craft et al., (1996) reported in patients with Alzheimer's disease, that hyperinsulinaemia enhanced memory to a greater extent than hyperglycaemia. However, these results must be treated with caution as the same results were not found with a healthy aged sample. Vanhanen et al., (1998) suggested that the cognitive deficits observed in an elderly population with persistent impaired glucose tolerance could be accounted for by hyperinsulinaemia.

In conclusion, the implication that good glucose tolerance following the RAG breakfast, and low blood glucose levels following consumption of the SAG breakfast, were indicative of better memory, suggested that good glucoregulation was an important factor. Furthermore, it has been demonstrated in elderly adults with diabetes that improved glycaemic control was associated with the reversal of cognitive deficits (Meneilly et al., 1993).

9.1.5 EFFECTS OF OTHER MACRONUTRIENTS

Effect of Protein

Protein failed to influence the number of words recalled. Participants who consumed 6.01-8g of protein, compared to those who consumed 0-2g or over 8.01g ($p<0.01$), took significantly less time to recall the word lists.

Was protein the influential factor with respect to memory performance, or did other macronutrients correlate with performance? As with carbohydrate consumed, the observed relationship with protein was non-linear, therefore, stepwise regressions were performed on each of the individual protein groupings. When the individual protein groupings were analysed, no consistent patterns indicating protein consumption as a predictor for memory enhancement were observed, suggesting that protein, per se, was not influential.

Effect of Fat

Consumption of 0-2g of fat, when compared to 11g and over, significantly increased the number of words recalled at 40 minutes. Regression equations performed on the whole sample demonstrated that fat was negatively associated with the number of words recalled at immediate recall at 40 minutes [$R^2 = 0.01$, $F(2,328) = 3.99$, $p<0.05$] and caloric intake was negatively associated with the number of words recalled at delayed recall at 40 minutes [$R^2 = 0.01$, $F(2,328) = 3.87$, $p=0.05$]. As expected, fat and caloric intake were positively correlated [$r(330) = 0.79$, $p<0.001$]. In addition, participants who consumed 0-2g of fat, compared to consumption of over 11g, took significantly longer to recall the word lists at delayed recall.

When the different fat groupings were examined, no significant differences were observed between the amounts of carbohydrate [$F(1,328) = 3.67$, $p=0.06$] and fibre consumed [$F(1,328) = 0.46$, $p=0.50$]. Consumption of 0-2g of fat, compared to over 11g, was associated with significantly more protein [$F(1,328) = 3.97$, $p=0.05$], with consumption of 0-2g of fat was associated with significantly less calories [$F(1,328) = 541.39$, $p<0.001$].

In summary it was found that consumption of low amounts of fat, associated with low caloric intake, resulted in significantly better memory performance at 40 minutes.

Effect of Fibre

In the meta-analysis the amount of fibre consumed failed to influence the number of words recalled, however, significant decreases in the number of words recalled over time were observed for each of the fibre groupings. Consumption of 2.01-4g of fibre resulted in significantly more time being taken to recall the word lists over the morning than either 0-2g or 4.01-6g of fibre ($p<0.001$).

Significantly more fat and calories ($p<0.001$) and less protein ($p<0.001$) were consumed by those who ate 2.01-4g of fibre, compared to the other fibre groupings. Furthermore consumption of meals that contained 2.01-4g of fibre had significantly higher G-loads ($p<0.05$). However, the breakfasts which fell into the 2.01-4g grouping come solely from Chapter 6, where the amounts of carbohydrate, fat and protein were manipulated, with fibre kept constant (3.2g-3.32g). Here low fat was associated with increased recall times.

Regression equations were performed on the selected sample of 2.1-4g of fibre, with the macronutrients, caloric intake and G-load as the independent variables, and immediate and delayed recall times as the dependent variables. Fat was negatively associated with recall times, the lower the fat intake the more time that was spent recalling the words.

Therefore, it appears that it is not the amount of fibre consumed that is important, but rather the consumption of low amounts of fat that was associated with increased recall times.

Effect of Caloric Intake

There was a significant difference in the number of words recalled by the different caloric intake groupings at 40 minutes (p=0.05). However, post-hoc tests only found a non-significant trend for participants who consumed 101-200 Kcal to recall more words than those who consumed 301 Kcal and above. No differences were observed with respect to the time taken to recall the word lists. Thus, caloric intake was not associated with enhanced memory.

9.1.6 CONCLUSIONS OF MACRONUTRIENTS AND MEMORY

In summary, low fat and energy intakes were associated with increased word recall at 40 minutes, resulting in significantly smaller G-loads being consumed. However, it is the amount and type of carbohydrate that is more important with respect to memory enhancement.

Consumption of 35.1-50g of carbohydrate, and 6.01-8g of protein, resulted in participants taking significantly less time to recall the word lists, despite a failure to enhance the number of words recalled. In both cases, the quicker recall times were correlated with decreased fibre consumption.

Previously it was suggested that quicker recall times may be indicative of either increased efficiency, or decreased motivation. The number of words recalled was positively correlated with the time being taken to recall the word lists at each time point. That is the more time that was taken to recall the lists, the better was memory. Therefore, it can be suggested that quicker recall times are a function of decreased motivation (Benton et al., 2001a), not increased efficiency.

The failure of breakfast consumption to influence word recall conflicts with some previous literature (Benton and Parker, 1998; Smith et al., 1994a; 1992; Benton and Sargent, 1992). However, the consumption of breakfast was associated with increased recall times and can be suggested to reflect increased motivation.

Benton et al., (2001a; 2001b) similarly failed to demonstrate an increase in the number of words recalled following the consumption of breakfast. Benton et al., (2001a) attributed these findings to the experience and 'warm-up' following baseline testing, however, enhancement of memory following breakfast has been demonstrated with (Smith et al., 1994a; 1992), or without (Benton and Parker, 1998; Benton and Sargent, 1992), the baseline cognitive testing. Baseline measures of cognition were not undertaken in the present studies due to the excessive demands already placed on the participants.

The quantities of macronutrients consumed within the meals in the studies, were substantially smaller than most previous research, this will be discussed in greater detail in Chapter 10. Experiments that have studied the effects of pure macronutrient meals have used 105g of either pure macronutrient (Fischer et al., 2001) or mixed carbohydrate and protein (Fischer et al., 2002). The authors concluded meals that elicit small changes in glucose metabolism and the glucagon to insulin ratio (GIR) were most beneficial, for example those resulting from a pure fat meal (Fischer et al., 2001).

Fischer et al., (2001; 2001) noted that carbohydrate was most beneficial over the first hour, with the emphasis shifting to protein rich and balanced meals (carbohydrate:protein, 1:1) over the second hour. The beneficial effects observed with carbohydrate rich meals may reflect a positive effect of a rise in plasma glucose following an overnight fast (Owens and Benton, 1994; section 1.3.3). The protein rich meals will therefore activate more glycogenolysis (breakdown from glycogen) and gluconeogenesis (synthesis from non-carbohydrates, e.g. amino acids) to produce fuel for the brain, if the majority of the carbohydrate has been utilised after the first hour of testing.

Markus et al., (1999) reported enhanced memory in participants following a carbohydrate-rich (219g)/protein-poor (12g) lunch compared to a carbohydrate-poor (123g)/protein rich (81g) meal. In both instances, one can speculate that it is the increased provision of glucose to the brain that may play a role, possibly through carbohydrate ingestion (Markus et al., 1999), or through gluconeogenesis (Thomas et al., 1999).

In conclusion the consumption of breakfast, despite not influencing the number of words recalled from the word list, did increase the time taken trying to recall the words. It can be suggested that this represents increased motivation and hence enhanced memory performance. One can also suggest that rather than the amount of fat, protein, fibre and calories consumed, the effects observed reflect their influence on blood glucose levels. Low blood glucose levels were associated with enhanced memory. The amount and type of carbohydrate consumed, and the relative changes in blood glucose levels, were major predictors of memory performance. One can suggest, therefore, that glucose provision, through carbohydrate utilisation, is the most influential factor in memory enhancement.

9.2 BREAKFAST AND POOR MEMORY

It is generally assumed that the memory processes of healthy young adults are fully functional and do not exhibit the impaired memory of the elderly. However, it was clear in the present studies, that in a sample of healthy young adults, there was great variability in the number of words recalled. As the amount of carbohydrate failed to influence memory in the whole sample (Chapters 4 and 5), the question arose as to whether carbohydrate selectively influenced those participants with poorer memory, those with low scores on the first memory test.

Using comparable data (Chapters 4 and 5), 3 participants were immediately able to recall 20 out of 30 words at immediate recall at 40 minutes, 17 were able to recall 16 words or more. Such a strong performance suggested that participants had been using memory strategies and that the resulting good performance prevented diet-induced improvements. It may be relevant that many of the participants tested were psychology students. It was argued that participants using a memory strategy would fall into the upper quartiles of the distribution. Those with poorer memory, who could potentially benefit from the diet, would appear in the lowest quartile.

When the whole sample was examined no significant differences were observed between those consuming different amounts of carbohydrate at immediate recall of the first word list [$F(2,327) = 0.001$, $p=0.99$]. Hence the sample was split arbitrarily into quartiles on the basis of the scores from the immediate recall test in the first session (40 minutes). Participants who scored up to and including 8 correct words at immediate recall at 40 minutes were examined exclusively (N=80). That is those in the bottom quartile.

Summary of Further Analysis

- Participants who consumed over 50.1g of carbohydrate, compared to 35.1-50g ($p<0.05$), recalled significantly more words at 125 minutes (Figure 9.1). In addition, participants who consumed 35.1-50g of carbohydrate, compared to 20.1-35g ($p<0.001$) or 50.1g and above ($p=0.05$), took significantly less time to recall the word lists.
- Protein failed to influence any aspect of memory.
- Fat failed to influence any aspect of memory.
- There was a non-significant trend for participants who consumed 2.1-4g of fibre, compared to 0-2g, to recall more words. In addition, participants who consumed 2.1-4g rather than 0-2g of fibre took significantly more time to recall the word lists ($p<0.05$).
- Energy intake failed to influence any aspect of memory.

In those that have poorer memory, carbohydrate had the most beneficial influence. The remaining macronutrients and energy intake had little or no effect on memory.

9.2.1 EFFECT OF CARBOHYDRATE

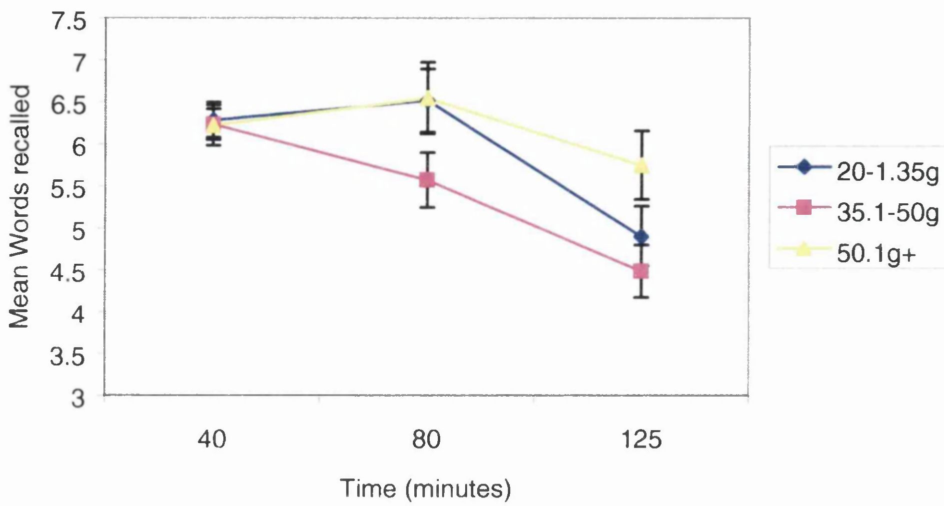
When the total number of words recalled was assessed, the interaction Carbohydrate X Session just missed significance [F (4,154) = 2.29, p=0.06]. SME's demonstrated that at 125 minutes, participants who consumed 50.1g and above recalled significantly more words than those who consumed 35.1-50g [F (2,77) = 3.04, p=0.05] (Figure 9.1). In addition, participants who consumed 50.1g and above, compared to lower amounts, failed to demonstrate a fall in the number of words recalled over the three sessions [F (2,154) = 1.94, p=0.15].

When the time taken to recall the word lists was assessed, the interaction Carbohydrate X Session reached significance [F (4,154) = 5.04, p=0.001]. All SME's performed on the data were significant. There was a main effect of Carbohydrate [F (2,77) = 9.29, p<0.001], participants who consumed 35.1-50g of carbohydrate, compared to consumption of over 50.1g (p<0.001) and 20.1-35g (p=0.05), took significantly less time to recall the word lists.

Table 9.1: Mean quantities of Fat, Protein, Fibre (grams), Caloric intake (Kcals) and G-load for each Carbohydrate grouping for those with poorer memory (means +/- s.e.m.)

	Fat	Protein	Fibre	Kcal	G-load
20.1-35g (N=26)	9.93 (1.52)	6.09 (0.82)	3.22 (0.01)	207.30 (13.80)	1688.28 (46.22)
35.1-50g (N=34)	4.00 (0.87)	8.39 (0.21)	2.01 (0.30)	228.81 (9.63)	2399.28 (56.25)
50.1g and above (N=20)	9.51 (1.76)	7.41 (0.86)	3.24 (0.01)	335.83 (16.21)	5199.33 (46.64)

Figure 9.1: Profile of Total Words recalled over Time for each Carbohydrate grouping (means +/- s.e.m.)



However, there was significantly less fat [F (2,77) = 7.06, p<0.01], less fibre [F 92,77) = 10.95, p<0.001] and more protein [F (2,77) = 3.91, p<0.05] associated with consumption of 35.1-50g of carbohydrate (Table 9.1). In this sample carbohydrate correlated positively with caloric intake [r (80) = 0.64, p<0.001] and highly with G-load [r (80) = 0.93, p<0.001], G-load also correlated positively with caloric intake [r (80) = 0.39, p<0.001].

Stepwise regressions were performed on the poor memory data set, with the macronutrients, fibre and caloric intake as the independent variables, and measures of memory as the dependent variables. Macronutrient intake failed to predict the number of words recalled. High carbohydrate and low protein intake was associated with increased immediate recall time at 125 minutes [R^2=0.11, F (2,77) = 5.93, p<0.01], with high carbohydrate associated with increased delayed recall times at 125 minutes [R^2=0.07, F (1,78) = 6.60, p<0.05].

Hence, in those who demonstrate poorer word recall and presumably fail to implement memory strategies, consumption of 50.1g and above is beneficial over the course of the morning. This resulted in significantly more words being recalled towards the end of the morning compared to lower doses of carbohydrate. Furthermore, over the morning those who consumed over 50.1g of carbohydrate took significantly longer to recall the word lists. Analysis of the other 3 quartiles individually found no significant effects of carbohydrate with respect to word recall (Appendix 4).

9.2.2 EFFECT OF BLOOD GLUCOSE LEVELS

As carbohydrate influences memory, an obvious question is whether the effect is mediated via blood glucose levels. Bivariate correlations (Pearson's R) and stepwise linear regressions were performed on this reduced data set (N=80), with blood glucose levels and changes in blood glucose levels as the independent variables, and immediate and delayed recall at each session as the dependent variables.

Low blood glucose levels at 100 minutes were associated with increased word recall at 80 minutes for both immediate [$R^2 = 0.06$, $F(1,78) = 6.22$, $p<0.05$] and delayed recall [$R^2 = 0.05$, $F(1,78) = 5.25$, $p<0.05$]. Furthermore, low baseline blood glucose levels were associated with increased delayed word recall at 40 minutes [$R^2 = 0.08$, $F(1,78) = 7.87$, $p<0.01$]. Lower blood glucose levels, therefore, were associated with increased recall in those with poor memory.

Low blood glucose levels at 150 minutes were associated with taking more time at delayed recall at 40 minutes [$R^2 = 0.06$, $F(1,78) = 6.05$, $p<0.05$], and rapidly falling blood glucose levels between 60-90/100 minutes were associated with taking more time at delayed recall at 125 minutes [$R^2 = 0.07$, $F(1,78) = 6.94$, $P=0.01$]. Falling and low blood glucose levels towards the end of the study were associated with increased time being taken to recall the word lists in those with poor memory.

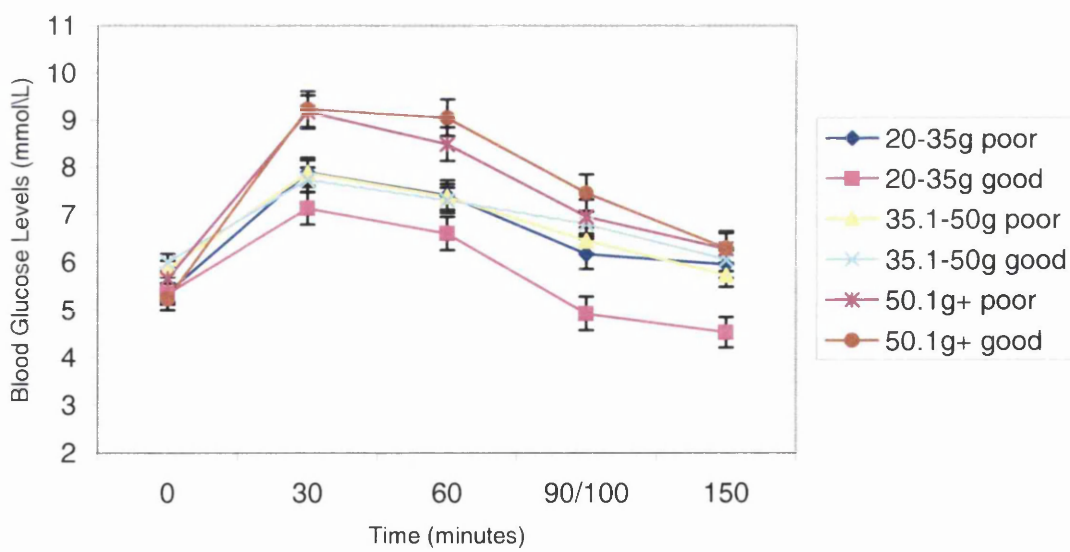
Are these low blood glucose levels associated with enhanced memory a function of the rate of fall in blood glucose levels following the consumption of the meal, or is this a reflection of a failure for blood glucose levels to rise in the first place? By analysing the effects of the change in blood glucose levels over time, it can be demonstrated that there were significant differences between the carbohydrate conditions with respect to the initial rise, but not with any other change [$F(2,77) = 6.91$, $p<0.01$]. 0-30 minutes after breakfast, consumption of over 50.1g, compared to 20.1-35g ($p<0.05$) and 35.1-50g ($p=0.001$), resulted in significantly increased blood glucose levels (Figure 8.1, section 8.1.2). Therefore, one can suggest blood glucose levels that fail to rise and fall dramatically are associated with better memory.

9.2.3 GLUCOSE TOLERANCE AND MEMORY

As observed with the whole sample, low blood glucose levels over time were associated with better memory, yet consumption of over 50.1g of carbohydrate significantly enhanced memory, and increased blood glucose levels. How can these findings co-exist? Although it is generally assumed that healthy young adults do not exhibit impaired glucose tolerance, previous research has demonstrated that greater increases in blood glucose levels are associated with poorer performance on memory and sustained attention measures (Donohoe and Benton, 1999b, Benton et al., 1994).

Those with good memory, the top quartile (N=74), and those classed with poor memory, the bottom quartile (N=80) were compared. Two-way Repeated Measures ANOVA's were performed, with carbohydrate consumed and memory (good/poor) as the independent variables and blood glucose levels as the dependent variables.

Figure 9.2: Mean Blood Glucose Levels over Time for each Carbohydrate grouping and level of Memory (good/poor) (means +/- s.e.m)



The three-way interaction Memory X Carbohydrate X Time reached significance [F (8,592) = 2.21, p<0.05]. SSME's demonstrated that in those who consumed 20-1-35g of carbohydrate glucose tolerance influenced memory (Figure 9.2); participants who were classed as having poor memory had significantly higher glucose levels compared to those with good memory at 90/100 minutes [F (1,150) = 4.42, p<0.05] and 150 minutes [F (1,150) = 8.75, p<0.01]. No differences were observed with the larger carbohydrate doses, suggesting that increasing the amount of carbohydrate eliminates the negative deficits associated with poor glucose tolerance.

It could be suggested that the larger doses of carbohydrate enhanced the memory of those classed as having poor memory, by allowing a reserve of glucose to be stored in the brain (McNay et al., 2001). It may be that those with poor glucoregulation have problems transporting glucose into the brain, and from compartment to compartment within the brain, such speculation awaits evidence. McNay et al., (2000) have demonstrated that hippocampal extracellular glucose is susceptible to the cognitive demand of a task. Therefore, in those with poorer memory, the reserves stored by pre-treatment, and the larger quantities of carbohydrate, may prevent the deficits usually observed with such memory measures in those with poor glucose regulation.

9.2.4 EFFECT OF OTHER MACRONUTRIENTS

Effect of Protein

The amount of protein consumed within the meal failed to influence word recall or the time taken to recall the word lists in those with poor memory (Appendix 4).

Effect of Fat

The amount of fat consumed within the meal failed to influence word recall or the time taken to recall the word lists in those with poor memory (Appendix 4).

Effect of Fibre

There was a trend for participants who consumed 2.01-4g of fibre, compared to 0-2g, to recall significantly more words at 80 minutes ($p=0.06$). Furthermore, participants who consumed 2.01-4g of fibre took significantly more time than the other groupings to recall the word lists at 40 minutes ($p<0.01$), and significantly more time than those who consumed 0-2g at 80 minutes ($p<0.05$).

There were no significant differences in the amount of carbohydrate consumed by the fibre groupings [$F(2,77) = 0.11$, $p=0.89$] or caloric intake [$F(2,77) = 2.38$, $p=0.10$]. However, participants who consumed 2.1-4g of fibre consumed a significantly higher G-load than those who consumed 4.01g and above ($p<0.05$) [$F(2,77) = 4.07$, $p<0.05$] due to the large amounts of carbohydrate consumed within the sample, as reported previously (section 9.1.5).

Regression equations were performed on this selected sub-sample who consumed 2.01-4g of fibre (N=46). High carbohydrate consumption predicted increased recall times at 125 minutes for both immediate [$R^2=0.10$, $F(1,44) = 5.77$, $p<0.05$] and delayed recall [$R^2=0.10$, $F(1,44) = p<0.05$]. Thus one can suggest that the higher carbohydrate intake associated with consumption of 2.01-4g of fibre was responsible for the longer recall times.

Effect of Caloric Intake

The caloric intake consumed failed to influence word recall or the time taken to recall the word lists (Appendix 4).

9.2.5 CONCLUSIONS WITH MACRONUTRIENTS AND POOR MEMORY

In those who demonstrated poorer memory the consumption of over 50.1g of carbohydrate significantly enhanced word recall. Low blood glucose levels were again associated with enhanced performance, a reflection of the glucose tolerance of the individual. The ability to utilise blood glucose effectively, demonstrated by falling and low blood glucose levels towards the end of the morning, was predictive of enhanced memory. In those who consumed 20.1-35g of carbohydrate, participants whose blood glucose levels stayed higher over time had significantly lower word recall scores, however, consumption of over 50g overcame this problem.

It is interesting to note that consumption of 35.1-50g resulted in the poorest performance over the course of the morning. As noted previously (section 9.2.3) the consumption of 35.1-50g resulted in more stable blood glucose levels over the morning. Can this now be interpreted as a failure of blood glucose levels to fall and as such poor glucose tolerance? This idea will be further discussed in Chapter 10.

The meals that fell into the 35.1-50g carbohydrate grouping contained very little fat and fibre and also contained 6.1-8g of protein, all of which were associated with poorer memory. It is of interest that the breakfasts consumed within this category were mostly cereals, e.g. Cornflakes and Rice Krispies, which have a high quantity of RAG, and therefore have high GI (80 and above, Foster and Brand-Miller, 1995). On may cautiously suggest that rather than the amount of carbohydrate consumed, it was the consumption of high GI breakfasts, that were detrimental to memory.

In conclusion, it can be argued that the amount of carbohydrate consumed, and its influence on blood glucose levels, may underlie the effects on memory. This has previously been demonstrated with the healthy elderly (Kaplan et al., 2000; Manning et al., 1990; Hall et al., 1989) and healthy young adults (Donohoe and Benton, 1999b; Benton et al., 1994). The separation of those with good memory from those with poorer memory has further highlighted the fact that even in the young, differences in the ability to control blood glucose levels have consequences for memory.

9.3 RAPID INFORMATION PROCESSING TASK (RIPT)

Consumption of the different meals within individual experiments significantly enhanced measures on the Rapid Information Processing Task (RIPT) (section 3.4.1; 4.4.1; 5.4.1; 6.4.1). However, as with other cognitive measures, the effects observed were often specific to the meal consumed (Chapters 3-6).

The meta-analysis (section 7.4) demonstrated that participants who consumed breakfast, rather than fasting, recorded more correct responses. Furthermore, the following relationships between macronutrients, fibre and caloric intake, and measures of the RIPT were observed.

- Participants who consumed 35.1-50g of carbohydrate, compared to those who consumed lower and higher amounts, recorded more correct responses over the three sessions (section 7.4.2; Figure 7.9), significantly less wrong responses and had the quickest reaction times over the morning.

- Participants who consumed 4.01-8g of protein recorded more correct responses over the three sessions compared to 0-4g and 8.01-10g (section 7.4.3; Figure 7.16) and demonstrated a more consistent performance over the three test sessions.
- Consumption of 7-12g of fat resulted in more wrong responses being recorded than following the consumption of less than 2.5g. Participants who consumed 16g of fat were significantly slower at 40 minutes (section 7.4.4; Figure 7.19).
- Participants who consumed over 3.1g of fibre, compared to less than 3g, were significantly slower at 40 minutes (section 8.4.5; Figure 8.37).
- Consumption of over 201kcal produced more correct responses over the three sessions (section 8.4.6; Figure 8.4.1), however, consumption of 101-200kcal elicited the lowest number of wrong responses (Figure 8.4.2) and the quickest reaction times.

9.3.1 EFFECT OF CARBOHYDRATE

Figure 7.9 illustrated that participants, who consumed 35.1-50g of carbohydrate, demonstrated no decrement in performance over time, recording an average of 4 correct responses in each session. Both those who consumed 20.1-35g, and 50.1g and above, significantly increased the number of correct responses over time. However, no significant differences were observed between the carbohydrate groupings at any time point (40, 80, 125 minutes).

In addition to the consistent high incidence of correct responses over the three sessions, consumption of 35.1-50g of carbohydrate, compared to 20.1-35g ($p<0.05$) and over 50.1g ($p=0.07$), resulted in significantly less wrong responses over the morning. Furthermore, consumption of 35.1-50g of carbohydrate resulted in significantly quicker reaction times over the morning when compared to the other carbohydrate groupings ($p<0.05$).

Were the differences associated with carbohydrate consumption due to this macronutrient or some other aspect of diet? Analysing the whole comparable sample, participants who consumed 35.1-50g of carbohydrate consumed significantly lower amounts of fat [$F(2,385) = 47.62$, $p<0.001$] and higher amounts of protein [$F(2,385) = 43.11$, $p<0.001$] compared to the other groupings. Furthermore, significant differences were also observed with respect to fibre, caloric intake and G-load, that reflected a linear relationship; as carbohydrate intake increased so did fibre, caloric intake and G-load consumption.

As the relationship was non-linear, with consumption of 35.1-50g of carbohydrate significantly enhanced performance on the RIPT compared to the other carbohydrate groupings, stepwise regression equations were further calculated for each carbohydrate grouping separately. The macronutrients, fibre and caloric intake were the independent variables with total correct responses, wrong responses and reaction times as the dependent variables. G-load was excluded from the analysis due to a high positive correlation with carbohydrate [$r(388) = 0.93$, $p<0.001$].

In those who consumed 35.1-50g of carbohydrate, high fat was significantly associated with more wrong responses at 40 [R^2 =0.05, F (1,129) = 8.36, $p<0.01$], 80 [R^2 =0.04, F (1,129) = 5.87, $p<0.05$] and 125 minutes [R^2 =0.04, F (1,129) = 6.96, $p<0.01$]. Furthermore, high fat was significantly associated with increased reaction times at 125 minutes [R^2 =0.06, F (1,129) = 8.91, $p<0.01$]. No significant relationships were observed following consumption of 20.1-35g of carbohydrate. Consumption of high amounts of protein was associated with increased reaction times at 125 minutes, however this appeared to be an anomalous finding, possibly by chance, that failed to relate to previous results.

Therefore, one can suggest that the significantly lower amounts of fat consumed by those in the 35.1-50g carbohydrate groupings was beneficial to performance on the RIPT, rather than carbohydrate consumption per se.

9.3.2 EFFECT OF BLOOD GLUCOSE LEVELS

Regression equations were performed on the entire data set, with blood glucose levels, and changes in blood glucose levels as the independent variables, and total correct, wrong and reaction times as the dependent variables.

No relationships were observed with the incidence of correct responses. High blood glucose levels at 90-100 minutes were associated with a lower number of wrong responses at 125 minutes [R^2 =0.01, F (1,386) = 4.42, $p<0.05$].

High and stable (slowly falling) blood glucose levels between 60-90/100 minutes were associated with quicker reaction times at 40 minutes [$R^2 = 0.02$, $F(1,386) = 8.07$, $p<0.01$]. Slowly rising levels between 0-30 minutes predicted quicker times at 80 minutes [$R^2 = 0.01$, $F(1,386) = 6.58$, $p<0.05$] and high baseline blood glucose levels predicted quicker times at 125 minutes [$R^2 = 0.01$, $F(1,386) = 5.47$, $p<0.05$]. One can suggest that stable blood glucose levels over the morning were beneficial for performance on the RIPT.

Figure 9.3: Profile of mean Blood Glucose Levels over time for each Carbohydrate grouping (means +/- s.e.m)

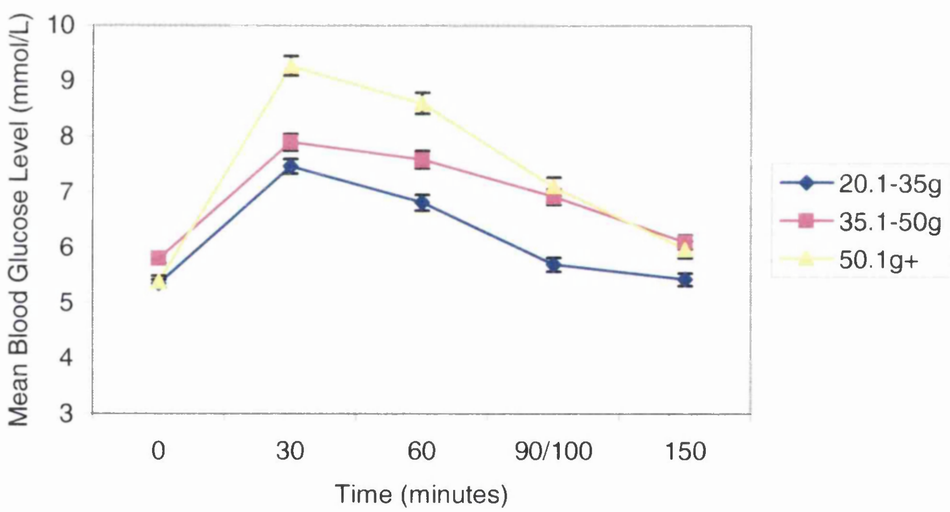


Figure 9.3 displays the profile of blood glucose levels over the morning for each carbohydrate grouping. Participants who consumed 35.1-50g had significantly smaller falls in blood glucose levels between 60-90/100 minutes [$F(2,385) = 7.51$, $p<0.01$] compared to those who consumed 20.1-35g ($p<0.05$) and 50.1g and above ($p<0.001$). Those who consumed 35.1-50g had significantly higher baseline blood glucose levels [$F(2,385) =$

8.48, $p<0.001$] than the other carbohydrate groupings ($p<0.01$) and displayed significantly lower increases in blood glucose levels between 0-30 minutes [$F(2,385) = 38.83$, $p<0.001$] than after the consumption of 50.1g and above ($p<0.001$).

Previously, falling blood glucose levels have been associated with enhanced performance on the RIPT (Donohoe and Benton, 1999b; Benton et al., 1994), however the testing procedures employed were different to this thesis. Benton et al., (1994) had participants practice the RIPT to achieve stable performance. In addition baseline performance was measured for 10 minutes on the test day, with the actual test session consisting of two 10 minutes sessions. Donohoe and Benton (1999b) used the RIPT to induce cognitive demand to see if this influenced subsequent word recall, and the task was performed for 10 minutes immediately after consumption of a glucose or placebo drink. Thus both studies employed different methods to the present studies.

The present findings suggest that high and stable blood glucose levels, rather than falling levels, were beneficial for enhanced performance on the RIPT. This was measured by quicker reaction times, less wrong responses and constant correct responses over the three sessions demonstrated following consumption of 35.1-50g of carbohydrate. These findings conflict with previous research (Donohoe and Benton, 1999b; Benton et al., 1994), however, this may reflect the differences in performance following consumption of a meal as opposed to consumption of a glucose drink, or differences in research methods employed.

9.3.3 EFFECT OF OTHER MACRONUTRIENTS

Effect of Protein

The consumption of different amounts of protein significantly influenced measures of the RIPT. The consumption of 4.01-8g of protein resulted in significantly better performance over the morning, with respect to correct (section 7.4.3; Figure 7.16) and wrong responses, however reaction times were not influenced. Consumption of 4.01-8g of protein resulted in more consistent performance over time.

Was protein the influential factor with respect to performance on the RIPT, or did other macronutrients correlate with performance? Analysing the whole sample, protein failed to predict any measure of the RIPT. However, the lower quantities of fat [$F(2,385) = 29.35$, $p<0.001$], fibre [$F(2,385) = 446.34$, $p<0.00$] and calories [$F(2,385) = 23.68$, $p<0.001$] consumed by those who ate 4.01-8g of protein were associated with better performance.

Again, as the relationship between protein consumption and performance was non-linear, stepwise regressions were performed on each protein condition separately. In those who consumed 4.01-8g of protein, high fat was significantly associated with more wrong responses at 40 [$R^2 =0.06$, $F(1,99) = 7.68$, $p<0.01$], 80 [$R^2 =0.06$, $F(1,99) = 7.89$, $p<0.01$] and 125 minutes [$R^2 =0.11$, $F(1,99) = 13.03$, $p<0.001$]. Furthermore, high fat was significantly associated with increased reaction times at 125 minutes [$R^2 =0.06$, $F(1,99) = 7.19$, $p<0.01$]. No significant patterns were observed following consumption of 0-4g of protein. Consumption of high amounts of fibre predicted enhanced performance following consumption of 8.01-10g of protein, however this may be a results of the meals consumed, as protein intake increased so did fibre consumption.

In summary, rather than the amount of protein consumed, it appears that the amount of fat is a critical factor on performance on the RIPT; low fat meals predict enhanced performance on the RIPT.

Effect of Fat

Fat consumption failed to influence the number of correct responses on the RIPT. Participants who consumed 7-12g of fat recorded significantly more wrong responses compared to those who ate 0-2.5g ($p<0.01$) and those who consumed 0-2.5g of fat took less time over the three sessions to react to the stimuli (section 7.4.4, Figure 7.19).

Stepwise regressions demonstrated that high quantities of fat were associated with more wrong responses being recorded at 40 minutes [$R^2 = 0.02$, $F(1, 386) = 7.91$, $p<0.01$], and also predicted increased reaction times with respect to the third session (125 minutes) [$R^2 = 0.02$, $F(1,386) = 7.77$, $p<0.01$].

High fat consumption predicted poorer performance on the RIPT, however, why was performance the poorest following consumption of 7-12g when higher doses were included in the analysis? Participants who consumed 7-12g fat consumed less carbohydrate than those who ate 0-2.5g ($p=0.10$) and 16g fat ($p<0.01$). In addition, participants who had 7-12g of fat consumed significantly less fibre [$F(2,387) = 58.89$, $p<0.001$] and fewer calories

[F (2,387) = 250.63, $p<0.001$]. It can be suggested that the higher fat intake, coupled with the lower macronutrient intake may responsible for the observed poorer performance of the 7-12g fat grouping.

Participants who consumed 16g of fat demonstrated significantly increased reaction times compared to those who ate lower than 16g at 40 minutes (Figure 7.19), with participants who consumed 0-2.5g, compared to 7-12g ($p=0.001$) and 16g ($p=0.07$), taking significantly less time at 125 minutes.

Therefore, consumption of low amounts of fat, less than 2.5g, which in turn results in low caloric intake and fibre consumption, resulted in enhanced performance on the RIPT.

Effect of Fibre

Fibre consumed failed to influence the number of correct or wrong responses.

Participants who consumed 3.1-6.5g of fibre, compared to 0-3g, took significantly more time to respond to the stimuli at 40 minutes ($p<0.001$) (section 7.4.5, Figure 7.23). In addition, those who consumed 3.1-6.5g of fibre demonstrated significant decreases in reaction times over the morning ($p<0.001$). High quantities of fibre consumed were associated with increased reaction times on the first test session (40 minutes) [$R^2 = 0.01$, F (1,386) = 4.06, $p<0.05$].

Participants who consumed 3.1-6.5g of fibre ate significantly higher amounts of carbohydrate [F (1,387) = 9.84, p<0.01], fat [F (1,387) = 9.09, p<0.01] and calories [F (1,387) = 14.31, p<0.001] compared to 0-3g, with protein just missing significance [F (1,387) = 3.59, p=0.06].

It can be suggested that the increased overall intake associated with consumption of 3.1-6.5g of fibre was detrimental to performance on the RIPT.

Effect of Caloric Intake

Participants who consumed over 201Kcal and above, significantly increased the number of correct responses over the morning compared to 101-200 Kcal, however, no significant differences between the caloric groupings were observed at any time point (section 7.4.6; Figure 7.26). Participants who consumed 101-200 Kcal demonstrated no significant changes in performance over the morning.

Participants who consumed 101-200Kcal recorded significantly fewer wrong responses than those who consumed 301Kcal and above at 40 minutes [F (2,387) = 3.60, p<0.05], and 201-300Kcal at 125 minutes [F (2,387) = 3.31, p<0.05] (section 7.4.6; Figure 7.27). Furthermore, those who consumed 101-200Kcal, compared to consumption of 301Kcal and above (p<0.05), were significantly quicker to respond to the stimuli over the morning.

Significant differences were observed between the caloric intake groupings with respect to carbohydrate [F (2,385) = 103.79, p<0.001] and fat intake [F (2,385) = 271.92, p<0.001]; as caloric intake increased so did carbohydrate and fat intake. Consumption of 101-200Kcal, compared to 201-300Kcal, resulted in significantly less fibre consumption [$F(2,385) = 3.88$, $p<0.05$].

Therefore, the overall lower intake, which was associated with low fat and fibre consumption, predicted enhanced performance on the RIPT.

9.3.4 CONCLUSIONS WITH MACRONUTRIENTS AND THE RIPT

Consumption of 35.1-50g of carbohydrate, 4.01-8g of protein, less than 2g of fat and between 101-200 Kcal significantly enhanced performance on the RIPT. Regression equations demonstrated that consumption of a low fat meal appeared to benefit performance, independent of other macronutrients consumed. Furthermore, falling blood glucose levels during 60-90/100 minutes were associated with poorer performance, indicated by increased wrong responses and longer reaction times. Consequently it can be concluded that participants who exhibit more stable blood glucose levels over the morning, through the consumption of a small meal, demonstrated enhanced performance.

Manipulating the composition of meals has often failed to influence measures of the RIPT following breakfast consumption (Green et al., 1997; Lloyd et al., 1996; Smith et al., 1994a; 1992). Wells and Read (1996) demonstrated that a high-carbohydrate (202g)/low-fat (7g) brunch (10:00am) increased the incidence of wrong responses compared to a low-carbohydrate (80g)/high-fat (47g) meal. The present studies found the opposite. However, one must note that the amounts of carbohydrate and fat used by Wells and Read (1996) were much larger than the quantities consumed in the present studies (carbohydrate 59.56g; fat 16.48g).

Furthermore, in manipulating fat and energy content consumed at lunchtime, Smith et al., (1994b) failed to observe any effects with the RIPT, whereas the present studies reported that a low fat meal predicted increased performance. The meals sizes (840/880kcal to 1290/1300kcal) were substantially larger in energy content compared to the present studies (114.34Kcal to 407.26), as were the range of fat intakes 18g to 84g (Smith et al., 1994b) compared to 0.34g to 16.48g (present studies).

In addition, the tests have not always been of the same format, or length. Smith et al., (1994a; 1994b; 1992) required participants to respond when the same number was presented on successive trials, and the task lasted for 8 minutes. Whereas Green et al., (1997) and Lloyd et al., (1996) used the Bakan Vigilance Task (Bakan, 1959), as employed in the present studies, although for different periods of time.

It could be argued with such a cognitively demanding task that a small change in blood glucose levels over time appears beneficial. Fischer et al., (2002; 2001) had previously concluded that meals that elicit small changes in glucose levels, and hence the glucagon to insulin ratio (GIR), were beneficial with respect to overall cognitive performance.

The amount of fat consumed was the major predictor of enhanced performance on the RIPT, however, it is interesting to note that the Cornflakes, Rice Krispies and Ricicles meals match the optimal macronutrient intake mentioned above. A further point of interest is that the macronutrients and meals associated with enhanced performance on the RIPT are not the same as observed with enhanced performance with respect to memory. It seems that different aspects of the diet may selectively influence particular aspects of cognition.

9.4 HICK PARADIGM

The manipulation of macronutrients, fibre, caloric intake and G-load influenced the measures of the Hick Paradigm in each of the individual studies (section 3.4.1, 5.4.1, 6.4.1) except Chapter 4. However, the effects were often specific to the meal consumed and relationships were not demonstrated across studies.

Following the meta-analysis, participants who consumed breakfast, as opposed to those who fasted, demonstrated significantly lower intercept values and higher slope values (section 7.4.1). The interaction Breakfast X Lamps with respect to decision times demonstrated that in those who consumed breakfast, as opposed to those who fasted, decision times were quicker on the 1, 2 and 4 lamp tasks, however participants who fasted were quicker on the 8 lamp task. Significant negative correlations were demonstrated between intercept and slope values at each session (40 minutes [$r(450) = -0.31$, $p<0.001$]; 80 minutes [$r(450) = -0.24$, $p<0.001$]; 125 minutes [$r(450) = -0.30$, $p<0.001$]).

This negative intercept X slope correlation has previously been interpreted as

"... evidence that something other than a general speed factor is involved in Hick performance, and that a different *strategy* for minimising RT is adopted in responding to a small number of alternatives from that used in responding to a larger number..." (Jensen, 1987, pp 142). Nettelbeck and Kirby (1983) suggest that individuals employ different strategies when faced with increasing task demands, "... some subjects have applied different criteria for responding at different levels of choice... some responses have been disproportionately more carefully made when eight stimulus alternatives were involved, although other explanations are equally viable. " (Nettelbeck and Kirby, 1983, pp 49-50). One can suggest, therefore, that participants who consumed breakfast and performed quicker on the less demanding 1, 2 and 4 lamp tasks, demonstrated better raw speed. However, when faced with the more demanding 8 lamp task, participants who fasted demonstrated quicker performance due to the employment of discrimination strategies employed.

In addition, decision times, intercept and slope values, and intra-individual variability failed to be influenced by consumption of the macronutrients, fibre or caloric intake. However, consumption of 7-12g of fat (section 7.4.4), and less than 3g of fibre (section 7.4.5) resulted in significantly longer movement times over the morning compared to those who consumed lower amounts.

Bivariate correlations (Pearson's R) and regression equations were performed on the data set, with the macronutrients, fibre, caloric intake and G-load as the independent variables and the median movement times for each lamp and session as the dependent variables.

High amounts of fat were associated with increased movement times at 40 minutes on the 8-lamp task [$R^2 = 0.01$, $F(1,371) = 5.45$, $p<0.05$]. At 80/100 minutes fat again was positively associated with increased movement times on the 8-lamp task, along with low amounts of carbohydrate [$R^2 = 0.02$, $F(2,371) = 5.41$, $p<0.01$].

In addition, bivariate correlations (Pearson's R) and regression equations were performed on the data set, with blood glucose levels and changes in blood glucose levels as the independent variables, with median movement times for each lamp and session as the dependent variables, however, no patterns were significant.

The question arose as to why consumption of 7-12g of fat resulted in significantly increased movement times, rather than less than 2.5g, when meals containing higher amounts of fat were present in the analysis. Further analysis, with fat split into groupings of 2g, demonstrated that this was indeed a real phenomenon. This could possibly be related to the consumption of fibre, as participants who consumed 7.12g of fat consumed significantly less fibre [$F(2,369) = 50.00$, $p<0.001$]. The meals that fell into this grouping were the SAG (9.0g fat), RAG (7.35g) and digestive biscuits breakfasts (11.76g).

Consumption of 0-3g of fibre resulted in significantly longer movement times compared to 3-6.5g. Significantly lower amounts of carbohydrate and fat ($p<0.01$) and caloric intake ($p<0.001$) were consumed by those in the 0-3g grouping. In addition, participants who consumed 0-3g of fibre were significantly less composed [$F(1,399) = 5.20$, $p<0.05$] and hungrier [$F(1,399) = 6.39$, $p<0.05$] compared to 3-6g. Regression equations reported no obvious patterns between hunger, composure and movement times.

Following the consumption of breakfast, various research groups have also failed to demonstrate an effect with respect to decision and movement times on the Hick Paradigm (Benton et al., 2001b; Green et al., 1997; Lloyd et al., 1996; Smith et al., 1994a). However, it is interesting that certain cognitive measures are influenced by the consumption of breakfast and its composition but others are not. This phenomenon will be discussed in more detail in the General Discussion (Chapter 10).

Chapter 10: General Discussion and Conclusions

10.1 GENERAL DISCUSSION

A variety of questions were posed within this thesis, the first of which asked **whether the consumption of breakfast was important?** It was demonstrated that consumption of breakfast significantly enhanced mood when compared to fasting (section 4.4.1; 5.4.1; 6.4.1; 7.4.1; 8.4.1), a finding previously reported (Benton et al., 2001b; Kissileff et al., 2000; Holt et al., 1999; Smith et al 1999; 1994a; Lloyd et al., 1996; section 1.8.3).

Following the meta-analysis and discussion (Chapters 7, 8 and 9), it was reported that participants who consumed breakfast, when compared to those who fasted, significantly increased the time taken to recall the word lists. As the number of words recalled failed to be influenced by the consumption of breakfast, one must consider what these increased recall times represent. Benton et al., (2001a) suggested that quicker recall times could be indicative of either increased efficiency, or decreased motivation. On more than one occasion within this thesis it was demonstrated that increased word recall was associated with increased recall times (sections 9.1 and 9.2). One can suggest, therefore, that increased recall times reflect increased motivation to try to recall the words from the lists.

Consumption of breakfast, as opposed to fasting, increased the number of correct responses recorded on the RIPT, suggesting enhanced cognitive performance (section 9.3). In addition, breakfast consumers, compared to those who fasted, demonstrated different strategies on the Hick Paradigm. In those who consumed breakfast, the quicker performance on the less demanding tasks was attributed to better raw speed in responding to the stimuli. In contrast, the quicker response times on the demanding task, in those who fasted, was due to the employment of discrimination strategies, and more accurate performance (section 9.4). This further suggested that the consumption of breakfast is beneficial to cognitive functioning in different ways.

As the consumption of breakfast was beneficial with respect to mood and cognitive functioning, one can ask **does the nature of the breakfast matter?** Following the results of the meta-analysis (Chapter 7) and further discussion (Chapters 8 and 9), it was clear that the nature of breakfast meal has an impact on cognitive performance and mood, however, what was beneficial for one measure was not necessarily beneficial across all the measures used.

Are the macronutrients consumed within the meal important? Each of the macronutrients consumed significantly influenced mood and cognition. The critical aspect of breakfast was the amount of carbohydrate present. Mood was significantly enhanced following the consumption of 20.1-35g of carbohydrate (Figure 7.2-7.5). Consumption of over 50.1g lead to poorer mood later on in the morning, despite having an initial beneficial effect (Benton et al., 2001a). However, in those participants who demonstrated impaired glucose tolerance, indicated by elevated blood glucose towards the end of the test session, consumption of over 50.1g of carbohydrate was beneficial. One can suggest, therefore, that it is not only the amount of carbohydrate consumed that was critical for enhanced mood, but also that once consumed, the carbohydrate interacts with the individual's physiology. This idea will be discussed in greater detail below.

Consumption of 35.1-50g of carbohydrate significantly enhanced performance on the RIPT (Figure 7.9), however, this dose was associated with taking less time trying to recall the word lists, and thus decreased motivation and poorer performance on the memory tests (Figure 7.8). It can be further suggested, therefore, that different tasks require the consumption of different amount of carbohydrate to significantly enhance performance.

The effects observed with the different doses of carbohydrate may reflect differences in the demands and the duration of the tasks employed. The memory tests took place over a 3 minute period, which involved one minute of listening to the words, trying to store them in working memory, followed by a maximum of 2 minutes trying to recall the words previously heard. The RIPT involved 5 minutes of directed attention. One could suggest that performance on the RIPT was more cognitively demanding as it involved responding to 8 correct stimuli per minute. It may be the case that increased glucose provision is needed to significantly influence the performance on the RIPT compared to the memory tests.

McNay et al., (2001) suggested that supply does not meet demands under periods of increased cognitive load but that pre-treatment with glucose allows a reserve to be stored. It has been previously demonstrated that task complexity is susceptible to raised blood glucose levels. Donohoe and Benton (1999) demonstrated no difference in performance on the easy versions of the Porteus Maze and Block design tests, however, performance was significantly enhanced following the active glucose drink on the more difficult versions. Furthermore, thee duration of the task is also susceptible to glucose provision. Keul et al (1982) demonstrated that up to 70km on a driving simulator task, performance was comparable in both the active and placebo condition, however, in those who consumed the glucose drink, performance after 70km was significantly better. It could be suggested that the natural reserves in the brain have been used up; the glucose drink prevented this decline in reserves on the more demanding RIPT.

These findings further add to the suggestion that the brain is not always supplied with enough glucose. One can suggest, therefore, that the consumption of carbohydrate and its action within the brain cannot be generalised across the different measures of cognition; the amounts of carbohydrate beneficial for measures of language processing, in the case of the memory tests, failed to be sufficient for measures of attentional processing as indicated by the RIPT.

Low fat consumption was a major predictor of enhanced performance on the RIPT, however, after closer inspection it was suggested that the combination of macronutrients associated with the 35.1-50g carbohydrate condition was responsible for the observed effects, rather than fat per se. Table 10.1 illustrates the correlations between the macronutrients investigated in this thesis. It is clear that the virtually all of the macronutrients correlate with each other, making it more difficult to tease out which macronutrient is of the greatest importance. Stepwise regressions (Chapters 8 and 9) demonstrated several associations between mood and cognitive measures assessed, however, carbohydrate, as discussed earlier, had a major influence on both enhanced mood and memory; carbohydrate content within the meal is still a crucial factor.

Table 10.1: Correlations between the Macronutrients

	Carbohydrate	Fat	Protein	Fibre	Caloric Intake	Glucose Load
Carbohydrate	----------------	-----------	-----------	----------	----------	----------
Fat	r = 0.14 **	-----------	-----------	----------	----------	----------
Protein	r = 0.15 **	r = -0.28 ***	-----------	----------	----------	----------
Fibre	r = 0.04 p=n.s.	r = -0.15 **	r = 0.50 ***	----------	----------	----------
Caloric Intake	r = 0.76 ***	r = 0.72 ***	r = 0.11 *	r = 0.02 p=n.s.	-----------	-----------
Glucose Load	r = 0.90 ***	r = 0.26 ***	r = -0.04 p=n.s.	r = -0.22 ***	r = 0.73 ***	-----------

*** p<0.001; ** p=0.001; * p<0.05

Table 10.2: Mean amounts of Fat, Protein, Fibre (grams) and Kilocalories for each Carbohydrate grouping (means +/-s.e.)

	Fat	Protein	Fibre	Kcal	G-load
Less than 20g	0.66 (0.05)	5.36 (0.12)	3.90 (0.38)	86.48 (0.73)	565.32 (45.78)
20.1-35g	6.66 (0.40)	6.41 (0.25)	3.52 (0.21)	199.34 (3.37)	1675.09 (36.25)
35.1-50g	2.31 (0.28)	9.17 (0.17)	3.34 (0.29)	222.11 (3.45)	2487.52 (35.29)
50g and above	7.51 (0.71)	6.98 (0.41)	3.78 (0.10)	313.37 (6.36)	4785.74 (76.64)

One must remember that 35.1-50g of carbohydrate was associated with the worst performance on the memory tests, however, this dose was associated with the best performance on the RIPT. Table 10.2 illustrates that significantly less fat and more protein ($p<0.001$) was consumed with 35.1-50g of carbohydrate. Furthermore, little changes in blood glucose levels over time were associated with enhanced performance on the RIPT (section 9.3.2). One can suggest that the interaction between the macronutrients in the meals within this 35.1-50g carbohydrate condition, rather than the amount of carbohydrate, was the critical factor in this case.

Fischer et al., (2002) demonstrated enhanced cognitive performance following consumption of a protein rich (4:1) or a balanced (1:1) carbohydrate:protein meal, compare to a carbohydrate rich (4:1) meal. The authors suggested that the small changes in blood glucose levels, and hence the glucose to insulin ratio (GIR) were beneficial for cognitive performance. Thus, the combination of macronutrients beneficial for one cognitive measure cannot be generalised across all cognitive measures.

Evidence from the previous literature has demonstrated that the composition of breakfast has little effect on cognitive performance (section 1.8.2), however, no systematic investigation of the composition of breakfast has been reported before the present studies. Furthermore, when manipulations of the breakfast macronutrient content have been reported in the previous literature, many of the meals still contained a percentage of carbohydrate that will in turn influence cognitive performance, making it difficult to determine if the effects observed were due to the carbohydrate consumed, another macronutrient or the total energy intake.

Various authors have reported the effects of pure macronutrient meals (Fischer et al., 2001; Kaplan et al., 2001), with pure fat meals eliciting the best overall performance. However, testing pure macronutrients has no ecological validity and realistic interest to the food consumer; no-one will never consume a diet consisting of a single macronutrient. Others have demonstrated meals balanced for carbohydrate and protein intake to be beneficial to cognition and mood (Fischer et al., 2002), however, these again are meals specific to the laboratory and are unlikely to be consumed on a day-to-day basis.

A number of studies have used isoenergetic breakfasts, however this creates an inverse relationship between fat and carbohydrate content, making it difficult to separate the fractions of the macronutrients, and also results in the consumption of breakfasts two to three times larger than most individuals would typically consume. Holt et al., (1999) reported the use of "realistic isoenergetic breakfasts" containing 486Kcal, however, the typical everyday caloric intake calculated from the food diaries in the present studies was

347Kcal. Furthermore, Lloyd et al., (1996) reported the use of 600Kcal isoenergetic breakfasts.

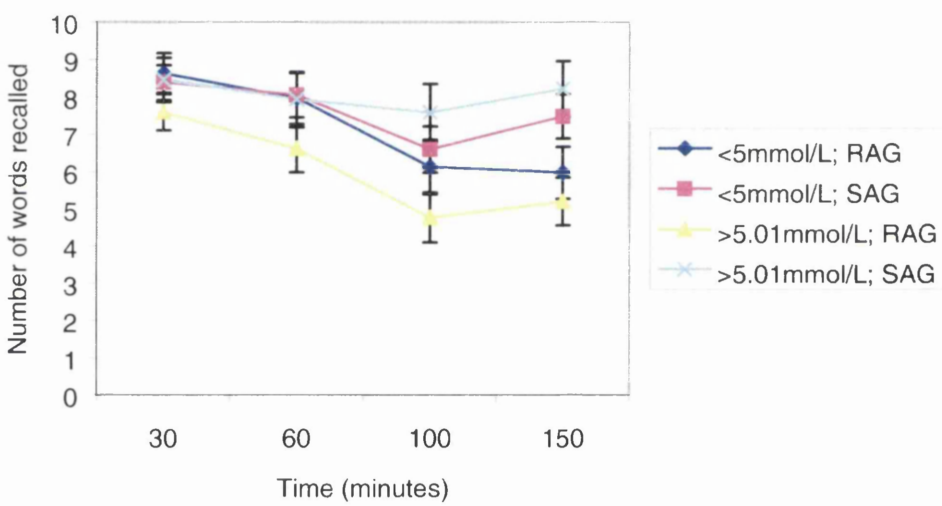
The results of the present studies indicate that, within limits, the size of the breakfast meal is not important. The caloric intake of the meals presented in the present studies ranged from 82Kcal to 407Kcal. Light meals of up to 300Kcal were suggested to be beneficial over the course of the morning when mood was considered, compared to fasting or larger meals. However, the balance of carbohydrate to the other macronutrients was the important factor with respect to measures of memory and cognitive functioning.

Not only was the amount of carbohydrate found to be important, but also **the type of carbohydrate consumed** had differential effects on measures of cognition, in particular memory. Chapter 6 reported that the consumption of a breakfast containing slowly releasing glucose (SAG) significantly enhanced word recall when compared to those who consumed rapidly available glucose (RAG) (Benton et al., 2003).

Chapter 9 concluded that carbohydrates that maintain low blood glucose levels throughout the morning significantly improved memory; it was not the amount of carbohydrate, but rather the type of carbohydrate and the interaction with glucose tolerance that was beneficial.

Investigating the differences in baseline blood glucose levels, and the interaction between carbohydrate type and the number of words recalled over the test session, SSME's demonstrated that participants with high baseline blood glucose levels (>5.01mmol/L) following consumption of the RAG breakfast, compared to the SAG breakfast, recalled significantly fewer words at 160 [F (1,68) = 7.69, p<0.01] and 220 minutes [F (1,68) = 9.61, p<0.01] (Figure 10.1). Arbitrarily baseline blood glucose levels were split in half; high baseline levels were 5.01mmol/L and above.

Figure 10.1: Profile of Total words recalled over Time for baseline blood glucose levels and meal conditions (means +/- s.e.m.)



How the carbohydrate consumed interacts with the individuals' physiology is critical in cognitive functioning. Fasting blood glucose levels are suggested to be normal when below 6mmol/L (Joslin Diabetes Centre, Boston). Fasting blood glucose levels between 6.1 and 7mmol/L are suggested to be indicative of impaired fasting glucose (IFG), a marker for the development of diabetes. Impaired glucose tolerance (IGT) is also associated with IFG. IGT is determined as fasting levels of 7mmol/L and below, that rise to between 7.8 and

11mmol/L 2 hours after consumption of a glucose drink. Thus, one may suggest that the higher the fasting blood glucose, the increased likelihood of that individual demonstrating poorer glucose tolerance.

The interaction between fasting blood glucose levels (<6.1mmol/L), type of carbohydrate consumed and memory has previously been investigated in an elderly sample exhibiting normal glucose tolerance (Kaplan et al., 2000). The authors demonstrated that consumption of barley, classified as a slowly releasing carbohydrate, significantly improved memory, when compared to rapidly releasing carbohydrates. It has previously been demonstrated that elderly subjects with poor glucoregulation perform worse on memory tests than aged matched controls as do subjects with type 2 diabetes (section 1.3.5). The fact that similar observations can be made in a healthy, young adult sample give further weight to the importance of the interaction between the physiology of the individual and the amount and type of carbohydrate consumed and the relative effects observed with mood and cognitive performance.

The GI of the food has an impact on memory. Kaplan et al., (2000), using the following foods, instant mashed potato (GI 83), barley (GI 25) and glucose (GI 100), demonstrated that low GI foods were beneficial for memory. The study presented in Chapter 6 used Lu Prince Petit Dej breakfast biscuits (GI 42) and Kelloggs Choco Krispies (GI 66) and similarly demonstrated foods with a low GI significantly enhanced word recall.
A subsequent question asked whether glucose tolerance, crudely measured by baseline blood glucose levels, interacted with the carbohydrate consumed and mood over the

morning. A significant Baseline Blood Glucose X Carbohydrate X Time interaction was demonstrated with respect to Total mood, with baseline blood glucose levels arbitrarily split into quartiles [$F(27,1608) = 2.06$, $p=0.01$](Appendix 10). Figure 10.2-10.5 illustrate the interactions following consumption of each carbohydrate grouping for baseline blood glucose levels over time.

SSME's demonstrated that in those with baseline blood glucose levels between 4.91-5.5mmol/L, and 5.51-6.1mmol/L, those who consumed 20.1-35g of carbohydrate reported the best mood (Figure 10.3). Furthermore, lower doses of carbohydrate coupled with better glucose tolerance, indicated by low baseline blood glucose levels, was associated with a more constant mood over the morning. Figure 10.5 again demonstrates that high doses of carbohydrate resulted in poorer mood towards the end of the morning.

When those with low baseline blood glucose levels were considered (<5.5mmol/L), low amounts of carbohydrate consumed (<35g) resulted in no significant decrement in mood over the morning. When those with higher baseline levels were considered (>6.1mmol/L) a greater amount of carbohydrate (>35g) had to be consumed to avoid the deterioration in mood.

Figure 10.2: Profile of Total mood for each Baseline blood glucose levels following consumption of less than 20g Carbohydrate

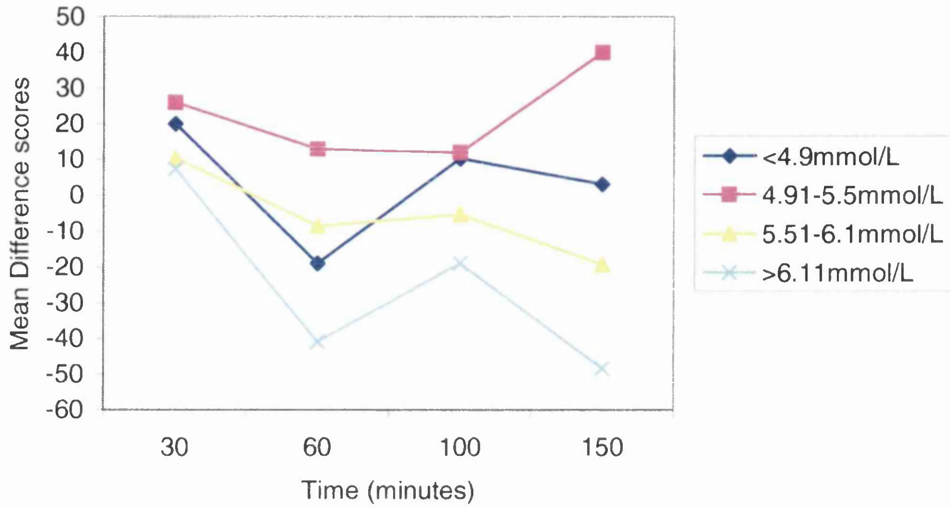


Figure 10.3: Profile of Total mood for each Baseline blood glucose levels following consumption of 20.1-35g Carbohydrate

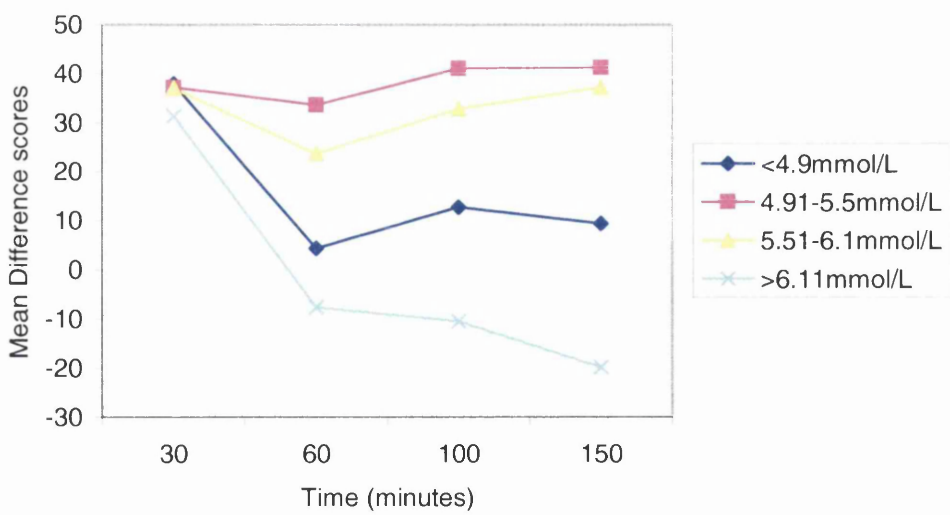


Figure 10.4: Profile of Total mood for each Baseline blood glucose levels following consumption of 35.1-50g Carbohydrate

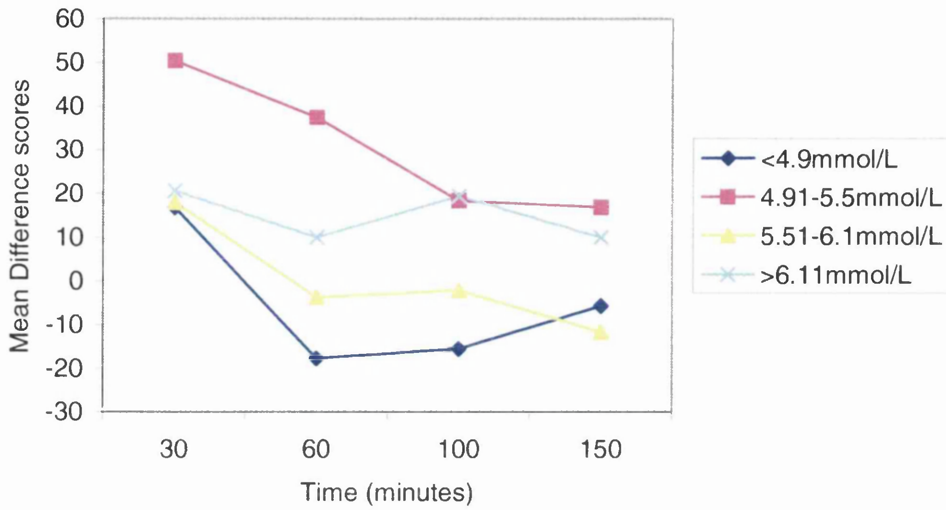
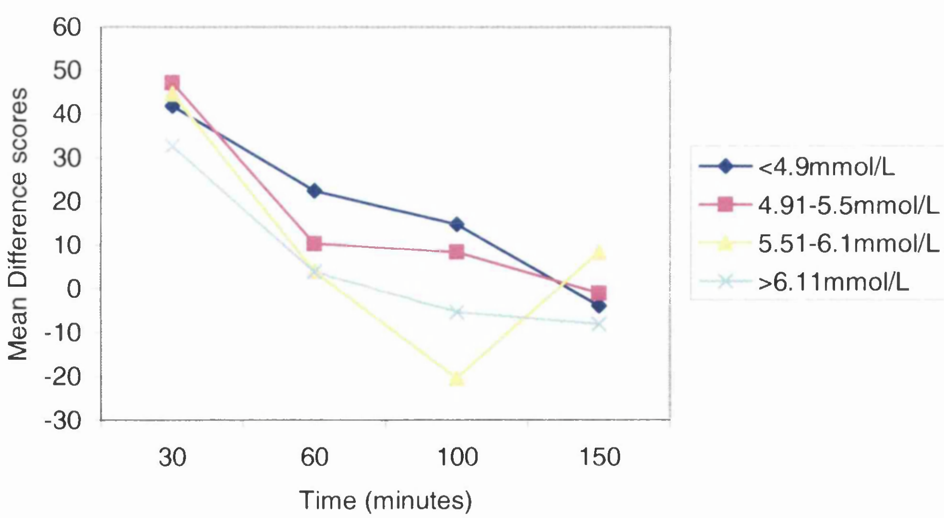


Figure 10.5: Profile of Total mood for each Baseline blood glucose levels following consumption of over 50.1g Carbohydrate



In summary, the amount and type of carbohydrate, and how, following consumption, this interacts with the physiology of the individual is a critical aspect for enhancement in healthy young adult populations with respect to mood and memory.

10.2 CONCLUSIONS

Before reporting the conclusions of the present thesis, one must address the limitation of the findings. Firstly, as all participants were healthy, young adults, the results cannot be generalised to other populations. Yet Kaplan et al., (2000) similarly reported the interaction between the physiology of the indvidual and the amount and type of carbohydrate consumed to be crucial in cognitive enhancement. Furthermore, all participants were female; the results may not apply to males. However, Benton and Owens (1993) failed to demonstrate any sex differences on memory following consumption of a glucose drink.

Secondly, it must be noted that all studies reported the effects following breakfast interventions. Previous research has demonstrated that glucose absorption is susceptible to circadian rhythms. Carroll and Nestel (1973) found that the rate of fall in blood glucose levels to be greatest in the morning, with the rate of glucose absorption from the blood to be slower in the evenings. One must be careful, therefore, before generalising the present findings to other times of the day.

Finally, one must note that glucose tolerance was never assessed in the present thesis. Baseline blood glucose levels are, at best, a crude measurement of an individuals' glucose tolerance, and again any generalisations must be treated with caution.

With these limitations in mind, the following conclusions can be drawn:

1. From the results of the present thesis it is clear that, with respect to measures of mood and memory, carbohydrate was the critical macronutrient. Furthermore, the consumption of SAG resulted in significant memory enhancement over a more prolonged time period (4 hours). In addition, the consumption of 20.1-35g of carbohydrate was suggested to be the optimal dose for mood and cognitive enhancement in a healthy, young adult population with 'normal' glucoregulation.

2. Breakfast consumption in itself significantly enhanced mood, memory and cognitive enhancement. However, the other macronutrients present in the meal failed to affect cognitive enhancement to the same extent as carbohydrate.

3. The results of the present studies indicate that consumption of a breakfast containing 20.1-35g of carbohydrate, with a higher proportion of SAG to RAG, that offers a light breakfast (<300Kcal) to be beneficial for enhanced mood, memory and cognitive functioning. However, consideration must be given to the glucose tolerance and overall physiology of the individual.

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ID NUMBER: ______

MOOD QUESTIONNAIRE

Please place a line through each of the following lines, which best describes how you are feeling **right now**

e.g. HAPPY ____________________ SAD

COMPOSED ________________________________ ANXIOUS

HOSTILE ________________________________ AGREEABLE

ELATED ________________________________ DEPRESSED

UNSURE ________________________________ CONFIDENT

ENERGETIC ________________________________ TIRED

CONFUSED ________________________________ CLEARHEADED

not at all HUNGRY ________________________________ extremely HUNGRY

WORD LIST 1: CHAPTER 2

world
frame
grape
dance
sheet
pearl
train
beard
blade
pound
chief
plane
group
white
brush
point
cross
fight
spoon
sweat
bench
cream
straw
brake
chain
green
faint
guard
sword
snail

WORD LIST 2: CHAPTER 2

badge
train
sheet
point
world
guide
flash
stool
aisle
glove
couch
brake
stick
waist
bloom
faint
guest
witch
prize
straw
wound
snail
frame
ridge
ranch
green
sweat
birth
brute
clown

WORD LIST 1: CHAPTER 3

spice
beast
verse
shape
grape
trail
flame
blush
pearl
spoon
guard
pound
dough
smell
spark
cross
flute
paste
clasp
snake
cream
drill
slope
graph
voice
white
blade
rough
chain
cheek

WORD LIST 2: CHAPTER 3

widow
ulcer
alley
crowd
swamp
plant
chalk
feast
motor
baton
bloom
chief
trash
lemon
fudge
bench
grave
stork
lunch
chest
cabin
hedge
dummy
cider
medal
basin
drain
adder
smile
water

WORD LIST 3: CHAPTER 3

pedal
globe
daisy
brick
flute
linen
spike
paste
beard
shark
prune
cedar
tooth
ankle
queen
chart
plane
belly
organ
arrow
crypt
mixer
honey
river
trunk
couch
ruler
ivory
spade
elbow

WORD LIST 1: CHAPTER 4 & 5

CONCRETE	ABSTRACT
beach	thick
table	meant
rifle	force
earth	brief
horse	clear
chain	reach
paper	least
woman	order
shore	guess
drink	eight
glass	issue
coast	think
truck	worse
child	quick
staff	value

(list was recorded as follows: beach, thick, table, meant…)

WORD LIST 2: CHAPTER 4 & 5

CONCRETE	ABSTRACT
chest	whole
river	moral
light	quiet
blood	claim
metal	under
smile	dozen
phone	right
frame	extra
uncle	south
wheel	allow
knife	learn
crowd	rural
heart	truth
teeth	apart
court	proud

(list was recorded as follows: chest, whole, river, moral…)

WORD LIST 3: CHAPTER 4 & 5

CONCRETE	ABSTRACT
spoke	power
cover	phase
radio	alone
judge	short
flesh	minor
bible	ideal
money	happy
stone	wrote
hotel	carry
water	might
novel	empty
china	event
plant	break
dress	theme
board	style

(list was recorded as follows: spoke, power, cover, phase…)

WORD LIST 1: CHAPTER 6

army	C
bear	C
easy	A
animal	C
health	A
dust	C
ship	C
advice	A
market	C
normal	A
film	C
beauty	A
king	C
rain	C
danger	A
circle	C
kept	A
jury	C
food	C
caught	A
estate	C
method	A
band	C
factor	A
clay	C
hall	C
review	A
ground	C
junior	A
rose	C

(C = Concrete; A = Abstract)

WORD LIST 2: CHAPTER 6

ball	C
seat	C
whom	A
corner	C
effort	A
bank	C
foot	C
search	A
artist	C
minute	A
snow	C
broken	A
fire	C
road	C
appeal	A
engine	C
else	A
wine	C
moon	C
permit	A
letter	C
growth	A
cell	C
chance	A
neck	C
lady	C
manner	A
forest	C
motion	A
hair	C

(C = Concrete; A = Abstract)

WORD LIST 3: CHAPTER 6

soil	C
desk	C
hope	A
coffee	C
escape	A
page	C
wind	C
afraid	A
island	C
series	A
sign	C
hardly	A
rock	C
note	C
pretty	A
battle	C
wish	A
bill	C
farm	C
closer	A
doctor	C
belief	A
park	C
length	A
camp	C
date	C
impact	A
person	C
higher	A
post	C

(C = Concrete; A = Abstract)

WORD LIST 4: CHAPTER 6

book	C
lake	C
idea	A
cousin	C
relief	A
boat	C
roof	C
amount	A
indian	C
latter	A
baby	C
extent	A
test	C
hill	C
memory	A
bridge	C
sent	A
wall	C
poet	C
career	A
dinner	C
fourth	A
song	C
narrow	A
club	C
nose	C
simple	A
father	C
crisis	A
wood	C

(C = Concrete; A = Abstract)

Table 2.1: Two-way ANOVA for Breakfast (breakfast/fast) X Time (0, 30, 60, 105, 150 minutes) for Blood Glucose Levels (mmol/L)

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	940.187	8	117.523	18.017	0.001
Error	1337.166	205	6.523		
Within Participants					
Time	1236.076	4	309.019	210.649	0.001
Breakfast X Time	333.746	32	10.430	7.110	0.001
Error	1202.929	820	1.467		

Table 2.2: One-way ANOVAs for Breakfast (breakfast/fast) at each level of Time

	SS	df	MS	F-ratio	p-value
0 minutes					
Breakfast	27.7235	8	3.467	2.833	0.005
Error	250.829	205	1.224		
30 minutes					
Breakfast	542.164	8	67.771	30.626	0.001
Error	453.626	205	2.213		
60 minutes					
Breakfast	349.780	8	43.722	11.552	0.001
Error	775.887	205	3.785		
105 minutes					
Breakfast	251.059	8	31.382	11.373	0.001
Error	565.654	205	1.759		
150 minutes					
Breakfast	103.195	8	12.899	5.352	0.001
Error	494.099	205	2.410		

Table 2.3: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Time (0, 30, 60, 105, 150 minutes) for Blood Glucose Levels (mmol/L)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	200.279	1	200.279	30.173	0.001
Fat	1.808	1	1.808	0.272	0.602
Protein	42.598	1	42.598	6.418	0.012
Carbohydrate X Fat	116.150	1	116.150	17.499	0.001
Carbohydrate X Protein	14.475	1	14.475	2.181	0.141
Fat X Protein	35.016	1	35.016	5.275	0.023
Carbohydrate X Fat X Protein	5.703	1	5.703	0.859	0.355
Error	1201.412	181	6.638		
Within Participants					
Time	1347.286	4	336.822	219.893	0.001
Carbohydrate X Time	95.603	4	23.901	15.604	0.001
Fat X Time	13.270	4	3.317	2.166	0.071
Protein X Time	25.993	4	6.498	4.242	0.002
Carbohydrate X Fat X Time	27.685	4	6.921	4.519	0.001
Carbohydrate X Protein X Time	2.987	4	0.747	0.488	0.745
Fat X Protein X Time	22.658	4	5.665	3.698	0.005
Carbohydrate X Fat X Protein X Time	12.678	4	3.170	2.069	0.083
Error	1108.987	724	1.532		

Table 2.4: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Time (30, 60, 105, 150 minutes) for Composure ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	2637.987	1	2637.987	1.553	0.214
Fat	559.476	1	559.476	0.329	0.567
Protein	446.706	1	446.706	0.263	0.609
Carbohydrate X Fat	928.357	1	928.357	0.547	0.461
Carbohydrate X Protein	1929.090	1	1929.090	1.136	0.288
Fat X Protein	878.109	1	878.109	0.517	0.473
Carbohydrate X Fat X Protein	7146.147	1	7146.147	4.207	0.042
Error	307468.986	181	1698.724		
Within Participants					
Time	4192.121	3	1397.374	8.482	0.001
Carbohydrate X Time	293.875	3	97.958	0.595	0.619
Fat X Time	989.938	3	329.979	2.003	0.113
Protein X Time	1145.905	3	381.968	2.318	0.075
Carbohydrate X Fat X Time	175.199	3	58.400	0.354	0.786
Carbohydrate X Protein X Time	619.600	3	206.533	1.254	0.290
Fat X Protein X Time	500.885	3	166.962	1.013	0.386
Carbohydrate X Fat X Protein X Time	272.977	3	90.992	0.552	0.647
Error	89458.322	543	164.748		

Table 2.5: Two-way ANOVA for Breakfast (breakfast/fast) X Time (30, 60, 105, 150 minutes) for Composure ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	16060.666	8	2007.583	1.111	0.357
Error	370.496	205	1807.301		
Within Participants					
Time	4876.380	3	1625.460	9.545	0.001
Breakfast X Time	4695.632	24	195.651	1.149	0.284
Error	104734.642	615	170.300		

Table 2.6: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Time (30, 60, 105, 150 minutes) for Agreeability ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	7621.382	1	7621.382	6.765	0.010
Fat	682.435	1	682.435	0.606	0.437
Protein	7111.819	1	7111.819	6.313	0.013
Carbohydrate X Fat	181.483	1	181.483	0.161	0.689
Carbohydrate X Protein	4896.419	1	4896.419	4.346	0.038
Fat X Protein	64.813	1	64.813	0.058	0.811
Carbohydrate X Fat X Protein	175.735	1	175.735	0.156	0.693
Error	203915.897	181	1126.607		
Within Participants					
Time	5768.413	3	1922.804	13.023	0.001
Carbohydrate X Time	1204.702	3	401.567	2.720	0.044
Fat X Time	2.509	3	0.836	0.006	0.999
Protein X Time	279.352	3	93.117	0.631	0.595
Carbohydrate X Fat X Time	308.648	3	102.883	0.697	0.554
Carbohydrate X Protein X Time	353.197	3	117.732	0.797	0.496
Fat X Protein X Time	487.074	3	162.358	1.100	0.349
Carbohydrate X Fat X Protein X Time	194.259	3	64.753	0.439	0.725
Error	80171.228	543	147.645		

Table 2.7: Two-way ANOVA for Breakfast (breakfast/fast) X Time (30, 60, 105, 150 minutes) for Agreeability ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	25282.734	8	3160.342	2.779	0.006
Error	233112.397	205	1137.134		
Within Participants					
Time	6564.702	3	2188.234	14.232	0.001
Breakfast X Time	3061.659	24	127.569	0.830	0.700
Error	94558.808	615	153.754		

Table 2.8: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Time (30, 60, 105, 150 minutes) for Elation ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	1617.677	1	1617.677	2.024	0.157
Fat	60.413	1	60.413	0.076	0.784
Protein	1974.966	1	1974.966	2.472	0.118
Carbohydrate X Fat	1618.698	1	1618.698	2.026	0.156
Carbohydrate X Protein	1180.227	1	1180.227	1.477	0.226
Fat X Protein	1245.543	1	1245.543	1.559	0.213
Carbohydrate X Fat X Protein	387.328	1	387.328	0.485	0.487
Error	144634.244	181	799.084		
Within Participants					
Time	2140.614	3	713.538	8.212	0.001
Carbohydrate X Time	87.599	3	29.200	0.336	0.799
Fat X Time	444.128	3	148.043	1.704	0.165
Protein X Time	150.323	3	50.108	0.577	0.631
Carbohydrate X Fat X Time	103.428	3	34.476	0.397	0.755
Carbohydrate X Protein X Time	2.423	3	0.808	0.009	0.999
Fat X Protein X Time	336.819	3	112.273	1.292	0.276
Carbohydrate X Fat X Protein X Time	140.469	3	46.823	0.539	0.656
Error	47181.433	543	86.890		

Table 2.9: Two-way ANOVA for Breakfast (breakfast/fast) X Time (30, 60, 105, 150 minutes) for Elation ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	8072.489	8	1009.061	1.311	0.240
Error	157831.484	205	769.910		
Within Participants					
Time	2561.820	3	853.940	9.922	0.001
Breakfast X Time	1458.922	24	60.788	0.706	0.848
Error	52932.353	615	86.069		

Table 2.10: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Time (30, 60, 105, 150 minutes) for Confidence ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	194.045	1	194.045	0.162	0.688
Fat	846.272	1	846.272	0.706	0.402
Protein	155.489	1	155.489	0.130	0.719
Carbohydrate X Fat	2391.961	1	2391.961	1.996	0.159
Carbohydrate X Protein	67.952	1	67.952	0.057	0.712
Fat X Protein	1374.714	1	1374.714	1.147	0.286
Carbohydrate X Fat X Protein	241.116	1	241.116	0.201	0.654
Error	216905.673	181	1198.374		
Within Participants					
Time	801.438	3	267.146	2.222	0.085
Carbohydrate X Time	444.850	3	148.283	1.233	0.297
Fat X Time	409.402	3	136.467	1.135	0.334
Protein X Time	215.643	3	71.881	0.598	0.617
Carbohydrate X Fat X Time	372.729	3	124.243	1.033	0.377
Carbohydrate X Protein X Time	61.537	3	20.512	0.171	0.916
Fat X Protein X Time	704.530.	3	234.843	1.953	0.120
Carbohydrate X Fat X Protein X Time	266.098	3	88.699	0.738	0.530
Error	65291.255	543	120.242		

Table 2.11: Two-way ANOVA for Breakfast (breakfast/fast) X Time (30, 60, 105, 150 minutes) for Confidence ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	5604.870	8	700.609	0.483	0.867
Error	297342.313	205	1450.450		
Within Participants					
Time	1161.726	3	387.242	3.147	0.025
Breakfast X Time	2889.811	24	120.409	0.978	0.493
Error	75685.655	615	123.066		

Table 2.12: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Time (30, 60, 105, 150 minutes) for Energy ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	878.644	1	878.644	0.705	0.402
Fat	2996.727	1	2996.727	2.406	0.123
Protein	1178.829	1	1178.829	0.946	0.332
Carbohydrate X Fat	104.915	1	104.915	0.084	0.772
Carbohydrate X Protein	3021.302	1	3021.302	2.426	0.121
Fat X Protein	342.857	1	342.857	0.275	0.600
Carbohydrate X Fat X Protein	3547.700	1	3547.700	2.848	0.093
Error	225442.108	181	1245.537		
Within Participants					
Time	20236.627	3	6745.542	37.663	0.001
Carbohydrate X Time	1483.835	3	494.612	2.762	0.041
Fat X Time	883.993	3	294.664	1.645	0.178
Protein X Time	155.380	3	51.793	0.289	0.833
Carbohydrate X Fat X Time	886.877	3	295.626	1.651	0.177
Carbohydrate X Protein X Time	344.996	3	114.999	0.642	0.588
Fat X Protein X Time	1008.687	3	336.229	1.877	0.132
Carbohydrate X Fat X Protein X Time	405.299	3	135.100	0.754	0.520
Error	972582.610	543	179.102		

Table 2.13: Two-way ANOVA for Breakfast (breakfast/fast) X Time (30, 60, 105, 150 minutes) for Energy ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	16069.317	8	2008.665	1.636	0.116
Error	251721.108	205	1227.908		
Within Participants					
Time	23445.513	3	7815.171	43.877	0.001
Breakfast X Time	5295.778	24	220.657	1.239	0.200
Error	109540.330	615	178.114		

Table 2.14: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Time (30, 60, 105, 150 minutes) for Clearheadedness ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	930.701	1	930.701	0.717	0.398
Fat	107.866	1	107.866	0.083	0.773
Protein	492.015	1	492.015	0.379	0.539
Carbohydrate X Fat	19.452	1	19.452	0.015	0.903
Carbohydrate X Protein	1093.691	1	1093.691	0.843	0.360
Fat X Protein	328.062	1	328.062	0.253	0.616
Carbohydrate X Fat X Protein	4285.539	1	4285.539	3.303	0.071
Error	234.829.740	181	1297.402		
Within Participants					
Time	8475.520	3	2825.173	17.209	0.001
Carbohydrate X Time	1256.656	3	418.885	2.552	0.055
Fat X Time	125.612	3	41.871	0.255	0.858
Protein X Time	421.519	3	140.506	0.856	0.464
Carbohydrate X Fat X Time	207.052	3	69.017	0.420	0.738
Carbohydrate X Protein X Time	54.406	3	18.135	0.110	0.954
Fat X Protein X Time	626.197	3	208.732	1.271	0.283
Carbohydrate X Fat X Protein X Time	70.695	3	25.565	0.144	0.934
Error	89143.972	543	164.169		

Table 2.15: Two-way ANOVA for Breakfast (breakfast/fast) X Time (30, 60, 105, 150 minutes) for Clearheadedness ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	7849.238	8	981.155	0.774	0.626
Error	259788.740	205	1267.262		
Within Participants					
Time	10176.858	3	3392.286	18.878	0.001
Breakfast X Time	2941.920	24	122.580	0.682	0.871
Error	110510.172	615	179.691		

Table 2.16: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Time (30, 60, 105, 150 minutes) for Total Mood ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	12822.617	1	12822.617	0.705	0.402
Fat	6201.509	1	6201.509	0.341	0.560
Protein	37617.999	1	37617.999	2.067	0.152
Carbohydrate X Fat	2188.625	1	2188.625	0.120	0.729
Carbohydrate X Protein	19656.466	1	19656.466	1.080	0.300
Fat X Protein	527.311	1	527.311	0.029	0.865
Carbohydrate X Fat X Protein	36922.480	1	36922.480	2.209	0.156
Error	3293500.806	181	18196.137		
Within Participants					
Time	158864.121	3	2954.707	25.277	0.001
Carbohydrate X Time	7709.256	3	2569.752	1.227	0.299
Fat X Time	8378.277	3	2792.759	1.333	0.263
Protein X Time	3836.838	3	1278.946	0.610	0.608
Carbohydrate X Fat X Time	484.412	3	161.471	0.077	0.972
Carbohydrate X Protein X Time	2824.146	3	941.382	0.449	0.718
Fat X Protein X Time	7920.033	3	2640.011	1.260	0.287
Carbohydrate X Fat X Protein X Time	1921.569	3	640.523	0.306	0.821
Error	1137563.777	543	2094.961		

Table 2.17: Two-way ANOVA for Breakfast (breakfast/fast) X Time (30, 60, 105, 150 minutes) for Total Mood ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	151893.968	8	18986.746	1.021	0.421
Error	3811807.266	205	18594.182		
Within Participants					
Time	193840.373	3	64613.458	29.609	0.001
Breakfast X Time	41111.773	24	1712.991	0.785	0.758
Error	1342057.077	615	2182.207		

Table 2.18: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Time (30, 60, 105, 150 minutes) for Hunger ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	1711.018	1	1711.018	0.980	0.323
Fat	1410.033	1	1410.033	0.808	0.370
Protein	4070.152	1	4070.152	2.332	0.128
Carbohydrate X Fat	56.220	1	56.220	0.032	0.858
Carbohydrate X Protein	531.985	1	531.985	0.305	0.582
Fat X Protein	1989.212	1	1989.212	2.859	0.093
Carbohydrate X Fat X Protein	555.119	1	555.119	0.318	0.573
Error	315872.730	181	1745.153		
Within Participants					
Time	29715.399	3	9905.133	52.895	0.001
Carbohydrate X Time	268.611	3	89.537	0.478	0.698
Fat X Time	413.315	3	137.772	0.736	0.531
Protein X Time	657.072	3	219.024	1.170	0.321
Carbohydrate X Fat X Time	194.910	3	64.970	0.347	0.791
Carbohydrate X Protein X Time	53.013	3	17.671	0.094	0.963
Fat X Protein X Time	99.767	3	33.256	0.178	0.912
Carbohydrate X Fat X Protein X Time	105.053	3	35.018	0.187	0.905
Error	101681.446	543	187.259		

Table 2.19: Two-way ANOVA for Breakfast (breakfast/fast) X Time (30, 60, 105, 150 minutes) for Hunger ratings

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	84466.561	8	10558.320	6.046	0.001
Error	357998.090	205	1746.332		
Within Participants					
Time	35964.787	3	11988.262	64.985	0.001
Breakfast X Time	2442.135	24	101.756	0.552	0.960
Error	113454.406	615	184.479		

Table 2.20: Five-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) X Total Words recalled from the Word Lists (immediate/delayed)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	0.536	1	0.536	0.018	0.894
Fat	77.752	1	77.752	2.578	0.110
Protein	81.203	1	81.203	2.693	0.103
Carbohydrate X Fat	110.207	1	110.207	3.655	0.057
Carbohydrate X Protein	28.371	1	28.371	0.941	0.333
Fat X Protein	62.808	1	62.808	2.083	0.151
Carbohydrate X Fat X Protein	0.264	1	0.264	0.009	0.926
Error	5458.169	181	30.156		
Within Participants					
Session	1321.678	2	660.839	101.018	0.001
Carbohydrate X Session	15.054	2	7.527	1.151	0.318
Fat X Session	2.196	2	1.098	0.168	0.846
Protein X Session	9.526	2	4.763	0.728	0.484
Carbohydrate X Fat X Session	19.566	2	9.783	1.495	0.226
Carbohydrate X Protein X Session	50.717	2	25.359	3.876	0.022
Fat X Protein X Session	1.262	2	0.631	0.096	0.908
Carbohydrate X Fat X Protein X Session	17.850	2	8.925	1.364	0.257
Error	2368.122	362	6.542		
Recall	4378.090	1	4378.090	1221.553	0.001
Carbohydrate X Recall	0.01589	1	0.01589	0.004	0.947
Fat X Recall	5.281	1	5.281	1.473	0.226
Protein X Recall	2.696	1	2.696	0.752	0.387
Carbohydrate X Fat X Recall	1.650	1	1.650	0.460	0.498
Carbohydrate X Protein X Recall	2.572	1	2.572	0.718	0.398
Fat X Protein X Recall	0.234	1	0.234	0.065	0.799
Carbohydrate X Fat X Protein X Recall	0.198	1	0.198	0.055	0.814
Error	648.711	181	3.584		
Session X Recall	186.264	2	93.132	42.684	0.001
Carbohydrate X Session X Recall	5.189	2	2.594	1.189	0.306
Fat X Session X Recall	0.467	2	0.234	0.107	0.899
Protein X Session X Recall	0.244	2	0.122	0.056	0.946
Carbohydrate X Fat X Session X Recall	0.915	2	0.457	0.210	0.811
Carbohydrate X Protein X Session X Recall	4.260	2	2.130	0.976	0.378
Fat X Protein X Session X Recall	1.406	2	0.703	0.322	0.725
Carbohydrate X Fat X Protein X Session X Recall	5.402	2	2.701	1.238	0.291
Error	789.850	362	2.182		

Table 2.21: Five-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) X Concrete Words recalled from the Word Lists (immediate/delayed)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	3.981	1	3.981	0.339	0.561
Fat	3.972	1	3.972	0.338	0.562
Protein	42.453	1	42.453	3.612	0.059
Carbohydrate X Fat	27.572	1	27.572	2.346	0.127
Carbohydrate X Protein	6.040	1	6.040	0.514	0.474
Fat X Protein	20.204	1	20.204	1.719	0.191
Carbohydrate X Fat X Protein	0.221	1	0.221	0.019	0.891
Error	2127.261	181	11.753		
Within Participants					
Session	923.002	2	461.501	134.378	0.001
Carbohydrate X Session	14.158	2	7.079	2.061	0.129
Fat X Session	0.265	2	0.132	0.039	0.962
Protein X Session	8.247	2	4.124	1.201	0.302
Carbohydrate X Fat X Session	10.897	2	5.448	1.586	0.206
Carbohydrate X Protein X Session	25.154	2	12.577	3.662	0.027
Fat X Protein X Session	0.389	2	0.195	0.057	0.945
Carbohydrate X Fat X Protein X Session	1.545	2	0.772	0.225	0.799
Error	1243.229	362	3.434		
Recall	997.894	1	997.894	611.810	0.001
Carbohydrate X Recall	0.06979	1	0.06979	0.043	0.836
Fat X Recall	0.106	1	0.106	0.065	0.799
Protein X Recall	1.610	1	1.610	0.987	0.322
Carbohydrate X Fat X Recall	0.974	1	0.974	0.597	0.441
Carbohydrate X Protein X Recall	0.119	1	0.119	0.073	0.787
Fat X Protein X Recall	0.08095	1	0.08095	0.050	0.824
Carbohydrate X Fat X Protein X Recall	0.190	1	0.190	0.116	0.733
Error	295.220	181	1.631		
Session X Recall	77.437	2	38.719	38.452	0.001
Carbohydrate X Session X Recall	1.886	2	0.943	0.937	0.393
Fat X Session X Recall	0.315	2	0.157	0.156	0.855
Protein X Session X Recall	0.416	2	0.208	0.206	0.814
Carbohydrate X Fat X Session X Recall	0.718	2	0.359	0.356	0.700
Carbohydrate X Protein X Session X Recall	0.244	2	0.122	0.121 0.206	0.886 0.814
Fat X Protein X Session X Recall	0.415	2	0.208		
Carbohydrate X Fat X Protein X Session X Recall	1.993	2	0.997	0.990	0.373
Error	364.511	362	1.007		

Table 2.22: Five-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) X Abstract Words recalled from the Word Lists (immediate/delayed)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	7.626	1	7.626	1.058	0.305
Fat	45.354	1	45.354	6.294	0.013
Protein	5.798	1	5.798	0.805	0.371
Carbohydrate X Fat	29.114	1	29.114	4.040	0.046
Carbohydrate X Protein	8.399	1	8.399	1.166	0.282
Fat X Protein	11.951	1	11.951	1.659	0.199
Carbohydrate X Fat X Protein	1.032	1	1.032	0.143	0.706
Error	1304.233	181	7.206		
Within Participants					
Session	46.913	2	23.456	9.082	0.001
Carbohydrate X Session	8.995	2	4.497	1.741	0.177
Fat X Session	2.003	2	1.002	0.388	0.679
Protein X Session	0.652	2	0.326	0.126	0.882
Carbohydrate X Fat X Session	1.295	2	0.647	0.251	0.778
Carbohydrate X Protein X Session	4.270	2	2.135	0.827	0.438
Fat X Protein X Session	0.573	2	0.286	0.111	0.895
Carbohydrate X Fat X Protein X Session	13.022	2	6.511	2.521	0.082
Error	934.983	362	2.583		
Recall	1197.468	1	1197.468	1023.856	0.001
Carbohydrate X Recall	0.285	1	0.285	0.244	0.622
Fat X Recall	3.989	1	3.989	3.411	0.066
Protein X Recall	0.215	1	0.215	0.184	0.669
Carbohydrate X Fat X Recall	0.07196	1	0.07196	0.062	0.804
Carbohydrate X Protein X Recall	1.677	1	1.677	1.434	0.233
Fat X Protein X Recall	0.317	1	0.317	0.271	0.603
Carbohydrate X Fat X Protein X Recall	0.0005947	1	0.0005947	0.001	0.982
Error	211.692	181	1.170		
Session X Recall	25.191	2	12.595	13.823	0.001
Carbohydrate X Session X Recall	0.968	2	0.484	0.531	0.588
Fat X Session X Recall					
Protein X Session X Recall	0.07543	2	0.03772	0.041	0.959
Carbohydrate X Fat X Session X	0.850	2	0.425	0.466	0.628
Recall	0.217	2	0.108	0.119	0.888
Carbohydrate X Protein X					
Session X Recall	3.036	2	1.518	1.666	0.190
Fat X Protein X Session X Recall					
Carbohydrate X Fat X Protein X	0.722	2	0.361	0.396	0.673
Session X Recall					
Error	1.854	2	0.927	1.017	0.363
	329.846	362	0.911		

Table 2.23: Five-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) X Time taken to recall Word Lists (immediate/delayed)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	1662.803	1	1662.803	1.758	0.187
Fat	23301.453	1	23301.453	24.636	0.001
Protein	13.144	1	13.144	0.014	0.906
Carbohydrate X Fat	4868.958	1	4868.958	5.148	0.024
Carbohydrate X Protein	1438.867	1	1438.867	1.521	0.219
Fat X Protein	523.096	1	523.096	0.553	0.458
Carbohydrate X Fat X Protein	430.009	1	430.009	0.455	0.501
Error	171195.423	181	945.831		
Within Participants					
Session	36108.058	2	18054.029	145.000	0.001
Carbohydrate X Session	594.733	2	297.367	2.388	0.093
Fat X Session	504.250	2	252.125	2.025	0.133
Protein X Session	79.360	2	39.680	0.319	0.727
Carbohydrate X Fat X Session	130.520	2	65.260	0.524	0.593
Carbohydrate X Protein X Session	551.217	2	275.609	2.214	0.111
Fat X Protein X Session	305.148	2	152.574	1.225	0.295
Carbohydrate X Fat X Protein X Session	1615.750	2	807.875	6.488	0.002
Error	45072.855	362	124.511		
Recall	84425.004	1	84425.004	676.674	0.001
Carbohydrate X Recall	473.629	1	473.629	3.796	0.053
Fat X Recall	41.329	1	41.329	0.331	0.566
Protein X Recall	193.775	1	193.775	1.553	0.214
Carbohydrate X Fat X Recall	0.149	1	0.149	0.001	0.972
Carbohydrate X Protein X Recall	158.576	1	158.576	1.271	0.261
Fat X Protein X Recall	84.7136	1	84.7136	0.679	0.411
Carbohydrate X Fat X Protein X Recall	79.133	1	79.133	0.634	0.427
Error	22582.413	181	124.765		
Session X Recall	925.138	2	462.569	5.902	0.003
Carbohydrate X Session X Recall	243.794	2	121.897	1.555	0.213
Fat X Session X Recall	335.514	2	167.3757	2.141	0.119
Protein X Session X Recall	350.189	2	175.095	2.234	0.109
Carbohydrate X Fat X Session X Recall	243.019	2	121.509	1.550	0.214
Carbohydrate X Protein X Session X Recall	808.715	2	404.357	5.159	0.006
Fat X Protein X Session X Recall	71.989	2	35.995	0.459	0.632
Carbohydrate X Fat X Protein X Session X Recall	65.588	2	32.794	0.418	0.658
Error	28370.473	362	78.371		

Table 2.24: Five-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) X Lamps (1, 2, 4, 8) for Decision Times on the Hick Paradigm

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	15219.366	1	15219.366	0.814	0.368
Fat	1512.469	1	1512.469	0.081	0.776
Protein	7885.064	1	7885.064	0.422	0.517
Carbohydrate X Fat	1135.381	1	1135.381	0.061	0.806
Carbohydrate X Protein	36845.361	1	36845.361	1.972	0.162
Fat X Protein	23724.715	1	23724.715	1.270	0.261
Carbohydrate X Fat X Protein	8387.542	1	8387.542	0.449	0.504
Error	3083184.435	165	18685.966		
Within Participants					
Session	4450.889	2	2225.445	1.309	0.272
Carbohydrate X Session	3200.199	2	1600.099	0.941	0.391
Fat X Session	179.850	2	89.925	0.053	0.949
Protein X Session	8529.276	2	4264.638	2.508	0.083
Carbohydrate X Fat X Session	7038.252	2	3519.126	2.069	0.128
Carbohydrate X Protein X Session	2023.656	2	1011.828	0.595	0.552
Fat X Protein X Session	1794.703	2	97.351	0.528	0.590
Carbohydrate X Fat X Protein X Session	695.384	2	347.692	0.204	0.815
Error	561221.431	330	1700.671		
Lamps	2828074.385	3	942691.462	487.198	0.001
Carbohydrate X Lamps	314.243	3	104.748	0.054	0.983
Fat X Lamps	9529.715	3	3176.572	1.642	0.179
Protein X Lamps	7124.049	3	2374.683	1.227	0.299
Carbohydrate X Fat X Lamps	2798.374	3	932.791	0.482	0.695
Carbohydrate X Protein X Lamps	7564.344	3	2521.448	1.303	0.273
Fat X Protein X Lamps					
Carbohydrate X Fat X Protein X	2225.348	3	741.783	0.383	0.765
Lamps	5471.544	3	1823.848	0.943	0.420
Error					
Session X Lamps	957788.689	495	1934.927		
Carbohydrate X Session X	2070.545	6	345.091	0.407	0.875
Lamps	5068.713	6	844.786	0.995	0.427
Fat X Session X Lamps					
Protein X Session X Lamps	2227.006	6	371.168	0.437	0.854
Carbohydrate X Fat X Session X	1012.104	6	168.684	0.199	0.977
Lamps	2799.574	6	466.596	0.550	0.770
Carbohydrate X Protein X					
Session X Lamps	8135.381	6	1355.897	1.598	0.144
Fat X Protein X Session X Lamps					
Carbohydrate X Fat X Protein X	2685.031	6	447.505	0.527	0.788
Session X Lamps					
Error	3014.410	6	502.402	0.592	0.737
	840161.130	990	848.648		

Table 2.25: Five-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) X Lamps (1, 2, 4, 8) for Movement Times on the Hick Paradigm

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	30263.742	1	30263.742	1.473	0.227
Fat	16185.623	1	16185.623	0.788	0.376
Protein	1121.883	1	1121.883	0.055	0.816
Carbohydrate X Fat	5640.793	1	5640.793	0.275	0.601
Carbohydrate X Protein	77.119	1	77.119	0.004	0.951
Fat X Protein	48042.737	1	48042.737	2.338	0.128
Carbohydrate X Fat X Protein	6262.392	1	6262.392	0.305	0.582
Error	3390605.473	165	20549.124		
Within Participants					
Session	6872.579	2	3436.290	1.831	0.162
Carbohydrate X Session	4238.007	2	2119.004	1.129	0.325
Fat X Session	3340.626	2	1670.313	0.890	0.412
Protein X Session	1076.543	2	538.272	0.287	0.751
Carbohydrate X Fat X Session	4007.270	2	2003.635	1.068	0.345
Carbohydrate X Protein X Session	16523.622	2	8261.811	4.402	0.013
Fat X Protein X Session	680.082	2	340.041	0.181	0.834
Carbohydrate X Fat X Protein X Session	11906.57	2	5953.278	3.172	0.043
Error	619303.165	330	1876.676		
Lamps	149379.442	3	49793.147	100.605	0.001
Carbohydrate X Lamps	913.652	3	304.551	0.615	0.605
Fat X Lamps	4848.138	3	1616.046	3.265	0.021
Protein X Lamps	1925.763	3	641.921	1.297	0.275
Carbohydrate X Fat X Lamps	3567.762	3	1189.254	2.403	0.067
Carbohydrate X Protein X Lamps	8418.246	3	2806.082	5.670	0.001
Fat X Protein X Lamps					
Carbohydrate X Fat X Protein X	7897.051	3	2632.350	5.319	0.001
Lamps	2872.149	3	957.383	1.934	0.123
Error					
Session X Lamps	244994.006	495	494.937		
Carbohydrate X Session X	4892.784	6	815.464	2.306	0.032
Lamps	4824.912	6	804.152	2.274	0.035
Fat X Session X Lamps					
Protein X Session X Lamps	3848.677	6	641.446	1.814	0.093
Carbohydrate X Fat X Session X	400.373	6	66.729	0.189	0.980
Lamps	1786.560	6	297.760	0.842	0.538
Carbohydrate X Protein X					
Session X Lamps	2329.036	6	388.173	1.098	0.362
Fat X Protein X Session X Lamps					
Carbohydrate X Fat X Protein X	1173.576	6	195.596	0.553	0.768
Session X Lamps					
Error	1776.378	6	296.063	0.837	0.541
	350148.477	990	353.685		

Table 2.26: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) for Intercept values on the Hick Paradigm

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	6458.499	1	6458.499	1.999	0.159
Fat	2350.286	1	2350.286	0.727	0.395
Protein	0.141	1	0.141	0.000	0.995
Carbohydrate X Fat	916.177	1	916.177	0.284	0.595
Carbohydrate X Protein	2626.815	1	2626.815	0.813	0.369
Fat X Protein	4140.873	1	4140.873	1.282	0.259
Carbohydrate X Fat X Protein	43.405	1	43.405	0.013	0.908
Error	533144.900	165	3231.181		
Within Participants					
Session	402.612	2	201.306	0.301	0.740
Carbohydrate X Session	2598.455	2	1299.228	1.941	0.145
Fat X Session	1352.887	2	676.443	1.011	0.365
Protein X Session	1899.678	2	949.839	1.419	0.243
Carbohydrate X Fat X Session	2965.936	2	1482.968	2.216	0.111
Carbohydrate X Protein X Session	114.255	2	57.128	0.085	0.918
Fat X Protein X Session	852.532	2	426.266	0.637	0.530
Carbohydrate X Fat X Protein X Session	411.540	2	205.770	0.307	0.736
Error	820880.158	330	669.334		

Table 2.27: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) for Slope values on the Hick Paradigm

	SS	Df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	35.234	1	35.234	689.181	0.001
Fat	1480.444	1	1480.444	0.044	0.834
Protein	1347.864	1	1347.864	1.843	0.176
Carbohydrate X Fat	250.226	1	250.226	1.678	0.197
Carbohydrate X Protein	1338.306	1	1338.306	0.312	0.577
Fat X Protein	220.789	1	220.789	1.666	0.199
Carbohydrate X Fat X Protein	1063.326	1	1063.326	0.275	0.601
Error	132512.194	165	803.104	1.324	0.252
Within Participants					
Session	0.101	2	0.005067	0.000	1.000
Carbohydrate X Session	856.763	2	428.381	1.681	0.188
Fat X Session	230.510	2	115.255	0.452	0.637
Protein X Session	8.938	2	4.469	0.018	0.983
Carbohydrate X Fat X Session	340.147	2	170.073	0.667	0.514
Carbohydrate X Protein X Session	305.430	2	152.715	0.599	0.550
Fat X Protein X Session	226.335	2	113.168	0.444	0.642
Carbohydrate X Fat X Protein X Session	405.075	2	202.538	0.795	0.453
Error	84120.717	330	254.911		

Table 2.28: Four-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) for Intra-Individual Variability values on the Hick Paradigm

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	747.088	1	747.088	0.029	0.866
Fat	51361.777	1	51361.777	1.974	0.162
Protein	10515.406	1	10515.406	0.404	0.526
Carbohydrate X Fat	12747.943	1	12747.943	0.490	0.485
Carbohydrate X Protein	58088.226	1	58088.226	2.233	0.137
Fat X Protein	27303.976	1	27303.976	1.050	0.307
Carbohydrate X Fat X Protein	3539.975	1	3539.975	0.136	0.713
Error	4292442.879	165	26014.805		
Within Participants					
Session	4779.784	2	2389.892	0.313	0.732
Carbohydrate X Session	14422.204	2	7211.102	0.944	0.390
Fat X Session	17207.712	2	8603.856	1.126	0.326
Protein X Session	7977.561	2	3988.780	0.522	0.594
Carbohydrate X Fat X Session	5460.184	2	2730.092	0.357	0.700
Carbohydrate X Protein X Session	13033.915	2	6516.958	0.853	0.427
Fat X Protein X Session	67644.153	2	33822.076	4.426	0.013
Carbohydrate X Fat X Protein X Session	4672.394	2	2336.197	0.306	0.737
Error	252.1989.618	330	7642.393		

Table 2.29: Five-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) X Minute (1, 2, 3, 4, 5) for Correct responses on the RIPTs

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	5.664	1	5.664	0.249	0.618
Fat	33.215	1	33.215	1.461	0.228
Protein	4.985	1	4.985	0.219	0.640
Carbohydrate X Fat	10.592	1	10.592	0.466	0.496
Carbohydrate X Protein	26.074	1	26.074	1.147	0.286
Fat X Protein	17.530	1	17.530	0.771	0.381
Carbohydrate X Fat X Protein	44.159	1	44.159	1.942	0.165
Error	4069.690	179	22.736		
Within Participants					
Session	57.187	2	28.594	9.876	0.001
Carbohydrate X Session	7.853	2	3.927	1.356	0.259
Fat X Session	6.061	2	3.031	1.047	0.352
Protein X Session	8.795	2	4.397	1.519	0.220
Carbohydrate X Fat X Session	6.624	2	3.312	1.144	0.320
Carbohydrate X Protein X Session	2.717	2	1.359	0.469	0.626
Fat X Protein X Session	2.966	2	1.483	0.512	0.600
Carbohydrate X Fat X Protein X Session	2.295	2	1.147	0.396	0.673
Error	1036.552	358	2.895		
Minutes	1045.202	4	261.301	110.027	0.001
Carbohydrate X Minutes	2.517	4	0.629	0.265	0.900
Fat X Minutes	10.909	4	2.727	1.148	0.333
Protein X Minutes	0.376	4	0.09408	0.040	0.997
Carbohydrate X Fat X Minutes	4.061	4	1.015	0.427	0.789
Carbohydrate X Protein X Minutes	5.845	4	1.461	0.615	0.652
Fat X Protein X Minutes	5.768	4	1.442	0.607	0.658
Carbohydrate X Fat X Protein X Minutes	7.395	4	1.849	0.778	0.539
Error	1700.412	716	2.375		
Session X Minutes	16.705	8	2.088	1.252	0.265
Carbohydrate X Session X Minutes	52.542	8	0.693	0.415	0.912
Fat X Session X Minutes	11.047	8	1.381	0.828	0.578
Protein X Session X Minutes	11.440	8	1.430	0.857	0.552
Carbohydrate X Fat X Session X Minutes	5.691	8	0.711	0.426	0.906
Carbohydrate X Protein X Session X Minutes	23.859	8	2.982	1.787	0.075
Fat X Protein X Session X Minutes	9.841	8	1.230	0.737	0.659
Carbohydrate X Fat X Protein X Session X Minutes	20.253	8	2.532	1.517	0.146
Error	2389.302	1432	1.669		

Table 2.30: Five-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) X Minute (1, 2, 3, 4, 5) for Wrong responses on the RIPTs

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	33.547	1	33.547	0.247	0.620
Fat	0.0003608	1	0.0003608	0.001	0.999
Protein	15.352	1	15.352	0.113	0.737
Carbohydrate X Fat	38.300	1	38.300	0.282	0.596
Carbohydrate X Protein	0.245	1	0.245	0.002	0.966
Fat X Protein	32.327	1	32.327	0.238	0.626
Carbohydrate X Fat X Protein	0.02825	1	0.02825	0.001	0.989
Error	24336.476	179	135.958		
Within Participants					
Session	185.993	2	92.997	9.679	0.001
Carbohydrate X Session	2.655	2	1.328	0.138	0.871
Fat X Session	39.753	2	19.877	2.069	0.128
Protein X Session	13.878	2	6.939	0.722	0.486
Carbohydrate X Fat X Session	31.891	2	15.946	1.660	0.192
Carbohydrate X Protein X Session	42.966	2	21.483	2.236	0.108
Fat X Protein X Session	29.713	2	14.856	1.546	0.214
Carbohydrate X Fat X Protein X Session	65.876	2	32.938	3.428	0.034
Error	3439.811	358	9.608		
Minutes	28.832	4	7.208	1.784	0.130
Carbohydrate X Minutes	13.069	4	3.267	0.808	0.520
Fat X Minutes	26.893	4	6.723	1.664	0.157
Protein X Minutes	4.006	4	1.002	0.248	0.911
Carbohydrate X Fat X Minutes	35.828	4	8.957	2.216	0.066
Carbohydrate X Protein X Minutes	15.739	4	3.935	0.974	0.421
Fat X Protein X Minutes	14.846	4	3.712	0.918	0.453
Carbohydrate X Fat X Protein X Minutes	10.018	4	2.504	0.620	0.649
Error	2893.474	716	4.041		
Session X Minutes	184.407	8	23.051	6.092	0.001
Carbohydrate X Session X Minutes	20.407	8	2.551	0.674	0.715
Fat X Session X Minutes	39.608	8	4.951	1.308	0.235
Protein X Session X Minutes	67.470	8	8.4734	2.229	0.023
Carbohydrate X Fat X Session X Minutes	15.6424	8	1.953	0.516	0.845
Carbohydrate X Protein X Session X Minutes	28.520	8	3.565	0.942	0.480
Fat X Protein X Session X Minutes	47.118	8	5.890	1.557	0.133
Carbohydrate X Fat X Protein X Session X Minutes	33.175	8	4.147	1.096	0.363
Error	5418.434	1432	3.784		

Table 2.31: Five-way ANOVA for Carbohydrate (25g, 60g) X Fat (1g, 16g) X Protein (2g, 10g) X Session (1, 2, 3, 4) X Minute (1, 2, 3, 4, 5) for Reaction Times on the RIPTs

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	2886.451	1	2886.451	0.036	0.849
Fat	52966.474	1	52966.474	0.667	0.415
Protein	235909.906	1	235909.906	2.972	0.086
Carbohydrate X Fat	75531.471	1	75531.471	0.951	0.331
Carbohydrate X Protein	137019.854	1	137019.854	1.726	0.191
Fat X Protein	3536.770	1	3536.770	0.045	0.833
Carbohydrate X Fat X Protein	98811.739	1	98811.739	1.245	0.266
Error	14210087.31	179	79385.963		
Within Participants					
Session	955170.989	2	477585.495	13.895	0.001
Carbohydrate X Session	5319.546	2	2659.773	0.077	0.926
Fat X Session	4408.151	2	2204.076	0.064	0.938
Protein X Session	72237.926	2	36118.963	1.051	0.351
Carbohydrate X Fat X Session	36723.677	2	18361.839	0.534	0.587
Carbohydrate X Protein X Session	49692.841	2	24846.421	0.723	0.486
Fat X Protein X Session	12887.238	2	6443.619	0.187	0.829
Carbohydrate X Fat X Protein X Session	1969189.124	2	98094.562	2.854	0.059
Error	12305122.45	358	34371.850		
Minutes	764694.785	4	191173.696	5.979	0.001
Carbohydrate X Minutes	48329.782	4	12082.446	0.378	0.825
Fat X Minutes	75022.751	4	18755.688	0.587	0.672
Protein X Minutes	437456.185	4	109364.046	3.420	0.009
Carbohydrate X Fat X Minutes	94575.416	4	23643.854	0.739	0.565
Carbohydrate X Protein X Minutes	166127.800	4	41531.950	1.299	0.269
Fat X Protein X Minutes	97066.397	4	24266.599	0.759	0.552
Carbohydrate X Fat X Protein X Minutes	296605.715	4	74151.429	2.319	0.056
Error	22895394.65	716	31976.808		
Session X Minutes	362399.574	8	45299.947	1.642	0.108
Carbohydrate X Session X Minutes	342205.392	8	42775.674	1.550	0.135
Fat X Session X Minutes	70501.855	8	8812.732	0.319	0.959
Protein X Session X Minutes	201712.050	8	25214.006	0.914	0.504
Carbohydrate X Fat X Session X Minutes	190636.674	8	23829.584	0.864	0.547
Carbohydrate X Protein X Session X Minutes	106480.683	8	13310.085	0.482	0.869
Fat X Protein X Session X Minutes	133249.613	8	16656.202	0.604	0.775
Carbohydrate X Fat X Protein X Session X Minutes	268054.348	8	33506.794	1.214	0.286
Error	39509296.56	1432	27590.291		

Table 3.1: One-way ANOVAs for Macronutrients for each level of Carbohydrate (20.1-35g, 35.1-50g, 50.1g+) with respect to Mood

	SS	df	MS	F-ratio	p-value
Between Participants					
Fat	3334.823	3	111.608	36.114	0.001
Error	16867.636	548	30.780		
Between Participants					
Protein	950.454	3	316.818	27.954	0.001
Error	6210.760	548	11.334		
Between Participants					
Fibre	18.516	3	6.172	0.661	0.001
Error	5117.898	548	9.339		
Between Participants					
Caloric Intake	1771204.2	3	590401.402	221.493	0.001
Error	14600724.0	548	2665.555		

Table 3.2: Two-way ANOVA for Percentage of Total Caloric Energy from Protein X Time (30, 60, 90/100, 150/120 minutes) with respect to Mood

	SS	df	MS	F-ratio	p-value
Between Participants					
Percentage	76381.318	6	12730.220	0.721	0.633
Error	9901624.477	561	17649.955		
Within Participants					
Time	223103.157	3	74367.719	36.458	0.001
Percentage X Time	86354.916	18	4797.495	2.352	0.001
Error	3432999.901	1683	2039.810		

Table 3.3: One-way ANOVAs for Macronutrients for each level of Fat (>2.5g, 7-12g, 16g+) with respect to Mood

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	2107.089	2	1053.544	6.239	0.002
Error	92705.079	549	168.862		
Between Participants					
Protein	981.522	2	490.761	43.599	0.001
Error	6179.691	549	11.256		
Between Participants					
Fibre	596.473	2	298.237	36.065	0.001
Error	4539.941	549	8.269		
Between Participants					
Caloric Intake	1538361.4	2	769180.682	249.344	0.001
Error	1693566.8	549	3084.821		

Table 3.4: One-way ANOVAs for Macronutrients for each level of Fibre (>2g, 2.01-5g, 5.01-7g, 12g+) with respect to Mood

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	4004.187	3	1334.729	8.055	0.001
Error	90807.980	548	165.708		
Between Participants					
Fat	4636.381	3	1545.460	54.408	0.001
Error	15566.077	548	28.405		
Between Participants					
Protein	2328.989	3	776.330	88.040	0.001
Error	4832.225	548	8.818		
Between Participants					
Caloric Intake	412826.91	3	137608.969	26.750	0.001
Error	2819101.3	548	5144.345		

Table 3.5: Two-way ANOVA for Caloric Intake (0, >100Kcal, 101-200Kcal, 201-300Kcal, 301Kcal+) X Time (30, 60, 90/100, 120/150 minutes) with respect to Mood

	SS	df	MS	F-ratio	p-value
Between Participants					
Caloric Intake	185493.871	4	46373.468	2.710	0.029
Error	11054410.147	646	17112.090		
Within Participants					
Time	213181.599	3	71060.533	36.724	0.001
Caloric Intake X Time	47084.273	12	3923.689	2.028	0.019
Error	3749990.151	1938	1934.979		

Table 3.6: One-way ANOVAs for Macronutrients for each level of Carbohydrate (20.1-35g, 35.1-50g, 50.1g+) with respect to Hunger

	SS	df	MS	F-ratio	p-value
Between Participants					
Fat	3334.823	3	1111.608	36.114	0.001
Error	16867.636	548	30.780		
Between Participants					
Protein	950.454	3	316.818	27.954	0.001
Error	6210.760	548	11.334		
Between Participants					
Fibre	18.516	3	6.172	0.661	0.001
Error	5117.898	548	9.339		
Between Participants					
Caloric Intake	1771204.2	3	590401.402	221.493	0.001
Error	1460724.0	548	2335.555		

Table 3.7: One-way ANOVAs for Blood Glucose Levels for each level of Carbohydrate (20.1-35g, 35.1-50g, 50.1g+) with respect to Hunger

	SS	df	MS	F-ratio	p-value
Between Participants					
0mins	14.573	3	4.858	4.774	0.003
Error	557.598	548	1.018		
Between Participants					
30mins	238.915	3	79.638	30.576	0.001
Error	1427.328	548	2.605		
Between Participants					
60mins	213.260	3	71.087	23.848	0.001
Error	1633.469	548	2.981		
Between Participants					
90/100mins	180.633	3	60.211	25.483	0.001
Error	1294.826	548	2.363		
Between Participants					
120/150mins	36.240	3	12.140	6.340	0.001
Error	1049.365	548	1.915		

Table 3.8: One-way ANOVAs for Macronutrients for each level of Fat (>2.5g, 7-12g, 16g+) with respect to Hunger

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	2107.089	2	1053.544	6.239	0.002
Error	92705.079	549	168.862		
Between Participants					
Protein	981.522	2	490.761	43.599	0.001
Error	6179.691	549	11.256		
Between Participants					
Fibre	596.473	2	298.237	36.065	0.001
Error	4539.941	549			
Between Participants					
Caloric Intake	1538361.4	2	769180.682	249.344	0.001
Error	1693566.8	549			

Table 3.9: Two-way ANOVA for Caloric Intake (0, >100Kcal, 101-200Kcal, 201-300Kcal, 301Kcal+) X Time (30, 60, 90/100, 120/150 minutes) with respect to Hunger

	SS	df	MS	F-ratio	p-value
Between Participants					
Caloric Intake	352972.791	4	88243.198	38.383	0.001
Error	1485182.023	646	2299.043		
Within Participants					
Time	58077.544	3	19359.181	100.427	0.001
Caloric Intake X Time	2014.382	12	167.865	0.871	0.577
Error	373584.665	1938	192.768		

Table 4.1: One-way ANOVAs for Macronutrients for each level of Carbohydrate (20.1-35g, 35.1-50g, 50.1g+)

	SS	df	MS	F-ratio	p-value
Between Participants					
Fat	3147.359	2	1573.679	38.017	0.001
Error	13535.836	327	41.394		
Between Participants					
Protein	500.113	2	250.057	23.762	0.001
Error	3441.076	327	10.523		
Between Participants					
Fibre	85.708	3	42.854	25.450	0.001
Error	550.631	327	1.684		
Between Participants					
Caloric Intake	979781.65	3	489890.827	131.512	0.001
Error	1218100.0	327	3725.076		

Table 4.2: Correlations between the Macronutrients with respect to the Memory Tests (N=330)

	Carbohydrate	Fat	Protein	Fibre	Caloric Intake	Glucose Load
Carbohydrate	---------------	-----------	-----------	-----------	-----------	-----------
Fat	r = 0.102 0.064	-----------	-----------	-----------	-----------	-----------
Protein	r = -0.035 0.525	r = -0.138 0.012 *	-----------	-----------	-----------	-----------
Fibre	r = 0.030 0.592	r = 0.119 0.031 *	r = 0.075 0.176	-----------	-----------	-----------
Caloric Intake	r = 0.667 0.001 ***	r = 0.787 0.001 ***	r = 0.050 0.361	r = 0.100 0.071	-----------	-----------
Glucose Load	r = 0.943 0.001 ***	r = 0.215 0.001 ***	r = -0.104 0.058	r = -0.005 0.935	r = 0.694 0.001 ***	-----------

*** p<0.001; ** p=0.001; * p<0.05

Table 4.3: One-way ANOVAs for Macronutrients for each level of Fat (>2g, 11g+)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	655.222	1	655.222	3.666	0.056
Error	58621.521	328	178.724		
Between Participants					
Protein	47.165	1	47.165	3.973	0.047
Error	3894.025	328	11.872		
Between Participants					
Fibre	0.889	1	0.889	0.459	0.499
Error	635.450	328	1.937		
Between Participants					
Caloric Intake	1368671.9	1	1368671.940	541.388	0.000
Error	829209.67	328	2528.078		

Table 4.4: One-way ANOVAs for Macronutrients for each level of Fibre (>2g, 2.01-4g, 4.01-6g)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	855.187	2	427.593	2.393	0.093
Error	58421.556	327	178.659		
Between Participants					
Fat	3268.293	2	1634.146	39.834	0.001
Error	13414.902	327	41.024		
Between Participants					
Protein	696.632	3	348.316	35.105	0.001
Error	3244.557	327	9.922		
Between Participants					
Caloric Intake	191076.26	3	95538.131	15.568	0.001
Error	2006805.4	327	6137.019		
Between Participants					
Glycaemic Load	96114098	3	48057049.020	26.446	0.001
Error	594000000	327	1817182.860		

Table 4.5: One-way ANOVA for Carbohydrate (>20g, 20.1-35g, 35.1-50g, 50.1g+) for Immediate Words recalled from the first Word List

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	0.016	2	0.008	0.001	0.999
Error	2522.290	327	7.713		

Table 4.6: Three-way ANOVA for Carbohydrate (20.1-35g, 35.1-50g, 50.1g+) X Session (1, 2, 3) X Total Words recalled from the Word Lists (immediate/delayed)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	2.160	2	1.080	0.035	0.966
Error	10230.921	327	31.287		
Within Participants					
Session	2178.516	2	1089.258	175.120	0.001
Carbohydrate X Session	66.865	4	16.716	2.687	0.030
Error	4067.934	654	6.220		
Recall	7283.259	1	7283.259	2250.917	0.001
Carbohydrate X Recall	1.073	2	0.536	0.166	0.847
Error	1058.069	327	3.236		
Session X Recall	340.153	2	170.077	81.668	0.001
Carbohydrate X Session X Recall	6.535	4	1.634	0.784	0.535
Error	1361.973	654	2.083		

Table 4.7: Three-way ANOVA for Carbohydrate (20.1-35g, 35.1-50g, 50.1g+) X Session (1, 2, 3) X Time taken to recall Word Lists (immediate/delayed)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	34663.052	2	17331.526	19.910	0.001
Error	284648.496	327	870.485		
Within Participants					
Session	42634.204	2	21317.102	220.837	0.001
Carbohydrate X Session	4661.183	4	1165.296	12.072	0.001
Error	63129.616	654	96.528		
Recall	120890.444	1	120890.444	1205.423	0.001
Carbohydrate X Recall	2581.901	2	1290.951	12.872	0.001
Error	32794.443	327	100.289		
Session X Recall	710.479	2	355.240	5.906	0.003
Carbohydrate X Session X Recall	784.533	4	196.133	3.261	0.012
Error	39337.627	654	60.149		

Table 4.8: Three-way ANOVA for Protein (>2g, 6-8g, 8.01-10g) X Session (1, 2, 3) X Total Words recalled from the Word Lists (immediate/delayed) for those with Poor Memory

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	9.162	2	4.581	0.458	0.635
Error	770.963	77	10.013		
Within Participants					
Session	138.466	2	69.233	20.181	0.001
Breakfast X Session	17.448	4	4.362	1.272	0.284
Error	528.302	154	3.431		
Recall	1098.874	1	1098.874	605.835	0.001
Breakfast X Recall	6.203	2	3.101	1.710	0.188
Error	139.664	77	1.814		
Session X Recall	129.749	2	64.874	39.339	0.001
Breakfast X Session X Recall	6.173	4	1.543	0.936	0.445
Error	253.961	154	1.649		

Table 4.9: Three-way ANOVA for Protein (>2g, 6-8g, 8.01-10g) X Session (1, 2, 3) X Time taken to recall Word Lists (immediate/delayed) for those with Poor Memory

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	3417.771	2	1708.886	2.990	0.056
Error	44012.094	77	571.586		
Within Participants					
Session	4710.020	2	2355.010	26.228	0.001
Breakfast X Session	423.371	4	105.843	1.179	0.322
Error	13827.445	154	89.789		
Recall	13057.792	1	13057.792	137.878	0.001
Breakfast X Recall	261.866	2	130.933	1.383	0.257
Error	7292.299	77	94.705		
Session X Recall	280.347	2	140.174	2.483	0.087
Breakfast X Session X Recall	214.491	4	53.623	0.950	0.437
Error	8693.225	154	56.450		

Table 4.10: Three-way ANOVA for Fat (>2g, 11g+) X Session (1, 2, 3) X Total Words recalled from the Word Lists (immediate/delayed) for those with Poor Memory

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	1.534	1	1.534	0.154	0.696
Error	778.591	78	9.982		
Within Participants					
Session	167.373	2	83.687	24.079	0.001
Breakfast X Session	3.573	2	1.787	0.514	0.599
Error	542.177	156	3.475		
Recall	1502.578	1	1502.578	839.867	0.001
Breakfast X Recall	6.320	1	6.320	3.532	0.064
Error	139.547	78	1.789		
Session X Recall	153.017	2	76.509	46.453	0.001
Breakfast X Session X Recall	3.201	2	1.600	0.972	0.381
Error	256.933	256	1.647		

Table 4.11: Three-way ANOVA for Fat (>2g, 11g+) X Session (1, 2, 3) X Time taken to recall Word Lists (immediate/delayed) for those with Poor Memory

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	39.786	1	39.786	0.065	0.799
Error	47390.079	78	607.565		
Within Participants					
Session	6854.742	2	3427.371	38.191	0.001
Breakfast X Session	251.025	2	125.513	1.399	0.250
Error	13999.791	156	89.742		
Recall	18220.341	1	18220.341	198.245	0.001
Breakfast X Recall	385.308	1	385.308	4.192	0.044
Error	7168.856	78	91.908		
Session X Recall	234.857	2	117.428	2.112	0.124
Breakfast X Session X Recall	234.890	2	117.445	2.113	0.124
Error	8672.827	156	55.595		

Table 4.12: Three-way ANOVA for Fibre (>2g, 2.01-4g, 4.01-6g) X Session (1, 2, 3) X Total Words recalled from the Word Lists (immediate/delayed) for those with Poor Memory

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	42.378	2	21.189	2.212	0.116
Error	737.747	77	9.581		
Within Participants					
Session	164.429	2	82.214	24.620	0.001
Breakfast X Session	31.489	4	7.872	2.357	0.056
Error	514.261	154	3.339		
Recall	955.761	1	955.761	512.518	0.001
Breakfast X Recall	2.274	2	1.137	0.610	0.546
Error	143.592	77	1.865		
Session X Recall	86.038	2	43.019	25.715	0.001
Breakfast X Session X Recall	2.503	4	0.626	0.374	0.827
Error	257.631	154	1.673		

Table 4.13: Three-way ANOVA for Fibre (>2g, 2.01-4g, 4.01-6g) X Session (1, 2, 3) X Time taken to recall Word Lists (immediate/delayed) for those with Poor Memory

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	7603.352	2	3801.676	7.350	0.001
Error	39826.513	77	517.227		
Within Participants					
Session	2417.089	2	1208.544	14.203	0.001
Breakfast X Session	1146.599	4	286.650	3.369	0.011
Error	13104.217	154	85.092		
Recall	9976.672	1	9976.672	104.575	0.001
Breakfast X Recall	208.230	2	104.115	1.091	0.341
Error	7345.934	77	95.402		
Session X Recall	209.140	2	104.570	1.855	0.160
Breakfast X Session X Recall	228.650	4	57.162	1.014	0.402
Error	8679.067	154	56.358		

Table 4.14: Three-way ANOVA for Caloric Intake (101-200Kcal, 201-300Kcal, 301Kcal+) X Session (1, 2, 3) X Total Words recalled from the Word Lists (immediate/delayed) for those with Poor Memory

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	2.731	2	1.366	0.135	0.874
Error	777.394	77	10.096		
Within Participants					
Session	158.040	2	79.020	22.533	0.001
Breakfast X Session	5.692	4	1.423	0.406	0.804
Error	540.058	154	3.507		
Recall	1505.309	1	1505.309	893.247	0.001
Breakfast X Recall	16.106	2	8.053	4.778	0.011
Error	129.761	77	1.685		
Session X Recall	150.425	2	75.212	45.372	0.001
Breakfast X Session X Recall	4.851	4	1.213	0.732	0.572
Error	255.282	154	1.658		

Table 4.15: Three-way ANOVA for Caloric Intake (101-200Kcal, 201-300Kcal, 301Kcal+) X Session (1, 2, 3) X Session (1, 2, 3) X Time taken to recall Word Lists (immediate/delayed) for those with Poor Memory

	SS	df	MS	F-ratio	p-value
Between Participants					
Breakfast	885.975	2	442.988	0.733	0.484
Error	46543.889	77	604.466		
Within Participants					
Session	6615.093	2	3307.546	35.995	0.001
Breakfast X Session	100.082	4	25.021	0.272	0.895
Error	14150.735	154	91.888		
Recall	18347.851	1	18347.851	205.595	0.001
Breakfast X Recall	682.469	2	341.234	3.824	0.026
Error	6871.696	77	89.243		
Session X Recall	175.373	2	87.686	1.566	0.212
Breakfast X Session X Recall	287.391	4	71.848	1.284	0.279
Error	8620.326	154	55.976		

Table 4.16: One-way ANOVAs for Macronutrients for each level of Carbohydrate (20.1-35g, 35.1-50g, 50.1g+)

	SS	df	MS	F-ratio	p-value
Between Participants					
Fat	3284.180	2	1642.090	47.620	0.001
Error	13275.993	385	34.483		
Between Participants					
Protein	797.3223	2	398.662	43.109	0.001
Error	3560.390	385	9.248		
Between Participants					
Fibre	64.632	2	32.316	17.907	0.001
Error	694.780	385	1.805		
Between Participants					
Caloric Intake	943067.34	2	471533.671	149.017	0.001
Error	1218256.1	385	3164.602		

Table 4.17: Correlations between the Macronutrients with respect to the RIPT (N=388)

	Carbo	Fat	Protein	Fibre	Caloric Intake	Glucose Load
Carbohydrate	--------------- -	-----------	-----------	-----------	-----------	-----------
Fat	r = 0.073 0.150	-----------	-----------	-----------	-----------	-----------
Protein	r = 0.024 0.641	r = -0.170 0.001 ***	-----------	-----------	-----------	-----------
Fibre	r = 0.103 0.043 *	r = 0.079 0.122	r = 0.151 0.003 **	-----------	-----------	-----------
Caloric Intake	r = 0.666 0.001 ***	r = 0.769 0.001 ***	r = 0.065 0.202	r = 0.129 0.011 *	-----------	-----------
Glucose Load	r = 0.928 0.001 ***	r = 0.159 0.002 **	r = 0.014 0.783	r = 0.058 0.254	r = 0.671 0.001 ***	-----------

*** p<0.001; ** p=0.001; * p<0.05

Table 4.18: One-way ANOVAs for Changes in Blood Glucose Levels for each level of Carbohydrate (20.1-35g, 35.1-50g, 50.1g+)

	SS	df	MS	F-ratio	p-value
Between Participants					
30-0mins	224.304	2	112.152	38.831	0.001
Error	1111.959	385	2.888		
Between Participants					
60-0mins	10.509	2	5.254	2.121	0.121
Error	953.969	385	2.478		
Between Participants					
90/100-0mins	38.492	2	19.246	7.510	0.001
Error	986.656	385	2.563		
Between Participants					
150-0mins	49.731	2	24.866	11.116	0.001
Error	861.192	385	2.237		

Table 4.19: One-way ANOVA for Carbohydrate (20.1-35g, 35.1-50g, 50.1g+) for Baseline Blood Glucose Levels

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	17.674	2	8.837	8.475	0.001
Error	401.454	385	1.043		

Table 4.20: One-way ANOVAs for Macronutrients for each level of Protein (>4g, 4.01-8g, 8.01-12g)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	1031.227	2	515.614	3.315	0.037
Error	59875.142	385	155.520		
Between Participants					
Fat	2190.603	2	1095.301	29.346	0.001
Error	14369.570	385	37.324		
Between Participants					
Fibre	530.579	2	265.290	446.338	0.001
Error	228.832	385	0.594		
Between Participants					
Caloric Intake	236763.62	2	118381.809	23.682	0.001
Error	1924559.8	385	4998.857		

Table 4.21: One-way ANOVAs for Macronutrients for each level of Fat (>2.5g, 7.12g, 16g+)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	1615.120	2	807.560	5.244	0.006
Error	59291.249	385	154.003		
Between Participants					
Protein	292.916	2	146.458	13.872	0.001
Error	4064.797	385	10.558		
Between Participants					
Fibre	177.886	2	88.943	58.885	0.001
Error	581.526	385	1.510		
Between Participants					
Caloric Intake	1222424.4	2	611212.181	250.630	0.001
Error	938899.09	385	2438.699		

Table 4.22: One-way ANOVAs for Macronutrients for each level of Fibre (>3g, 3.1-6.5g)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	1513.592	1	1513.592	9.837	0.002
Error	59392.778	386	153.867		
Between Participants					
Protein	40.138	1	40.138	3.588	0.059
Error	4317.575	386	11.185		
Between Participants					
Fat	381.075	1	381.075	9.092	0.003
Error	16179.098	386	41.195		
Between Participants					
Caloric Intake	77256.187	1	77256.187	14.309	0.001
Error	2084067.3	386	5399.138		

Table 4.23: One-way ANOVAs for Macronutrients for each level of Caloric Intake (101-200Kcal, 201-300Kcal, 301Kcal+)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	21335.393	2	10667.696	103.790	0.001
Error	39570.977	385	102.782		
Between Participants					
Protein	216.904	2	108.452	10.084	0.001
Error	4140.810	385	10.755		
Between Participants					
Fat	9696.102	2	4848.051	271.923	0.001
Error	6864.071	385	17.829		
Between Participants					
Fibre	14.989	2	7.494	3.876	0.022
Error	744.423	385	1.934		

Table 4.24: Correlations between the Intercept and Slope Values for each Session

	Intercept1	Intercept2	Intercept3	Slope1	Slope2	Slope3
Intercept1	---------------	-----------	-----------	----------	----------	----------
Intercept2	r = 0.603 0.001 ***	-----------	-----------	----------	----------	----------
Intercept3	r = 0.537 0.001 ***	r = 0.685 0.001 ***	-----------	----------	----------	----------
Slope1	r = -0.312 0.001 ***	r = 0.034 0.475	r = 0.045 0.343	----------	----------	----------
Slope2	r = -0.087 0.065	r = -0.241 0.001 ***	r = -0.015 0.744	r = 0.467 0.001 ***	-----------	-----------
Slope3	r = -0.052 0.268	r = -0.018 0.697	r = -0.303 0.001 ***	r = 0.376 0.001 ***	r = 0.485 0.001 ***	-----------

*** p<0.001; ** p=0.001; * p<0.05

Table 4.25: One-way ANOVAs for Macronutrients for each level of Fat (>2.5g, 7.12g, 16g+)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	1775.029	2	887.515	6.032	0.003
Error	54292.076	369	147.133		
Between Participants					
Protein	329.553	2	164.777	16.044	0.001
Error	3789.634	369	10.270		
Between Participants					
Fibre	162.376	2	81.188	49.996	0.001
Error	599.217	369	1.624		
Between Participants					
Caloric Intake	1207295.3	2	603647.659	256.906	0.001
Error	867031.57	369	2349.679		

Table 4.26: One-way ANOVAs for Macronutrients for each level of Fibre (>3g, 3.1-6.5g)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	1187.637	1	1187.637	8.007	0.005
Error	54879.468	370	148.323		
Between Participants					
Protein	56.637	1	56.637	5.158	0.024
Error	4062.549	370	10.980		
Between Participants					
Fat	344.260	1	344.260	8.320	0.004
Error	15310.218	370	41.379		
Between Participants					
Caloric Intake	67792.209	1	67792.209	12.501	0.001
Error	2006534.7	370	5423.067		

Table 5.1: Three-way ANOVA for Carbohydrate (<20g, 20.1-35g, 35.1-50g, 50.1g+) X Baseline Blood Glucose Levels (>4.9mmol/L, 4.91-5.5mmol/L, 5.51-6.1mmol/L, 6.11mmol/L+) X ratings for Total Mood (30, 60, 90, 120/150mins)

	SS	df	MS	F-ratio	p-value
Between Participants					
Carbohydrate	91080.658	3	30360.219	1.755	0.155
Baseline	137912.280	3	45970.76	2.657	0.048
Carbohydrate X Baseline	196861.874	9	21873.542	1.264	0.254
Error	9273251.907	536	17300.843		
Within Participants					
Session	171821.131	3	57273.710	29.938	0.001
Carbohydrate X Session	37845.725	9	4205.081	2.198	0.020
Baseline X Session	17481.316	9	1942.368	1.015	0.425
Carbohydrate X Baseline X Session	106537.943	27	3945.850	2.063	0.001
Error	3076188.277	1608	1913.052		