The Role of Olfactory Cues and their Effects on Food Choice and Acceptability

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Abstract

Food intake in humans is guided by a variety of factors, which include physiological, cultural, economic and environmental influences. The sensory attributes of food itself play a prominent role in dietary behaviour, and the roles of visual, auditory, gustatory and tactile stimuli have been extensively researched. Other than in the context of flavour, however, olfaction has received comparatively little attention in the field of food acceptability.

The investigation was designed to test the hypothesis that olfactory cues, in isolation of other sensory cues, play a functional role in food choice and acceptability.

Empirical studies were conducted to investigate: the effects of exposure to food odours on hunger perception; the effects of exposure to food odours with both high and low hedonic ratings on food choice, consumption and acceptability; and the application of odour exposure in a restaurant environment.

Results from these studies indicated that exposure to the food odours led to a conscious perception of a shift in hunger, the direction and magnitude of which was dependent on the hedonic response to the odour. Exposure to a food odour with a high hedonic rating prior to a meal significantly increased consumption and acceptability ($p<0.05$), and exposure to a food odour with a low hedonic rating had no significant effect ($p>0.05$). When applied to a restaurant environment, exposure to a food odour with a high hedonic rating significantly influenced food choice and acceptability ($p<0.05$).

Subject and stimulus variables, contributing to the role of olfactory cues, were identified from the results, facilitating the development of a conceptual olfactory cueing model. The model demonstrates how a series of independent variables, relating to odour exposure, may lead to either an enhancement of dietary patterns or suppression of food intake. The application and implications of the model are discussed. As such this research establishes direct links between stimulus and response in an ecologically valid environment.

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1.0 Introduction

This investigation focuses on the role of olfactory[1] cues in relation to selected aspects of food intake and dietary patterns. The interrelationships between the factors which influence eating behaviour are complex, with food intake in humans being guided by physiological, cognitive, social, cultural, economic, religious, environmental and sensory based influences (Kissileff and Van Itallie 1982). The extent to which any single factor or group of factors predominates in this process is unknown (Kissileff and Van Itallie 1982, Weingarten 1985, Meiselman and MacFie 1996), and may vary according to different conditions. The sensory attributes of food itself, which stimulate the senses of sight, hearing, touch, taste and smell, are known, however, to play a prominent role in food intake (Cardello, 1996).

Sensory stimuli enable foods to be recognised and make it possible for the appropriate food to be selected in accordance with a particular desire. These stimuli then initiate the appropriate responses in the viscera, aiding the digestion of the meal (Piggott 1984) and are important for the cessation of eating since they promote satiety (Rolls 1985). The hedonic properties of sensory stimuli contribute to the pleasantness or unpleasantness of the eating experience, exerting an influence on food choice, and providing the foundation for food acceptability[2]. Research into the contribution of the senses to food choice and acceptability show that both the physical senses (visual, auditory and tactile) and the chemical senses (gustatory and olfactory) play a functional role in dietary behaviour, albeit in varying degrees (Cardello, 1996). The role of the visual sense in relation to the appearance of food has been widely researched (Clydesdale 1978 and Dubose *et al.* 1980), and the importance of taste[3], and flavour[4] in dietary patterns is well documented (Garcia and Koelling 1966, Tepper and Mattes 1990). Auditory and textural qualities of foods have also been found to influence acceptability (Vickers 1983 and Mela 1987,

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1 Pertaining to the sense of smell. (British Standard (1975).

2 The state or quality of food which makes it agreeable, satisfactory, worth accepting and welcome. (Pierson 1997).

3 The sensation perceived via the taste buds resulting from the presence of certain soluble substances. (British Standard 1975).

4 The combination of taste and odour. It may be influenced by sensations of pain, heat and cold and by tactile sensations. (British Standard 1975).

respectively). Other than in the context of flavour, however, information regarding the role of olfaction in relation to food, tends to be anecdotal, and empirical evidence in this area is somewhat limited.

This situation is hardly surprising as far less research has been conducted on the chemical senses than on the physical senses, and olfaction is the least understood of the human senses. Early research into the human sense of smell dates back to the classification system for odours[5] established by Linnaeus (1756). Since that time a number of classification systems have been developed, including those of Henning (1916) and Amoore (1970). Research has also been conducted to investigate the factors which link a molecule to a specific odour. The classification system developed by Amoore (1970) was based on the chemical structure of odours which led to the Stereochemical theory. This theory identified odourous molecules as having definite shapes which fit into specific locations of the nerve axons in the nose, allowing the odour to be identified. A more recent theory on the mechanism of olfaction, however, suggests that the olfactory receptors are stimulated by the vibration of molecules rather then their shape (Turin 1995).

In addition to investigations into the mechanisms of olfaction, the anatomy and structure of the olfactory system have been widely researched (Parker and Stabler 1913, Stuiver, 1958, Gesteland 1982, Cain 1988, Douek 1988). Due to the anatomy of the olfactory system, odours are perceived both orthonasally, through the nose, and retronasally, by volatiles arising from the mouth. The retronasal odours combine with the sense of taste to form flavour, hence playing a vital role in food intake and dietary behaviour (Rozin 1982).

Whilst the roles of appearance, sound, taste and texture have been investigated as independent sensory attributes, the role of olfaction has, in the main, been researched through its interaction with the sense of taste.

In this study it is hypothesised, that in addition to their vital contribution to flavour, olfactory cues in isolation of other sensory cues, play an important role in food intake and dietary patterns.

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5 The sensation perceived via the olfactory organ from certain volatile substances. (British Standard 1975).

Before testing the hypothesis, it is necessary to review the current state of understanding of the olfactory system and its role in food intake. The theories and mechanisms of hunger and the concept of cueing will also be examined.

1.1 The anatomy and physiology of the olfactory system

1.11 The anatomy and structure of olfaction

The olfactory system is located in the roof of the nasal cavity and covers an area of 2.5 cm^2 in the epithelium of each nostril (figure 1). The *olfactory epithelium* or mucosa is located on both sides of the *nasal cavity*, divided by nasal septum. The mucosa houses the *olfactory receptors* and *supporting cells*, each nostril containing approximately 10 million receptors (Dodd and Squirrell 1980). The receptor cells are thin bipolar neurons, rounded at the nucleus. One end protrudes into the mucosa, its tip fringed with *cilia* pointing into the air passageway through the nostrils. The cilia are connected by *dendritic knobs* (or mitral cells) which are normally bathed in *mucus*. It is believed that the action between the stimuli and the receptors takes place on these cilia which are involved in the initial stage of the transduction process (Lancet 1984). This direct contact between the stimulus and the receptor differentiates olfaction from the visual and auditory senses, where the cornea (along with other structures) and the eardrum block direct contact in vision and hearing, respectively (Gibbons 1986). The opposite end of each receptor cell is the nerve axon and other nerve fibres which synapse at the *glomerulus*. There are approximately 10 thousand glomeruli, each of which receives input from an estimated one thousand axons (Carlson 1995). The axons from the olfactory receptors enter the skull through perforations in the *cribriform plate* (the bone at the base of the rostral area of the brain), and connect to the *olfactory bulb*, situated above the receptor cells. This forms the enlarged ending of the olfactory lobes at the front of the brain and performs the first processing of signals from the odour receptors. After relays through the *glomerulus* to the *olfactory bulb*, the fibre pathways continue through the *olfactory tract* to centres on the underside of the brain (to be discussed further in section 1.12).

The olfactory receptors differ from those of the visual, auditory and tactile senses in a number of ways. In addition to their direct contact with the stimulus, the olfactory system contains a single type of odour receptor. Secondly, the neurons in the physical sensory systems are irreplaceable, but in the olfactory system, the receptor cells undergo a continual process of degeneration and regeneration, each individual neuron set having a lifespan of approximately eight weeks (Gesteland 1982).

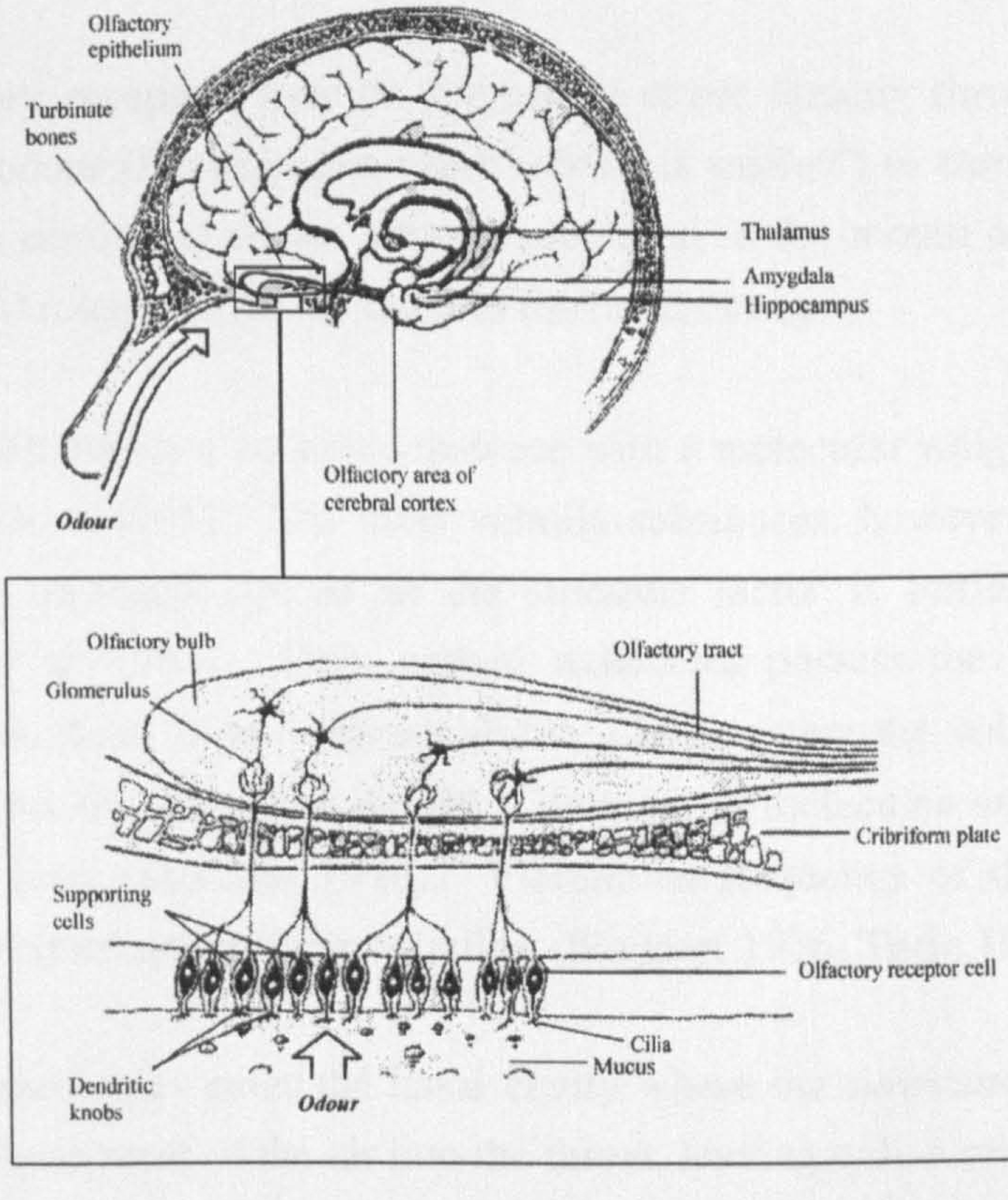

Figure 1 Anatomy of the olfactory system (adapted from Carlson 1995 and Turin 1995).

In addition to the odour receptors, the olfactory epithelium also houses a second group of receptors in the form of free nerve endings originating from the trigeminal nerve. These extend into the olfactory epithelium, and register sensations which are important in both taste and smell (Schiffman 1990). Many odour stimuli are accompanied by trigeminal or tactile components, pungency being one of the qualities within this group. Examples of these sensations in relation to food have been described as 'the *bite* of chilli pepper or the *coolness* of menthol' (Cain 1981). Many anosmics (those unable to perceive odours) are able to detect stimuli such as menthol and eugenol as they activate thermosensors[6] in the somatosensory[7] system.

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6 Receptors which respond to specific temperatures or changes in temperature (Goldstein 1980).

7 Area in the parietal lobe of the cortex that receives inputs from the skin (Goldstein 1980).

Other odourants activate nocisensors[8] in this system and produce sensations perceived as 'pricking' or 'burning' (Kobal *et al.* 1992).

1.12 The transduction and conduction process of olfactory information

The olfactory receptors may be stimulated either directly through the nose by an orthonasal odour (for example, when a food is sniffed[9]) or through the back of the mouth by a retronasal odour, which is released in the mouth as food is masticated and travels through the throat and into the nasal cavity.

An odour stimulus is a volatile substance with a molecular weight in the range of 15 to 300 (Carlson 1995). The most volatile substances, however, do not necessarily possess the strongest odours as the stimulus factor is intrinsic to the molecule (Wyburn *et al.* 1964). Only certain molecules possess the necessary properties which enable them to be odourous and to a large extent the volatility of a substance depends upon its molecular weight. Very large molecules are much less volatile than small ones (Stoddart 1976). Vibrational frequency of the molecules is also believed to contribute to their volatility (Stoddart 1976, Turin 1995).

Odourous molecules enter the nasal cavity where the *turbinate bones* at the top of the cavity force most of the air into the throat, leaving only a relatively small number of inhaled molecules to travel to the olfactory region (figure 1). The odourous molecules then travel to the olfactory epithelium and make contact with the receptors; Stuiver (1958) estimated that only two per cent of material available in a single sniff will reach the receptors. Only a small number of molecules, however, are required to stimulate the receptors and De Vries and Stuiver (1961) estimated that in some cases a single molecule may be sufficient. Odourous molecules are dissolved in the olfactory epithelium by its fluid covering which then stimulates the cilia of the receptors and produces neural activity in the olfactory cells (Schiffman 1990). It is believed that the more vigorous the inhalation, the more the olfactory epithelium is bathed by the odourant and stimulation is increased (Schiffman 1990). Laing (1983), however, reported that it is very difficult to improve the efficiency of inhalation in humans and a single intake of air provides as much information about the presence and intensity of an odour as do several intakes. The neuronal activity in

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8 Receptors which respond to stimuli which are damaging to the skin (Goldstein 1980).

9 To inhale forcefully through the nose. To draw forcibly through the nostrils (Webster's English dictionary 1992), whereby the volume and velocity of the air entering the nose are increased.

the cells transmits electric impulses along nerve fibres to the olfactory bulb which are then transmitted in two circuits of the brain. One circuit passes through the thalamus (part of the forebrain serving as relay stations for sensory stimulation) where the other senses also synapse. The other circuit passes through the amygdala, the hippocampus and the hypothalamus (figure 2), all structures which play roles in the regulation of hunger and thirst. It has been suggested that the pathway through the thalamus is primarily responsible for the perception of odours, whereas the pathway through the hypothalamus may help determine odour quality (Cain 1988) and influence the acceptance or rejection of food (Carlson 1995). These circuits meet in the orbitofrontal cortex which also receives gustatory information (Cain 1988).

The olfactory system also projects directly into the limbic area of the brain (originally known as the rhinencephalon) which is believed to be linked to arousal and emotion (figure 2). The limbic system consists of the amygdala, hippocampus, septum and septal nuclei, fornix, cingulate gyrus and parts of the hypothalamus. The system lies along the inner edge of the cerebrum and is fully evolved only in mammals. As well as memory, it is involved in the drives of hunger, sex and aggression (Carlson 1995).

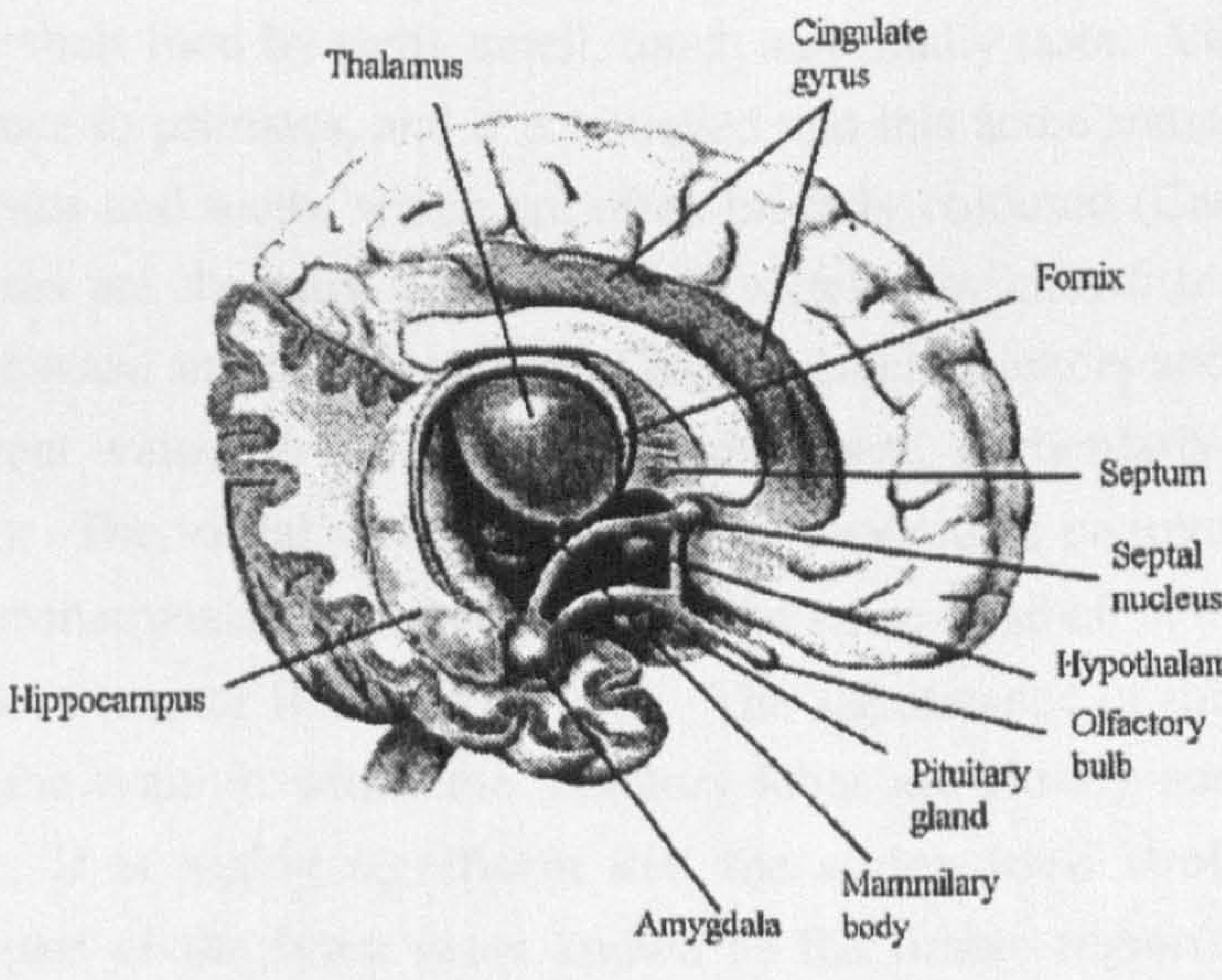

Figure 2 The limbic system (Source: Carlson 1995)

Olfaction appears to be the only sense to project directly into the limbic system, while other senses reach the limbic system, after passing through other brain regions linked with language centres (the Broca's and Wernicke's area of the cerebral cortex). This information suggests that the olfactory sense may have important functions in relation to hunger, thirst, memory and emotion, although in modern man[10] the sense of smell is regarded as an ancillary sense (Amerine *et al.* 1965).

1.13 The evolution of the sense of smell

Man's interpretation of his environment is influenced largely by a complex pattern of sight and sound, with only an occasional impression of odour. (Amerine *et al.* 1965)

The pattern of behaviour, suggested by this quotation may differ from that of prehistoric man, whose judgments were apparently based largely upon olfactory, gustatory and tactile stimuli (Proetz 1953). As man developed an erect posture, the importance of vision to detect, distinguish and estimate objects at a distance increased, and sight and sound became of primary importance. Concurrently, the sense of smell became a secondary sense as the evolution of an upright posture removed the olfactory organ away from the source of many odours (Nilsson 1974). These adaptations are linked to an arboreal way of life in which survival depends more on stereoscopic vision, to provide good depth perception, than on an acute sense of smell (Proetz 1953).

Primates identify their food by sight, smell, touch and finally taste. Vision is of pre-eminent importance to primates, and it is believed that this acute sense was of value in recognising fruits and seeds, which are often brightly coloured (Campbell 1966). Birds and primates are the only two groups of vertebrates known to have a well-developed colour sense and the development of the visual receptors and visual cortex has been of great value to primates in many ways, particularly for survival (Campbell 1966). The visual sense is also highly evolved in carnivores and some ungulates, but for mammals other than primates the sense of smell is by far the most important distance receptor (Campbell 1966). The significance of this is related to the structure of the brain in which the olfactory lobes are closely connected to the cerebral cortex. It is highly significant that the cortex itself evolved from the rhinencephalon part of the brain (now known as the limbic region) to which the sense of smell is directly linked (Campbell 1966). The theory that olfaction is the only sense to project directly into the limbic system, is believed to make it the most basic and primitive of the human senses (Carlson 1995). Consequently, although in the evolution of the primates the visual sense overtakes the olfactory sense in overall importance, the latter plays some part in the deeply rooted behaviour patterns of

10 Term used to describe Homo Sapiens (The Chambers English dictionary 1994).

feeding and mating. This importance is not altogether lost in modern man even though the role of odour is often underestimated and the sense of smell appears to be under-utilised.

Modern man is generally only conscious of odours when they intrude upon, or distract him, and he is made aware more of those that can be classed easily as pleasant or unpleasant (i.e. have an immediate and obvious hedonic impact). They are usually the latter, if an object is said to 'smell', the implication is that it is unpleasant (Burton 1976). This lack of discrimination is likely to be due to the fact that man has become almost completely reliant on his senses of sight and hearing. For certain professions such as perfumery and wine tasting, the capabilities of the olfactory sense are still of great importance. It is also apparent that olfaction may play an important, but unappreciated role in humans, as man often only realises the importance of his sense of smell when it is impaired, for example when suffering from a cold (Burton 1976).

1.14 The evolution of the nose

In conjunction with the decline in importance of the olfactory sense, the shape and structure of the nose has also undergone a number of changes. The *rhinarium,* the sensitive skin around the nostrils, was an important sense organ in lower primates, and its wet surface is believed to have enhanced its sensitivity to air currents, used to determine direction. In the open plains, the direction of the wind and the scent it carries was of great importance. In the arboreal environment, however, it supplies information limited to the quality and intensity of odour, with no direct spatial implications (Campbell 1966).

In the higher primates, both the size of the nasal cavity and the complexity of the turbinal bones have been reduced, together with the total area of the olfactory epithelium. There were vast differences between Paleocene and Eocene primates. Eocene primates had reduced snouts, suggesting a reduction in importance of olfaction. Analogous to this, their eyes were forward facing, providing overlapping fields of vision and thus probably some degree of stereoscopic sight (Nilsson 1974). The reduction of the muzzle came early in the evolution of the primates and the reductions of the jaws came late in the evolution of man. This has resulted in a flat face and the change has altered the centre of gravity of the head and contributed to the balance of the skull upon the spine (figure 3).

The human nose, however, is more prominent than that of most monkeys and apes, perhaps partly due to the recession of the jaws and the expansion of the brain, which left only a small space for the nasal cavity (Campbell 1966).

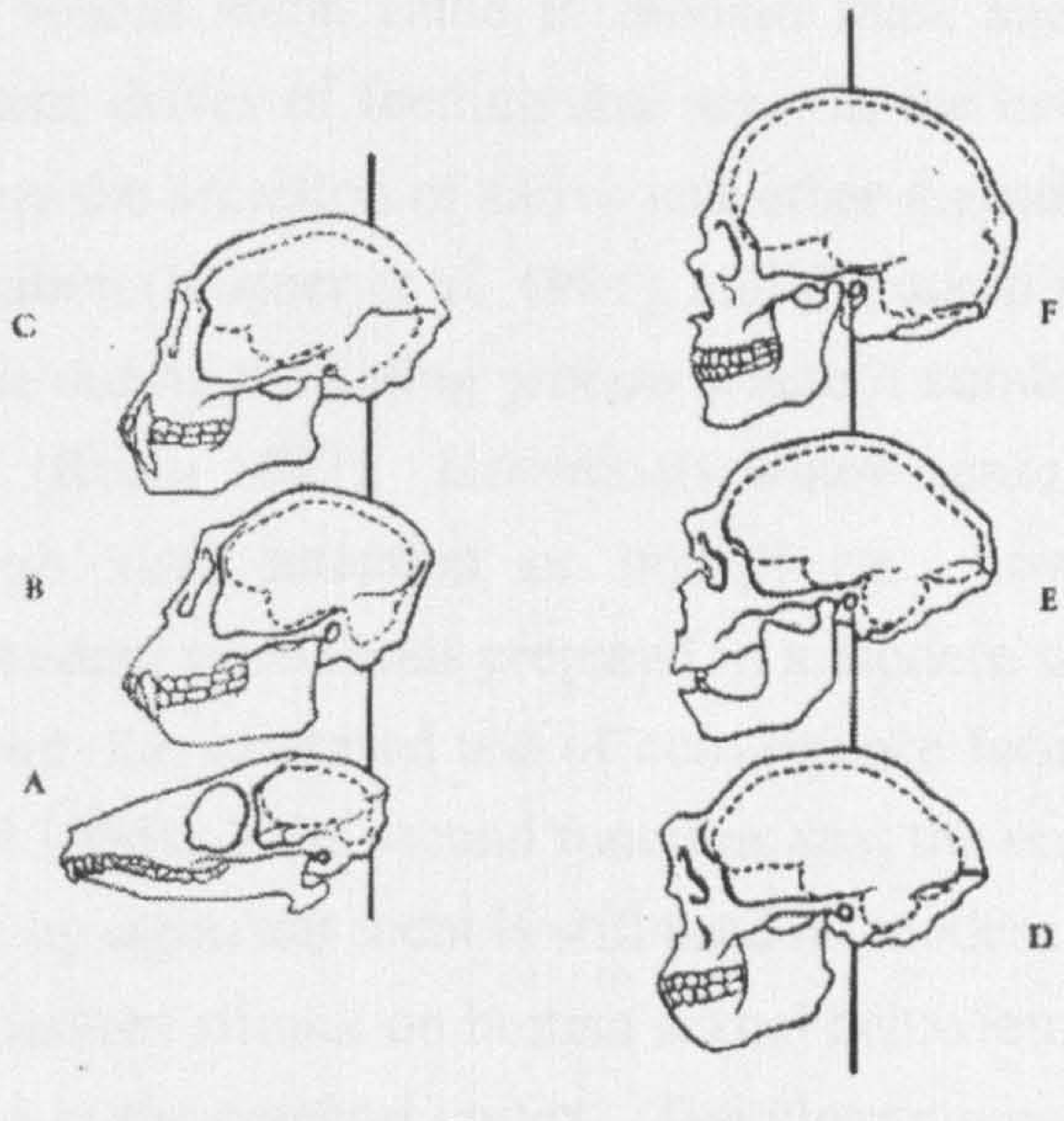

Figure 3 Skulls of various primates aligned upon the point on which they pivot on the spine, the occipital condyles (A=*Tupaia,* B=*Ceropithecus,* C=*Hybolates,* D=*Homo erectus,* E=*Homo Sapiens neanderthalensis* and F=modern man). From the lower primates to the higher primates, the centre of gravity moves back, the brain expands and the jaw recedes.
(Source: Campbell 1966)

The human nostrils consist of adipose tissue and blood vessels, lined with a moist mucous membrane. This membrane acts to humidify the inspired air (maintaining relative humidity of 95 per cent at body temperature) as well as providing an insulating function (Weiner 1954).

A rise in air temperature increases the volatility of odourous molecules, enhancing the stimulation of the olfactory receptors. It is believed that the insulating function of the nose may be important, not only to protect the internal organs during inhalation of air at sub-zero temperatures, but perhaps also to increase the effectiveness of the olfactory organ (Weiner 1954). The nasal index of modern man (which indicates the shape of the nasal openings) is highly correlated with the absolute humidity of the air of the region he inhabits. Thus, many of the tropical races of man have flatter, more open noses than have those occupying dry areas, such as Mongolia (Weiner 1954).

1.15 The sense of smell in modern man

Although the sense of smell is reduced in the higher primates compared to their predecessors, it retains some value in modern man, and its functions are closely related to the basic drives of feeding and sex. In the eating process, physiological responses, such as the secretion of saliva and other digestive substances, may follow olfactory stimulation (Klajner *et al.* 1981), and the odour of a food continues to take an important role during the eating process where it combines with the sense of taste to form flavour (Rozin 1982). Individuals whose sense of smell is impaired (for example, through viral infection or injury) can, however, survive with little difficulty if dependent upon foods prepared in a modern sophisticated society, where it could be argued, the increased use of convenience foods have minimised sensory input (Campbell 1966). In its second function, sex, the sense of smell has again been replaced mainly by sight, but scent is still used by modern man as a sexual stimulant. The effect of olfactory stimuli on human sexual behaviour is, as discussed in section 1.13, also linked to the cerebral cortex. The close connection between the sense of smell and this region of the brain which deals with memory, arousal and emotion has an important effect on sexual experiences in modern man (Campbell 1966). Recent research has indicated that the vomeronasal organ, situated in the nose (but independent of olfaction) may play a role in subliminal sexual signalling. It has been proposed that this may be regarded as a sixth sense and may work in conjunction with the olfactory sense in relation to sexual behaviour (Berliner *et al.* 1996).

Research indicates that both olfactory experience and ability varies considerably amongst individuals and this is believed to be caused by a number of factors. Age has been reported to be one of the causes of this variation and olfactory sensations have been found to diminish with age (Bartoshuk 1991). Thresholds for tested food odours were reported to be 11 times as high for elderly subjects (mean age 81 years), than for younger subjects (mean age 22 years) (Schiffman *et al.* 1976). It is not known, however, whether these effects occur purely with age, or other causes that may accumulate over time (Bartoshuk 1991). Other research has reported little decline in olfactory ability with age, suggesting that the regular replacement of the olfactory receptors perhaps provides a resistance to the effects of time. Perception of odour intensity, however, has been found to be affected by age (Gilbert and Wysocki 1987).

Gender has also been reported to be a contributing factor to variations in olfactory ability, with females outperforming males in their ability to detect and identify selected odourants (Gilbert and Wysocki 1987). Hormonal status has also been found to effect olfactory thresholds (Doty *et al.* 1981).

Another cause of variation in sensory experience is the clinical loss of the sense of smell. Three major causes have been found to be associated with olfactory loss: Head injury, upper respiratory infection and nasal disease (Duncan and Smith 1996). The olfactory system is prone to viruses (for example, influenza, arboviral encephalitis) and allergies (for example, hayfever, allergic rhinitis) which lead to a reduction in olfactory acuity.

Anosmia refers to the permanent loss of the sense of smell in human beings and typically results from a head injury or viral infection which may damage the olfactory epithelium or exert pressure on the olfactory bulb or tract (Douek 1988). Although in anosmiacs, odours cannot be detected through the olfactory system, as outlined in section 1.11, certain trigeminal sensations associated with some odours may be perceived through the somatosensory system. Within this, different types of specific anosmia have been identified. These include: *merosmia*, the loss of acuity to certain odourants (which may be unilateral); *parosmia*, the perception of false odours; *autosmia*, an odour sensation in the absence of odour stimuli; *cacosmia*, the persistent perception of unpleasant odours and *hyperosmia*, an excessive response to odour stimuli (Amerine *et al.* 1965). Temporary olfactory loss or reduction in olfactory acuity is relatively common (Gilbert and Wysocki 1987) and can be caused by physical obstructions to the nasal pathways due to colds, hayfever, etc. but olfactory ability usually returns once the inflammation of the mucous membranes is reduced. Individuals suffering from such olfactory deficiencies are able to survive with little difficulty, although their perception of odours in the environment is reduced. Additionally, they may also suffer from a decrease in flavour awareness, hence their perception of foods may differ from individuals not suffering from such deficiencies.

Odour perception has also been found to have worldwide variations (Gilbert and Wysocki 1987), indicating that cultural and ethnic origin may be a contributing factor to the degree of liking for certain odours (see section 1.22).

Pregnancy and smoking have both been found to affect olfactory performance and impair odour quality. Hepper (1992) reported that smokers require a stronger concentration to identify experimental odours than both passive smokers and non-smokers, and passive smokers require a stronger concentration than non-smokers. Olfactory sensitivity has been reported to be reduced during pregnancy and odour quality was also affected, although pregnancy has been found to be one of the least common causes of smell loss (Gilbert and Wysocki 1987).

Individual differences such as gender, age, culture, smoking and pregnancy, therefore, play an important role in olfactory ability and odour perception. Investigations into the effects of exposure to odours must take these individual variations into account. When exposing a group of assessors to a particular odour, individual variations in sensitivity may exist. If so, this will lead to different intensities of the odour being perceived. Due to the fundamental role of olfaction in flavour, it is also proposed that the absence or variation of any olfactory input will, inevitably, lead to considerable differences in the perception of food.

1.16 The role of olfaction in flavour perception

The sense of smell is more highly developed than the sense of taste. Parker and Stabler (1913) observed that the olfactory organ can detect dilutions of alcohol 24,000 times greater than those required to stimulate the organ of taste. Additionally, the sense of smell is a dual sensory modality which senses both orthonasal odours and retronasal odours, and when combined with the sense of taste produces the flavour of food (section 1.12).

Studies by Aristotle did not make links between taste and smell. To Aristotle, if a sensation originated in the mouth, it was taste. If it arose from sniffing, it was olfaction (Rolls 1985). The failure to realise that olfaction is stimulated by volatiles arising from the mouth during consumption, led to the classification of many olfactory qualities as taste qualities.

It has been reported that the terms taste and flavour are often confused (Rozin 1982). Taste refers to the gustatory properties of food in the mouth, the four basic tastes being salt, sweet, acid and bitter which are detected by papillae in different areas of the tongue. Flavour is an integration of any of these tastes, with odour in the mouth, and has been defined as 'the element in the taste of a substance which depends on the cooperation of the sense of smell' (Rozin 1982). Experiments conducted by Rozin (1982) found that on average, the term 'taste', was used far more in the English language when describing the *flavour* of foods and indeed similar results were recorded in nine other languages. Overall, the data indicated that distinctions involving olfactory input are not usually made with reference to food in the mouth and there was a distinct lack of awareness, amongst the respondents, of the olfactory input in the perception of flavour.

The role of retronasal odours may be illustrated by examples of acids, such as citric and acetic. As it is possible to distinguish between these acids it is generally believed that they taste different. In fact all acids, when of corresponding concentration, have identical *tastes,* it is only the odour which differs and hence the *flavour.* Similarly, varieties of sugar such as cane and malt have identical tastes, only the odour varies. Additionally, a number of stimuli which are usually perceived to be tastes (examples include Citral and Vanillin) are actually odours perceived retronasally (Renner 1944).

The importance of retronasal odours with regard to flavour is, therefore, now recognised. Due to a number of factors such as mastication, airflow and salivation, however, individual differences in the perception of retronasal odours and hence flavour are likely to occur (Roberts 1995).

The duality of the olfactory sense leads to an unusual phenomenon in which a number of foods have an orthonasal odour which is often disliked but when sensed in conjunction with ingestion (retronasally) have a pleasant flavour. Examples include Limburger and other strong cheeses, fish, eggs and some vegetables (Rozin 1982). The opposite effect, where the odour is liked but the taste disliked, is more common. For example, black unsweetened coffee often has a pleasant odour but a bitter taste. This however, is due to the fact that the taste properties causing the unpleasantness are not sensed during orthonasal stimulation. Black coffee is disliked because a bitter taste is added to a pleasant odour. The implications of this when investigating the role of olfactory cues are very important, as orthonasal exposure to an odour may be regarded as unpleasant, but when sensed retronasally during mastication the food may be rated as pleasant.

1.17 Olfactory adaptation

In addition to the factors discussed in section 1.11, the olfactory sense also differs from the other senses, as it is readily prone to adaptation (or fatigue). This is a form of physiological fatigue in which the transmission of neural sensations between the stimulated receptors and the cerebral cortex is reduced. The physiological fatigue is a matter of the reduction or cessation of perception and differs from psychological fatigue where the acceptability of a sensation decreases, because it is repeated too often (Renner 1944).

The phenomenon of olfactory adaptation leads to a temporary decrease in olfactory sensitivity following stimulation of the sense of smell. This is caused either by the duration of the sensation, which lasts too long, or the simultaneous presence of other related sensations (Cometto-Muniz and Cain 1995). Olfactory adaptation may be sub-divided into *self-adaptation* when the loss is to an odour which has been presented for too long, or *cross-adaptation* when the exposure to one odour influences the threshold of other odours (Beets 1987). It has been reported, however, that the presence of other odour stimuli (for example, tobacco smoke) in the atmosphere does not affect the particular odour one is sensing, to the same degree as prolonged exposure to the same odour (Renner 1944).

The extent to which adaptation occurs depends mainly on two factors; adaptation time, and the concentration of the adapting stimulus (Stuiver 1958). The olfactory threshold may eventually rise to the concentration of the adapting stimulus until eventually it is no longer perceived. This has been called the Adaptation Time required for the Cessation of Smell (Stuiver 1958). Other factors which are believed to influence the adaptation time include the individual's olfactory ability and sensitivity.

This physiological fatigue has important implications when investigating the effects of exposure to odours in relation to olfactory cueing. Constant exposure to an odour stimulus, for example, may lead to a reduction in the sensation and perception of that odour. The implications of olfactory adaptation in food consumption relate to the presence of the food odours throughout the eating experience. These are perceived before the commencement of a meal and, during mastication of the food, continue to be released into the nasal cavity retronasally. As the duration of the eating process of a food item may last for several minutes, it is possible that olfactory adaptation will occur towards that particular food odour.

This form of olfactory adaptation is believed to play a role in eating habits. Sternberg (1914) studied the phenomenon whereby favourite foods appear to be eaten quickly and less pleasant foods eaten slowly. It has been proposed that physiological fatigue is at least partly responsible for these habits. Dishes which are liked are eaten quickly, the unconscious purpose being to avoid fatiguing the sense of smell. If the odour is disliked, the desire (again unconsciously) is for the perception to be weakened or eliminated, hence by extending the duration of the sensation, the perception of the odour will be reduced (Renner 1944).

It has also been suggested that other eating habits may have come about as means of avoiding or reducing olfactory adaptation. The custom of eating bread at intervals between food is believed to be an unconscious attempt to avoid adaptation. This concept is based on findings that olfaction is less susceptible to adaptation when a mixture of odours are present (Renner 1944).

In contrast to the phenomenon of adaptation, it has been found that when arctic explorers return to civilization they report enhanced odour sensitivity (Harper 1972). Similarly, studies conducted in an odour-free environment have substantially reduced threshold values (Land 1979); and in the perfume industry, olfactory adaptation has a positive dimension where selective fatigue is used to 'sniff out' separate components in a blend (Harper 1972).

1.18 Sensory specific satiety and alliesthesia

The concept of olfactory adaptation is believed to be related in part to satiety. Renner (1944) investigated these links and termed the phenomenon psychological satiety where:

> *......satiation occurs in stages; for being unable to eat any more of one course, we nevertheless consume the next with gusto.*

It is believed that satiety is due to sensory fatigue and may be avoided by switching between foods. The roots of the traditional meal trend of a savoury starter followed by a fish course, then sorbet, meat, dessert, cheese and finally coffee may be partly related to this psychological satiety (Renner 1944). This concept has been investigated further by a number of researchers and is termed sensory specific satiety (Rolls *et al.* 1981, Rolls *et al.* 1988, Wisniewski *et al.* 1991). The phenomenon suggests that the liking and desire which occur as one food is consumed, are specific to the sensory characteristics associated with that food, since both liking and consumption can be reinstated by the presentation of a new food (Wisniewski *et al.* 1991)

Rolls *et al.* (1981) showed that the pleasantness of eaten foods decreased more than that of uneaten foods, indicating that satiety in humans is at least partly specific. These results are consistent with the view that although working in conjunction with internal satiety signals, external factors such as the sight, smell, taste and texture of food provide some degree of specificity to satiety (Rolls *et al.* 1982).

Wisniewski *et al.* (1991) demonstrated that hedonic responses to olfactory and gustatory food cues decline with repeated presentation and consumption of the same food. Salivary responses to taste cues showed a reliable decrease over trials, while salivary responses to olfactory cues showed a warm-up effect, or an initial increase for the first few trials, until a decrease in salivary responses was observed. The initial increase in salivation to olfactory cues may account in part for the role that odour cues have in accentuating the influence of taste cues (Wisniewski *et al.* 1991).

A similar conclusion was arrived at by Rolls *et al.* (1988a), where sensory specific satiety followed the ingestion of foods with a very low calorie content. This again, suggests that the changes in pleasantness were caused by the taste, texture, odour and appearance of the food rather than the energy values (Rolls *et al.* 1988b). Satiety also occurs more rapidly when only one type of food is offered. This effect may, however, be retarded by combining different foods. In humans, partial satiety may be produced by relatively small quantities of certain foods such as lobster, caviar and cheese which are usually mixed with much larger portions of other foods (Katz 1935).

The lateral hypothalamus of the brain has been found to play an important role in satiety (Rolls *et al.* 1988). Cells in the lateral hypothalamus of monkeys responded to the sight or taste of food, but as the food was consumed the neurons became less responsive and acceptability of the food gradually decreased. The neuronal responses decreased to repeated presentations of the same food, but neuronal activity and food acceptance were recovered when a new palatable food was presented (Rolls *et al.* 1988). As signals from the olfactory bulb travel to the hypothalamus (section 1.11), it is likely that the olfactory sense, and the concept of olfactory adaptation, will be at least partly responsible for this sensory satiety.

Duclaux *et al.* (1973) found food-related odours became relatively unpleasant after a meal, but reactions to non food-related odours were unchanged. It is believed that there is a modulation of the hedonic response to food-related tastes and odours produced by the internal nutritional state. This phenomenon has been termed *alliesthesia*, (*esthesia* = sensation, *allios* = changed), where a given external stimulus may be perceived as either pleasant or unpleasant depending on the body's internal signals. Experiments established that thermal sensations were regarded as pleasant when they were functional. Warm water, for example, was pleasant when the hands were cold and cold water was pleasant when the hands were warm. (Cabanac 1971).

A similar phenomenon was found with an olfactory stimulus. Sniffing orange syrup was pleasant to fasting subjects and remained pleasant when repeated. After ingestion of a glucose load this olfactory stimulus became unpleasant (Cabanac 1971). These results indicate that a stimulus may be perceived as pleasant or unpleasant depending on a modification of the internal state, following ingestion. This phenomenon, using gustatory and olfactory stimulations, forms part of satiety and indicates how food intake may be limited by the displeasure caused by peripheral stimuli. Pleasure, therefore, is a signal of usefulness and displeasure is a signal of the absence of any need. These findings indicate that through a number of different modalities olfaction has an important role to play in satiety.

Other sensory properties of foods which may contribute to the sensory-specific component of satiety and the enhancement of intake by variety, include taste, colour, shape, texture and temperature. Rolls (1985) found that the manipulation of flavour (whilst keeping the nutrient composition constant) can lead to an enhancement of intake, but it appears that the contrast in flavour, if not accompanied by changes in appearance or texture, must be large before this enhancement is evident. This has implications for investigating food choice and acceptability, as these findings indicate that it is the integration of the senses, and the stimuli present, which have a greater effect on meal intake, than variations in the stimuli for one sense in isolation.

Similar experiments with colour and shape variations indicated that variety in colour alone had no effect on intake but the taste of foods, which differ only in colour, is less appealing after they have been consumed than before eating (Rolls 1985). Food consumption was found to be greater when a variety of shapes were offered than one single shape (Rolls 1985). These findings have implications for diet control, as well as the continual stimulation of the palate. Specific satiety may achieve the biological purpose of increasing the range of nutrient intake, so increasing the chances that all nutritional needs are met. An implication for dieting, however, is that limiting the variety of the sensory aspects of foods which are readily available (while maintaining adequate nutritional content) will assist in reducing intake. Alternatively, variation in as many sensory aspects as possible will stimulate the palate and enhance appetite.

It may be concluded, that whilst the role of the human sense of smell has declined in prominence since prehistoric times, olfaction may still play an important role in food intake, particularly through its functions of adaptation, alliesthesia and satiety. Concurrent with investigations into the role and structure of the olfactory system, a number of theories and beliefs regarding the identification and classification of odours have been developed.

1.2 Olfactory coding

1.21 Odour identification and classification

It is estimated that the total number of individual odourous chemicals is approximately 17,000 with an almost infinite number of possible combinations or blends (Harper 1972). The understanding of the olfactory sense, however, is less advanced than that of vision and audition and this is particularly apparent with regard to the way in which odours are perceived and identified. It is known, for example, that the three primary colours make up an infinite number of hues, and that an audible note has a certain tone which can be identified. Similarly, it is understood that colour is due to the wavelength of light and an audible note is produced by the frequency of sound waves. Odour sensations, however, can often only be described in terms of direct or indirect associations, often unique to the individual, and although a number of theories have been developed, the factors which link a molecule to a specific odour are not fully understood.

An early classification for odour, which consisted of a dual system for categorising odours, was developed by Linnaeus (1756). The first category was concerned with a concept of seven odour classes, while the second grouped these classes according to their appeal (pleasantness and unpleasantness). Within this latter category, a sub-group was defined which classified odours as 'pleasant to some and unpleasant to others'.

A later system of classification was proposed by Henning (1916), in which a prism-shaped figure was constructed to define odours by six basic terms: Putrid, Fragrant, Spicy, Burned, Resinous and Ethereal (see appendix 1). It was proposed that the simple odours must be located on the surfaces of the prism and more complex odours (for example combinations of apple and cinnamon) could be represented inside the prism. This model, however, has been criticised due to the inconsistency of individuals' odour perceptions (Cain 1978).

In addition to the classification of odours, researchers have investigated the mechanism of olfaction in order to determine the factors which link a molecule to a specific odour. Amoore (1970) developed a system of classification based on the chemical structure of odours, (the Stereochemical theory). Odourous molecules are believed to have definite shapes which fit into specific sockets of the nerve axons inside the olfactory system, allowing the stimuli to be identified (a 'lock and key' concept). From this, Amoore suggested seven 'standard' primary odours (see appendix 2) and found that odours which were judged to smell like the standards also resembled them in their chemical structure. In 1977, Amoore expanded this total number of human primary odours to 32.

Odourants have been found, however, which have molecules of similar size and shape but produce very different odours (Schiffman 1990). Two carvone molecules (L-carvone and d-carvone), for example, which are almost identical in shape and size, have very different odour properties, one smelling of spearmint, the other caraway.

More recently, a mechanism of olfaction based on a vibrational theory of odour has been proposed in which the olfactory receptors respond, not to the shape of molecules, but to the vibrational energies of different modes of vibration within them (Turin 1996). This theory proposes that a particular vibrational mode absorbs a specific amount of energy from electrons which travel across the space in a receptor. If the electronic levels on either side of this space are such that the electrons can travel across the space when they have lost the right amount of energy, the receptor detects the particular vibrational mode, transmitting an impulse to the cerebral cortex. This theory, however, is still under development.

Whilst theories of odour mechanisms and systems to standardise odour classes continue to be developed, one of the most basic forms of classification remains in use. This categorises odours into those which are liked and those which are disliked (Harper 1972).

1.22 Odour preference and rejection

Experimental investigations have clearly shown that differences in pleasantness and unpleasantness are perhaps the most distinctive and readily identifiable source of variation in odours (Harper 1972, Engen 1988). Attraction and repulsion have an obvious biological importance in various contexts, but these primitive responses may be overlaid by a variety of learned responses, differing in nature and complexity, leading to the individuality of human reactions. Linnaeus (1756) defined a sub-group of odours referred to as *allis grati allis ingrati* (pleasant to some people and unpleasant to others). These included Ambrosiaci (musk-like) and Hircini (goat-like) odours. This difference in perception, however, was not clarified experimentally until the 20th Century but a substantial amount of research has now been conducted on the appeal of different odours (Land 1979, Engen 1982, Engen 1988). The existence of odours which produce different perceptions in sub-populations has a number of implications. There is a need to be aware of such odours in selecting representative stimuli for many aspects of research into olfaction and odour response, and to recognise such differences as real and not reject them as random and inconvenient noise (Stephens 1996).

Variations in perceived quality, sensitivity and hedonic response may, together with other factors such as culture and familiarity, provide an explanation and understanding for the well known variations in food preferences which are expressed as 'one man's meat is another man's poison' (Land 1979). An individual's odour preference is believed to be linked to the relationship between odour and memory (Gilbert and Wysocki 1987) and research has been conducted to determine whether the pleasantness of a recollection causes the odour to seem pleasant, or vice versa and whether a pleasant odour may evoke an unpleasant memory. Woskow (1964) found an individual who expressed a strong liking for the odour Skatole (usually regarded amongst the most unpleasant of odours) due to its personal associations with pleasant memories. This would suggest that the pleasantness of the recollection causes the odour to seem pleasant, or alternatively, the joy of the associated experience outweighed the effect of the odour. Similarly, bad experiences with certain foods have been found to cause aversions to associated odours (Garcia and Koelling 1966).

Gilbert and Wysocki (1987), highlighted that the liking of odours can vary among individuals and may be based on a number of factors including social, historical, cultural and situational influences. Cultural differences are particularly evident in flavour preferences where the consumption of different dishes can vary considerably from one country to another. Based on this variation in *flavour* differences, Pangborn *et al.* (1988) conducted research designed to quantify regional similarities and differences in rated pleasantness of *odours*. The results indicated that the degree of liking for the odours varied across regions due to differences in traditional food habits and the availability of regional flavour sources. As the study focused mainly on food and beverage odours, the results may also be interpreted in relation to food culture.

Data were also gathered on the frequency of use of the foods and beverages pertaining to the tested odours. The flavour usage trend was consistent with the different food habits and cuisines of the countries which participated in the study. The popularity of onion and garlic in many cuisines contrasted with their low acceptance of the odour in this study, suggesting that odours must be sampled in an appropriate food context to be liked and appreciated (Pangborn *et al.* 1988).

Acceptance and rejection behaviour in relation to food preference, therefore, may be influenced by a number of factors, including cultural and religious norms, personal influences and situational variables (Shepherd 1989)

In addition to food odours, there is evidence of a strong cultural preference for non-food odours (Van Toller *et al.* 1993) and findings relating to the appeal of different odours have important implications for investigations into the role of olfactory cues. The appropriateness of the context in which odours are presented appears to play an important role in odour acceptability (Rozin 1982, Pangborn *et al.* 1988 and Van Toller *et al.* 1993). Any research conducted into the role of olfactory cues is, therefore, likely to be affected by such contextual variations and individual differences in perception.

Harper (1966) proposed that, due to the fact that odours may be perceived differently by different people, in order to gain a stable indication of the perception of an odour stimulus, a combination of the views of at least 10 persons must be obtained.

Van Toller *et al.* (1993) analysed odours in terms of the processing with which they may be associated, and classified them under three main headings :

- *Sensory.* This refers to information which is characteristic of the stimulus and remains stable over time. (For example, the 'lemoness' of a lemon).
- *Hedonic.* This relates to a subjective perception of attractiveness and unpleasantness.
- *Evaluative dimension.* This is a set of comparative data learnt by associating sensory data with other information (For example, a 'clean', 'fresh', or 'pungent' smell).

The hedonic and evaluative dimensions are not related to fundamental properties of the stimulus, but are learnt by association and imitation learning. These may change over time and are subject to environmental influences. In addition to individual differences in the liking and disliking of odours, many odours are also associated with individuals' memories and emotions contributing further to the idiosyncratic perception of odours (Van Toller *et al.* 1993).

1.23 The relationship between odour and memory

As reviewed in section 1.12, due to the anatomy of the central nervous system, olfactory perception is linked to memory and emotion. Whilst detailed and well documented research into the field of memory and emotions is relatively new, odours have clearly been recognised as having associations with memory for hundreds of years. Poets and writers have been found to make use of the sense of smell in conveying memories and associations, for example, Richard Llewellyn (1939) and Charles Dickens 1842.

Dickens (1842) wrote

> *....a thousand odours floating in the air, each one connected with a thousand thoughts, and hopes, and joys, and cares long, long forgotten !*

This quotation, from 'A Christmas Carol', indicates that the connection between odour and memory is not a new discovery.

Research into the links between odour and memory has been conducted from a number of different perspectives, ranging from long and short term recall, personal associations and the effects of learning (Engen *et al.* 1973, Engen and Ross 1973, Desor and Beauchamp 1974, Witherley 1995). Achilles (1929) succinctly expressed the complex nature of odour perception which continues to be investigated today.

> *The first impression of an odour is not a pure sensation as it can be and perhaps often is in vision and hearing, but a complex feeling state. It is the development of this state which takes time, for it entails interactions with other aspects of the situation. Although the odour perception is slow to come to mind, it may last long.*

The role of the memory in sensory experiences relating to food is believed to be very important. Comparisons of dishes are often made, for example, with foods served in different restaurants or compared to 'home-made' dishes, all of which are based purely on memory. There is, in fact, no way of knowing, except by memory, how to judge the next bite from the one just swallowed, but it is difficult to determine how far the memory is exact and how this may be affected by time (Renner 1944).

An identification study, conducted by Desor and Beauchamp (1974), found that errors in odour identification were due to inadequate vocabulary, rather than an inadequate olfactory system as the participants were able to detect and recognise the odours but were unable to give them the correct label.

As discussed in section 1.12 the senses of audition and vision pass through various structures of the brain (including the Broca's and Wernicke's centres) before reaching the limbic system. Olfaction, however, projects directly into the limbic region giving it a much stronger link to memory and emotion, but a weaker connection to the language centres. This connection may explain why humans have strong emotional and physiological reactions to odours, but relatively poor ability to identify them linguistically (Benderley 1988).

Desor and Beauchamp (1974) also tested the effects of practice. Participants were trained extensively until they could identify 32 different odours on two successive trials. They were then tested again five days later where almost 100 per cent accuracy was achieved in identifying the same odours.

Similarly, Engen *et al.* (1973) studied the short-term memory of odours and also found that the apparent difference between the sense modalities may be related to the problem of coding. Odourants are usually described in terms of association. Certain odours may have special meaning to some individuals based on experience and it would obviously be beneficial if these odours happened to be selected in the experiment. In general, however, odours are difficult to describe or even identify without any delay at all. The results also indicated that short-term odour memory improves slightly up to a retention interval of 12 seconds. The two reasons suggested for this were firstly that sensory adaptation may be a more important factor in olfaction than vision and audition and secondly the subjective coding of an odour could be slower than that in other modalities. This phenomenon may be related both to the physical process of stimulation (the time required between sniffing and the experience of an odour sensation) and to the labelling of the experience in one's own thoughts (Engen *et al.* 1973). The structure and composition of the central nervous system (CNS) increases the feasibility of this explanation, as an odour initially targets the limbic system, taking longer to reach the Broca's and Wernicke's areas.

The maximum interval in the short-term memory experiment was only 30 seconds and thus fairly short. Engen and Ross (1973) later investigated the long-term memory. Unlike visual and auditory memories, immediate recognition tests for 20 or more odourants produced numerous errors, but there was little further retention loss for periods up to three months. It would appear, therefore, that neither verbal labelling nor odour familiarity aided memory, while long-term retention was retained even when there were no instructions to memorise. Based on these results, Engen and Ross (1973) suggested that odours are coded as unitary perceptual events with little attribute redundancy which leads to poor immediate retention but great subsequent resistance to distortion of immediately retained odours.

Witherley (1995), however, reported that the correct identification of odours improved from 58 per cent to 85 per cent with the aid of the odour names. Three months later the same subjects were asked to name the odours again, without the aid of the labels, and eighty two per cent were identified correctly. It may, therefore, be concluded that odour memory does not diminish with time. The memory for flavours was found to be related to the distinctiveness of the flavour and the duration of the contact (Witherley 1995). Odour memory is not connected to the name of the stimuli but related to emotions and events or objects associated with the stimuli. Odour, therefore, becomes a powerful stimulus through association and the odour memory has much less decline over time than memory for flavour (Witherley 1995).

In addition to the recollection of experimental stimuli, odours may also be associated with personal memories and emotions. Shleidt *et al.* (1988), conducted a study to investigate odours stored in the memory which can be verbalised during free recall. Three main points were elicited from the investigation; firstly, odour memories were found to reflect everyday experiences with the physical and social environment. Secondly, odour memories were found to be positive as well as negative, with the results indicating that the feelings and circumstances which accompany pleasant odours are just as important as the memory for negative odours (as discussed in section 1.13). Finally, it was found that preferences existed in reactions to odours. One third of the stimuli in this study were judged as both pleasant and unpleasant, suggesting the prevalence of individual attitudes.

Odour strength has been reported to be directly related to the vividness of memory recall, with women reporting more memories than men for most of the odours (Gilbert and Wysocki 1987). Extremely pleasant and extremely unpleasant odours were found to be more likely to evoke memories than odours with an average rating. It was also reported that odour-evoked memories fade gradually with age (Gilbert and Wysocki 1987).

Again, these findings highlight the importance of accounting for individual preferences and personal associations in odour investigations. This may lead to implications in relation to food research where a particular food odour may remind an individual, for example, of a favourite restaurant, leading to positive associations. Alternatively, an association with a bad restaurant or experience may lead to negative perceptions. Closely linked with memory, odour also plays a role in mood and emotion.

1.24 The relationship between odour and emotion

The memory for odours has been found to stem from strong initial associations and is resistant to decay. This is especially true if the odours are paired with emotionally significant events (Lawless and Cain 1975, Engen and Ross 1973, Davis 1977). Kirk-Smith *et al.* (1982) demonstrated that when an unfamiliar odour is associated with a stressful situation, subsequent exposure to this odour may elicit accompanying mood and attitudinal changes. The effects of odours on moods and attitudes, however, may be difficult to verbalise due to the fact that in humans, the auditory and visual senses predominate over the olfactory sense. The acquisition of the associations may, therefore, be below the level of verbal awareness. A further experiment found the lack of a verbal label for an odour prevented subjects from detecting it. Once the odour had been named, however, subjects recalled receiving it during the experimental session (Van Toller *et al.* 1983).

The results of these investigations indicate that in a variety of ways, odour plays a very important role in both memory and emotion. This is integrated with both the findings on the appeal of odour stimuli and the idiosyncrasy of an individual's response to an odourant. The findings suggest that it may be impossible to find one single odour which would have the same effect on everyone, hence, these factors produce a number of implications for investigating food choice and acceptability. These implications, however, may have both positive and negative dimensions for the food industry, as the inaccuracy of the memory may be taken advantage of to change the character of a dish. The inaccuracy of the memory is similarly exploited by food manufacturers in making changes to their products (Renner 1944).

The function of odour stimuli in relation to preference or rejection and memory and emotion may have implications for eating behaviour, and along with other sensory stimuli may play a role in food choice, consumption and acceptability. As sensory based factors have been found to promote satiety, they also appear to form part of the very complex equation of hunger.

1.3 The mechanisms involved in hunger and food intake

The concept of hunger involves the integration of a number of mechanisms ranging from physiological and environmental, to cognitive and stimulus based factors. One of the main factors contributing to the complexity of hunger is, that in order to maintain optimum health, animals, including humans, must regulate their food intake on both a short and long term basis. This long and short term energy regulation is termed *homeostatis* and may be defined as 'the maintenance of relatively constant conditions in the body, by physiological processes, that act to counter any departure from the normal' (derived from Cannon 1929 and The Chambers Dictionary 1994). Any deviations from these normal conditions usually induce reactions designed to re-instate the 'set point' and are referred to as negative feedback (Logue 1986).

1.31 Physiological and psychological theories of hunger

Theories of hunger have been developed, most of which are based on the concept of homeostatis through negative feedback. Many of these theories are related to peripheral cues of hunger and satiety involving parts of the body's physiology other than the central nervous system. These include *stomach contractions*, where a "....contracting, growling stomach...." was found to be synonymous with hunger (Cannon 1912). More recent research indicated, however, that neither stomach contractions nor indeed a stomach are necessary prerequisites for reports of hunger (Stellar 1954). Other peripheral cues include *stomach distension* and *oral stimulation* (Janowitz and Grossman 1949). Oral factors have been found to contribute to the cessation of eating, but in isolation, oral factors do not precisely regulate food intake. It was also concluded that stomach distension does not have a significant effect in terminating a bout of eating. Investigations into the energy content of foods and its effects on feeding, indicated that decreasing the energy content does not result in subjects eating a greater volume of food (Brala and Hagan 1983), hence the energy value of foods does not directly influence the food eaten. These findings indicate that whilst each of the above cues may make a contribution, there is no single mechanism for hunger, and the body uses several ways of determining how much has been eaten and how much will be eaten (Logue 1986).

Another peripheral factor which has been reported to play a role in the eating process is *environmental temperature*. Observations of several different species, including humans, have shown that more food is consumed in cold environments and less in warm conditions. One explanation for this is that in cold conditions, the body needs more fuel to keep itself heated to 37°C (Brobeck 1948). Recent research, however, indicated that the cold does not directly cause an increase in energy requirements (Edwards *et al.* 1995).

In addition to the contribution of peripheral factors to hunger, it has been reported that *energy commitment* plays an important role (Carlson 1995). This is based on the concept that, as energy is used, food is consumed, and as the energy is regained, consumption stops. According to the glucostatic theory (Mayer 1955) the short term regulation of energy intake takes place when a fall in blood glucose leads to a metabolic signal for hunger. Blood glucose is known to be the primary energy source for the central nervous system, and levels of blood sugar increase rapidly after feeding, slowly decreasing with time until the next feeding. Circulating sugar levels were shown to act as a signal to the brain, indicating the amount of immediately available or needed energy. It is believed these signals are produced by glucoreceptors present in the hypothalmic centres (Mayer 1955).

Long-term regulation of hunger is also believed to be a mechanism related to the fat stores in the body, as excess energy is stored as fat. In order to take advantage of this storage system, the body requires a mechanism to detect the extent of its energy store. Lipostatic theories of hunger (Mayer 1955) propose that metabolites of the body's stored fat (free fatty acids) are responsible for the long-term regulation of this storage. When the circulating levels of free fatty acids are high, as a result of breaking down stored fat, food consumption is increased. When they are low, indicating that fat is being stored rather than utilized, less food is consumed (Keesey 1980). In this way, the glucostatic and lipostatic mechanisms could work together to regulate the body's intake on both a daily and long term basis.

More recent studies have proposed alternative hypotheses to Mayer's glucostatic and lipostatic theories. Blood glucose levels, for example, have been found to be too variable to predict feeding behaviour reliably and glycogen levels (a form of carbohydrate stored in cells, particularly in the liver and muscles) have been proposed as an alternative to the glucostatic theory. As energy may be stored in the body in the form of either fat or glycogen, this theory has been viewed as integrating the glucostatic and lipostatic mechanisms (Flatt 1987). Although the original glucostatic and lipostatic theories (Mayer 1955) have been developed, it is believed that a theory involving a single, simple mechanism is inadequate to describe the role of blood sugar and body fat in the consumption of food (Logue 1986).

The effects of certain gut peptides involved in the metabolism of nutrients have recently been strongly implicated as factors in satiety. High levels of these peptides decrease the amount of food eaten during a meal, which according to Logue (1986), are released during digestion and may help to terminate feeding. According to other studies, blood amino acid levels and the food-water ratio in the stomach and small intestine are also believed to have a peripheral influence on initiating and terminating eating (Lytle 1977).

Stomach contractions (Cannon and Washburn 1912), oral stimulation, stomach distension (Janowitz and Grossman 1949), temperature regulation (Brobeck 1948), glucostatic, lipostatic (Mayer 1955) and gut peptide mechanisms (Logue 1986) are some of the peripheral factors which have been proposed as determinants of hunger. The variety and extent of these theories indicate that a multitude of factors are involved in hunger, and it is believed that for this reason, research has been conducted to investigate particular locations within the brain that might coordinate and synthesize the peripheral information (Hetherington and Ranson 1940).

Studies into the integration of the CNS mechanisms have sought to determine whether or not there are particular locations in the brain that control hunger and satiety. It has been reported that the hypothalamus may be closely involved in eating behaviour. Findings by Bal and Brobeck (1951) indicated that the lateral hypothalamus may be responsible for the initiation of eating whereas the ventromedial hypothalamus controls the termination of eating (Hetherington and Ranson 1942). Rolls *et al.* (1988b) also found activity in the lateral hypothalamus of monkeys to be linked with satiety (see section 1.18).

Further research has provided evidence to show that whilst the hypothalamus serves as a major integrating role for sensory inputs and motor outputs relevant to feeding, hunger and satiety centres in the brain may not exist. It is believed that neural control of feeding is generalised throughout the brain (Logue 1986).

A number of non-physiological factors such as environmental stimuli have also been found to play an important role in the initiation and termination of eating, and experiments have demonstrated the effects of learning on subjects' tendency to eat (Van Wort and Smith 1987).

Human studies show that the hippocampus, which forms part of the limbic system, is involved in both non-spatial and spatial memory, for example, in paired associate learning and in episodic memory such as the memory of events. Rolls (1989) postulated that the reason these two types of memory are analogous is that the hippocampus contains one stage which acts as an autoassociation memory. The network learns to recognise a particular pattern of inputs and through association produces a unique output for each pattern. Subsequently, if a similar pattern is presented later, the network produces the appropriate output. This phenomenon of autoassociation is closely related to the concept of cueing, where the pattern of inputs acts as a cue to produce the relative output.

1.4 The concept of cueing

A *cue* may be defined as a factor which allows a decision to be made automatically and spontaneously without requiring elaborate thought (Goldstein 1980). Exposure to a variety of cues occurs everyday which may influence the perception of an object or situation. Over time, certain perceptual cues may become familiar and are analysed almost automatically with minimal thought processes. This may lead to implications, as found by the Stroop test (1935), in which these automatic processes are difficult to override. The 'Stroop effect' occurs when a 'higher' perceptual process (such as reading a word or identifying a number) interferes with a 'lower' process (such as counting the number of items in a row, or naming the colour of ink in which a word is written). It is believed to arise because some 'higher' perceptual skills become so well learned that they happen automatically, and their use is difficult, if not impossible to prevent.

This effect has been demonstrated in relation to sensory stimuli in which the effects of visual cues on odour identification were investigated (Blackwell 1995). The results indicated that when visual and odour cues conflict, the visual sense appears to override olfaction and distract assessors from correctly identifying a given odour.

The Stroop phenomenon may be applied to food intake as the appearance/colour of a product frequently gives an indication of its anticipated odour, flavour and texture (Clydesdale 1978). Through pattern recognition mechanisms a consumer may, for example, associate a certain food colour with a particular flavour, hence the visual cue would influence food choice and acceptability. Sensory based food cues are, therefore, believed to influence dietary patterns and eating behaviour (Cardello 1996).

1.41 Sensory cueing

Sensory experiences associated with food are important determinants of food choice (Meiselman 1979), but other than an influence via the innate or acquired hedonic aspects of foods, little is known about the mechanisms by which sensory cues effect food selection and ingestion. One mechanism by which such cues may exert their influence on food intake is through learned associations, and research suggests that an individual's responses to food are largely learned, not innate (Logue and Smith 1986, Hook 1978). Shoben (1963), found that learned associations contribute to the aesthetic function of the sense of smell, and research conducted by Engen (1982) indicated that new born babies were able to sense odours, but there was no evidence of hedonic discrimination. Results of research with children from various age groups also suggested that responses to odours are modified through experience (Stein *et al.* 1958). In contrast to these findings, Steiner (1977) examined the facial responses of infants shortly after birth and found negative responses were given to odours considered as unpleasant by adults, indicating innate preferences to odours.

Taste preferences are believed to be genetically determined, whereby, humans have an inherent liking for sweet foods, find bitter and acidic foods unpleasant and like salty foods at low concentrations. It is also evident that not all individuals like the same foods, and findings suggest that genetic differences result in individuals tasting foods differently (Bartoshuk 1980). Similarly, results have shown that past experience may shape food habits (Moskowitz *et al.* 1975), particularly across nationalities and cultures (Pangborn *et al.* 1988).

It is therefore possible that the sensory experience associated with a given meal or snack may be a particularly salient cue for influencing intake of that same meal or snack on subsequent days. Sensory stimuli of food produce cues which are perceived and interpreted by sight, sound, touch, hearing and smell (Meiselman and MacFie 1996).

1.42 Visual cues

Sight is now regarded as the primary human sense, and visual cues play an important role in food choice and acceptability (section 1.13). Sight is usually the first and sometimes the only sense used to analyse the quality or acceptability of a food product, particularly when purchasing a food item for the first time (Goldstein 1980). Foods are usually identified by visual cues and through repeated dietary experiences, evoke an anticipated set of oral sensations (Amerine *et al.* 1965).

Colour is one of a number of visual stimuli which have been found to have important effects on the perception and influences of food choice (MacDougall and Moncrieff 1987). This aids the identification of foods and is also important for identifying colour linked flavours (Clydesdale 1978). Christensen (1983) found that appropriately coloured foods were perceived to have a stronger and better quality odour, and to a lesser extent, a more intense and better quality flavour than similar products which had been given inappropriate colours. Dubose *et al.* (1980) reported the ability to correctly identify an orange flavoured solution increased from 30 per cent (when inappropriately coloured or colourless) to 80 per cent when coloured appropriately, indicating that relevant visual cues are necessary in order to identify the flavour of a given product. Similarly, the ability to identify the odour of a solution increased from 31 per cent (when inappropriately coloured) to 79 per cent when coloured appropriately. This study also indicated that the ability to rank odour intensity improved significantly when odour and colour strengths were compatible than when they were conflicting (Blackwell 1995).

The importance of visual cues when assessing wine has been investigated, and studies by Pangborn *et al.* (1963) established that experienced wine tasters were influenced by the colour of a wine when evaluating its sweetness. Singleton and Noble (1976) and Williams *et al.* (1983) also suggest that assessors give higher hedonic scores to red wines with darker colour, clearly indicating that appearance plays a significant role in the differentiation of wines.

The appearance of a food influences its desirability (Goldstein 1980), and food manufacturers expend considerable effort to produce appealing pictures of food for packaging and advertising campaigns (Hann and Colquhoun 1996). Through various different media, therefore, the majority of consumers are regularly exposed to a variety of visual stimuli relating to food. Research has found that visual images, such as brand names and logos are regarded as important cues when choosing between competing items (Chernatony 1991). Hence, the role of visual cues in food acceptability is two-fold, in that, the appearance of the food itself gives an indication of its palatability, and the packaging or brand image of a product may give an indication of the quality or sensory characteristics of the commodity.

Once a food has undergone an initial visual analysis, the other senses come into force in assessing the taste, odour and texture of the product, and the sensory experience associated with a food may influence intake of that same food on subsequent days (Piggott 1984).

1.43 Gustatory cues

The flavour or taste of a food may be a particularly salient cue for influencing future consumption, as once a food is consumed the taste/flavour will be memorised and used to aid future decisions regarding food choice (Tepper and Mattes 1990). In conjunction with this, sensory fatigue and habituation play an important role, as repeated presentation of preferred foods results in decreases in food palatability and consumption of these foods (Durrant and Royston 1980). Flavour and taste cues have also been found to be linked with the avoidance of certain foods. For example, a negative experience with a particular commodity such as drinking milk which had turned sour may influence the acceptance of milk in the future. The pairing of food with sickness often results in avoidance of the associated taste and is termed conditioned taste aversion. This is an example of classical conditioning and experiments showed that a sugar drink which was normally consumed by rats in large quantities was consequently avoided after a sample containing poison induced sickness (Garcia and Koelling 1966).

Learned flavour cues have been shown to influence snack food selection in children (Birch and Deysher 1985), and more recent research revealed the contribution of learned flavour cues to daily patterns of food ingestion (Tepper and Mattes 1990). This suggested that flavour cues, associated with an experimental lunch meal, influenced daily food intake in 25 per cent of the subjects. This finding is consistent with observations in adults (Booth *et al.* 1982) and children (Birch and Deysher 1985) where, following flavour-calorie conditioning, intake of a given experimental meal or set of snack items was influenced by its associated flavours. As only 25 per cent of the subjects responded to the flavour cues, this highlights the complexity of the food intake regulatory process and indicates that other factors such as social, cultural and environmental influences, play an important role in food intake (Tepper and Mattes 1990). In addition to the flavour or appearance of a food, other sensory cues have an important function either in conjunction with other senses or in isolation. These include auditory and tactile cues.

1.44 Auditory cues

The importance and desirability of crispness as a sensory quality in many food products is well documented (Cardello 1996). Drake (1963), reported that sounds produced by crushing a variety of foods differed in amplitude, frequency and temporal characteristics. Vickers and Bourne (1976) suggested that acoustical sensations are involved in the perception of crispness in foods, and Sherman and Deghaidy (1978) reported that assessors used auditory cues, particularly during their first bite, to determine food crispness. Vickers and Wasserman (1980) found a high positive correlation between perceived loudness of the food crushing sounds and their perceived crispness. This cumulative data suggest that biting and chewing sounds, particularly the loudness of these sounds relate to the sensation of crispness in foods.

Other work in this area, however, has produced conflicting results indicating that oral tactile cues are essential when judging hardness in foods and auditory cues play a far less vital role in food choice and acceptability (Szczesniak and Kleyn 1963, Szczesniak 1971, Vickers 1983). These studies indicate a link between tactile and auditory cues and it would appear, therefore, that further investigation is required to clarify these roles.

1.45 Tactile cues

In addition to oral tactile cues, texture cues in isolation have also been investigated. Research on the sensory cues involved in the perceptions of fat-related attributes found that visual and olfactory cues are not required for the detection of fat levels in dairy products (Pangborn and Dunkley 1964). The perception of the fat content in these products appears to be principally mediated by textural sensations (Mela 1987). The study also found a similarity between manual tactile and oral evaluations of oiliness.

Whilst a significant amount of research has been conducted on visual, auditory, gustatory and tactile cues, literature available on the effects of olfactory food cues on meal choice and acceptability, is somewhat limited. Studies which have been performed, appear to relate to sub-populations (for example, smokers) rather than the effects of olfactory food cues in general.

1.46 Olfactory cues

Olfactory cues have been found to be related to alcohol consumption, the typical cues for alcohol being visual and olfactory (Greeley 1993). Studies have revealed that social drinkers, who have not been diagnosed as physically dependant on alcohol, show an increased desire for alcohol and changes in other cognitive variables when presented with these alcohol cues (Greeley 1993). The two properties of these cues are that they represent a palatable substance and have a relatively strong odour. Other investigations have shown that alcohol abuse may be associated with olfactory loss (Gregson *et al.* 1981).

Another subset of studies on olfaction relates to the effects of smoking. Hepper (1992) found smokers and passive smokers required a stronger concentration than non-smokers to identify experimental odour cues. On the basis that smoking decreases olfactory function, it is believed that smoking reduces the perception of food flavours, thus potentially reducing the hedonic value of food (Frye *et al.* 1990). Smokers typically gain weight after cessation and changes in the perception of taste and olfactory cues are believed to be related to this eating change (Kleges *et al.* 1989). Recovery of the olfactory function has been found to occur in smokers after cessation, although the time required for recovery is usually equivalent to the number of years of smoking (Frye *et al.* 1990).

The links between olfaction and food intake have been researched in relation to animals, whose sense of smell is either their primary sense or is used principally for the location of food. Rodents possess greater peripheral and central processing capacity for olfactory information than visual information, and it has been shown that they are able to learn olfactory cues more rapidly than visual ones (Slotnick and Katz 1974).

The use of different sensory modalities depends on the availability of different types of cues. Janzen (1971) and Smith and Follmer (1972) found that visual cues for animals in search of food may be much reduced with complete burial or snow cover. This observation may be applied to humans on occasions when visual cues are not sufficient. For example, foods such as milk and butter become unfit for consumption some time before their visual appearance deteriorates. The odour properties of these foods, however, give a good indication of the quality, hence, the sense of smell is used to detect if milk has 'gone off' in preference to the visual sense (Frazier 1967).

In the food and beverage industry, the early detection of certain 'off' odours is essential for quality control purposes, and this importance of odour quality, coupled with the subjective, idiosyncratic nature of human olfaction has led to the development of electronic methods for odour assessment. The electronic nose, first released approximately five years ago, is based on arrays of electrochemical sensors, connected to a personal computer, programmed to recognise input from specific odourous molecules. These commercial devices are used in manufacturing to provide 24 hour, on-line quality control, and developments are currently taking place to reduce the size of the instrument to further increase its application (Pendick 1997).

Odour cues have also been found to be associated with food cravings and aversions. Bartoshuk and Wolfe (1990) reported that food aversions are more likely to be conditioned to odour than to taste, and craved items have odours that are pleasant as well as familiar. This may be in line with the theory of conditioned taste aversion (Garcia and Koelling 1966), as the odour of a food which has been linked with sickness is likely to lead to a dislike of that odour and avoidance of the food with which it is associated.

Sensory cues also play an important role in relation to sensory specific satiety and alliesthesia (section 1.18), where hedonic responses to food related tastes and odours are affected by an individual's internal nutritional state. Salivation to food cues is related to the palatability of food and the time since last eaten, and subjects reliably salivate more to food they like than do not like (Wooley and Wooley 1973, Klajner *et al.* 1981). Subjects also salivate more when food-deprived than when satiated (Wooley and Wooley 1973). Similarly subjects have been found to show decreases in salivation and lowering of their hedonic response to both repeated presentations of olfactory (Wisniewski *et al.* 1991) and gustatory (Epstein *et al.* 1992) food cues and these responses recovered when a new food was presented.

1.47 Non-sensory cues

A number of non-sensory stimuli have important functions in guiding appetitive feeding behaviour (Archer *et al.* 1979). Animal studies revealed that behaviour can be triggered by cues which have been repeatedly associated with food consumption leading to learned associations in a Pavlovian sense. Similarly, contextual cues, such as being alone or watching television have been found to trigger binge eating in bulimics (Jansen and Brokemate 1992). Nutritional meaning has also been found to influence decisions regarding food selection. Booth (1981) noted that once a food's sensory properties acquire nutritional meaning, they may influence future decisions regarding food selection and portion size by providing pre-absorptive information about the probable metabolic implications of ingesting the item.

1.5 Summary of literature reviewed

It is evident from the literature reviewed, that although the sense of smell has declined in relative importance since prehistoric times, it still plays a functional role in human behaviour. Olfaction is now very much an ancillary sense, with vision being of pre-eminent importance, but due to its vital role in flavour, the sense of smell still retains value in relation to dietary habits. The olfactory system differs from the other senses in a number of ways; firstly it consists of only one type of receptor which has direct contact with the stimulus and functions for up to eight weeks before being replaced; secondly, the system is prone to physiological fatigue, having important implications for food consumption in relation to adaptation and satiety; and finally olfaction is the only sense to project immediately into the limbic region of the brain, giving it a direct link to memory and emotion. This connection leads to personal memories, associations and physiological reactions to odours and may also contribute to variations in odour preference between individuals, making olfaction a very idiosyncratic sense.

The understanding of the olfactory system and classification of olfactory information differs from that of vision and audition, with odour sensations often being described in terms of direct or indirect associations. The functions and anatomy of the olfactory sense, however, are becoming more widely known, and the ways in which odours may be detected and classified continue to be researched.

In relation to dietary habits, both sensory and non-sensory stimuli play a functional role in food choice and acceptability. From a sensory perspective, stimuli released by a food may be perceived by all five of the sense organs; taste, texture, smell, touch and sight. In some instances a food may stimulate all five senses simultaneously, in others cases one sense may take priority and influence the others.

Although olfaction appears to play a role in human food consumption, this has been studied mainly in the context of flavour, or in relation to the habituation of food odours and their effects on satiety. The extent to which food odours, in isolation of taste cues, influence food selection and dietary patterns has *not* been investigated. Since taste and odour are known to have different effects on eating, it is considered to be necessary to separate the contribution of these sensory inputs to food hedonics and consumption, to gain a fuller understanding of the role of olfactory cues and their effects on food choice and acceptability. Due to the subjective nature of acceptance behaviour, certain elements of the investigation will take place in a practical restaurant environment (Blackwell and Pierson 1996) in order to investigate the effects of olfactory cues on eating behaviour under realistic conditions.

The hypothesis for this investigation, therefore, states that: *olfactory cues, in isolation of other sensory cues, play a functional role in food choice and acceptability*. In order to test the hypothesis, experimental investigations will be conducted to examine this neglected area and meet the following aims and objectives.

1.6 Aims and objectives

1.61 Aims

- To determine the role of olfactory cues in relation to hunger.
- To establish the role of olfactory cues in influencing food choice, consumption and acceptability.

1.62 Objectives

- To measure the effects of exposure to food odours on hunger perception.
- To measure the effects of exposure to food odours on food choice, consumption and acceptability.
- To develop a predictive model, demonstrating the role of olfactory cues in influencing food intake and dietary patterns.

2.0 *Empirical investigation*

In order to test the hypothesis, experiments were designed and conducted, in a sequential series, to meet the objectives of the investigation. Due to the complexity of the empirical research, the work is presented as a series of experiments, the results of which are discussed individually and specific conclusions drawn. Overall conclusions are presented collectively in section 4.0.

The structure and organisation of the empirical research was as follows:

Section 2.1	To select food odours suitable for further experimentation
Section 2.2	To measure the effects of exposure to food odours on hunger perception
Section 2.3	To measure the effects of exposure to food odours on food choice, consumption and acceptability.
Section 2.4	To measure the effects of odour exposure in a restaurant environment

2.1 Experiments to select food odours suitable for further experimentation

Based on the literature reviewed in section 1.4, it was evident that although the olfactory sense may have a role to play in food intake, it is not currently regarded as a primary function and may be overridden by other sensory stimuli. Hence, in order to isolate and measure the *actual* role of the olfactory sense, it was necessary to minimise all other sensory cues, such as those originating from visual or auditory stimuli.

The first stage of the empirical investigation was designed to select and examine a range of odour stimuli from a variety of sources, in order to establish a set of odours suitable for use in further experiments. To be appropriate for the design of the future experimentation it was essential that the selected odours met the following criteria:

- to realistically represent a specific food
- to be sufficiently intense to infuse into a volume of $36m^3$
- to persist throughout the duration of the experiments
- to produce a recognisable odour
- to be non-hazardous to health

Due to the fact that olfaction is a dual sensory modality (as discussed in section, 1.16), certain foods may be characterised by a flavour which is usually liked, but an odour, which when sensed in isolation, is often disliked. Examples of this include mature cheese and cabbage (Rozin 1982). When selecting odours for investigation into the role of olfactory cues, stimuli which have previously been found to possess such properties were amongst those chosen for examination in order to examine their comparative effects with other food odours.

A range of pure chemical substances, manufactured flavour compounds and actual food odours (produced by cooking) were selected and tested for their ability to meet the above criteria.

Savoury odours were selected for investigation for the following reasons; firstly, they were appropriate for the context and timing of the experiments which were to be conducted during the morning, leading up to lunch; secondly, it was possible to experiment with a variety of meat, vegetable and dairy products; and finally, the selected savoury odours were deemed to have characteristics which made it possible for them to be attributed to their generic foods.

Once the set of suitable odours had been established, hedonic attributes were calculated for each stimulus using the assessors[11] selected to take part in future experiments.

2.11 Experiment to test chemical odours

Chemical stimuli which would produce a single, pure odour, were initially selected and tested in order to provide a standard reference which could be accurately repeated in further experiments.

Method

The chemicals shown in table 1 were selected and tested for their suitability. Each chemical underwent the Controls of Substances Hazardous to Health (COSHH) analysis (Health and Safety Commission 1995) and the instructions regarding necessary precautions were adhered to during the tests.

The chemical odours were analysed by a small team of trained assessors, at various

11 Term used to describe all persons taking part in experiments throughout this investigation

levels of dilution, to simulate the required food odour.

Results

The assessors' judgements for each odour were evaluated using group discussion techniques (table 1).

Product Name	*Empirical Formula*	*Reported Sensory Properties**	*Test Results*
Phenethylamine	$C_8H_{12}O_2$	Fishy	Oily, smoky, sharp, rancid
Diacetyl	$C_4H_6O_2$	Powerful, buttery on high dilution	Intense, cream, butter
Methyl Sulphide, redistilled	C_2H_6S	Intense, boiled cabbage, sulphurous	Sulphur, rotten eggs
Eugenol	$C_{10}H_{12}O_2$	Strong, spicy, cinnamon, clove	Cloves, spices
Cyclopentanethiol	$C_5H_{10}S$	Meaty, alliaceous, vegetable	Beef, decaying vegetables, fatty
Butyric Acid	$C_4H_8O_2$	Sharp, cheesy, rancid, sweaty, putrid, sour	Rancid, putrid, sweaty
Hexanedithiol	$C_6H_{14}S_2$	Fatty, meaty	Meaty, greasy, fat

Table 1 Chemical odours tested for further experiments
(Source : *Aldrich Chemical Company. Gillingham, Dorset.)

Whilst the chemical substances were convenient, quick and reliable to use, the results indicated that the odours produced by the chemicals were not representative of any specific food. Based on these findings, and the results from the COSHH analysis, the chemical odourants were deemed to be impractical and inauthentic, dangerous, unethical and not found suitable for further investigation in a restaurant environment.

The chemical odours were therefore, rejected at this stage and a set of manufactured flavour compounds, designed as ingredients for food products, were tested for their ability to meet the requirements of the future experimental design.

2.12 Experiment to test manufactured flavour compounds

Method

Five savoury manufactured flavour compounds, provided by an ingredients company[12] were selected for examination; chicken, mushroom, cheese, beef and smoked

12 Pauls Food Group Ltd, Leicestershire

mackerel/kipper. The flavours were presented in sealed masked containers to a small team of experienced assessors who analysed the odours to meet the criteria set out in section 2.1.

Results

The results were evaluated through a group discussion and it was unanimously agreed that the odours in this form did not realistically represent the related foods. The odours were found to be synthetic in nature and introduced associations rather than reflecting the actual food products.

The flavour compounds were therefore rejected, and actual food products were tested for their ability to meet the requirements of the future experimental design.

2.13 Experiment to test food odours

Due to the complex nature of food, food odours do not consist of single, pure odour stimuli. In order to realistically represent an associated food, therefore, actual food products were cooked to produce the required odour stimulus.

Method

A series of foods were selected for their ability to meet the criteria set out in section 2.1, and tested under controlled conditions, using an automatic ventilated fume cupboard[13]. The savoury foods chosen for experimentation were smoked streaky back bacon, pork sausages, mature Cheddar cheese, freshly baked bread, Brussels sprouts and white cabbage. In order to establish the effects of individual food odours, it was necessary to use single food items rather than a 'whole meal'.

The foods were prepared according to the procedures described in table 2. Each food was then placed individually in the fume cupboard and data were recorded to measure the infusion time (i.e. time taken to fill the fume cupboard) and duration of the presence for each odour, in minutes. The intensity of the stimuli was also judged by the small team of assessors used in sections 2.11 and 2.12.

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13 ISOFLOW. Tom Green Products Ltd.
Cabinet size: 2000mm wide x 1200mm high x 940mm deep
Average air velocity: 0.51m/sec

Food Product	*Preparation*
Smoked streaky back bacon	Grilled for 12 minutes on full power (electric grill)
Pork sausages	Grilled for 20 minutes on full power (electric grill)
Mature Cheddar cheese	Grated and melted under grill on low power for 5 minutes
White cabbage	Simmered for 20 minutes and placed in fume cupboard in saucepan of boiling water
Brussels sprouts	Simmered for 20 minutes and placed in fume cupboard in saucepan of boiling water
Freshly baked bread	Baked in oven, broken into small pieces, placed in warm metal container in fume cupboard

Table 2 Food odours tested for further experiments

Results

The results recorded for infusion time, the time required for each odour to reach its maximum intensity and the duration of the presence of each odour are shown in table 3.

Food product	*Infusion time*	*Time of max. odour intensity*	*Duration*
Smoked streaky back bacon	60 seconds	5 minutes	15 minutes
Pork sausage	60 seconds	4 minutes	11 minutes
Melted cheese	90 seconds	5 minutes	7 minutes
White cabbage	60 seconds	6 minutes	19 minutes
Brussels sprouts	60 seconds	5 minutes	20 minutes
Freshly baked bread	90 seconds	3 minutes	4 minutes

Table 3 Analysis of foods used to produce odours

Discussion

Based on the results from these experiments, the chemical substances were rejected for use in future investigations. Although the chemicals produced a single odour which could be reliably replicated in future trials, they were not found to realistically represent the associated foods, nor deemed to be practical in a restaurant environment. Similarly, manufactured flavour compounds produced synthetic, inappropriate odours and were also deemed unsuitable. Whilst actual food products do not provide standard stimuli due to their inherent biological variability, the food products were found to produce the most realistic and representative odour on cooking. Actual food products were, therefore, selected to produce the odours for further experimentation. The evaluation of the food odours indicated that the freshly baked bread was the least successful product, as the odour had a low intensity, reached its optimum level at 3 minutes and declined very quickly. This odour stimulus was therefore eliminated at this stage. Similar results were recorded for both the Brussels sprouts and boiled cabbage and as the odours have similar properties (as outlined in section 2.27), only one of these food products was selected for the next stage of the experiments.

The odours selected for use in future investigations were, therefore, smoked bacon, pork sausages, melted cheese and white cabbage, as the results indicated that these foods met the criteria set out in section 2.1.

Although it was recognised that minor variations may occur in the reproduction of the odour stimuli due to the nature of the food products, the odours produced were generic to their associated foods and control measures were followed to minimise any variations.

2.14 Experiment to determine the hedonic attributes of the selected food odours

This stage of the investigation tested the selected food odours to establish the relationship between the potential theoretical desirability of each food and the direct hedonic response to its odour.

Assessors

The experiment was conducted using 20 assessors (in order to allow for the variations in perception as observed by Harper (1966), section 1.22), 10 males and 10 females, age range 23 to 56 years, (mean 34, SD ± 9). Assessors were all members of staff from the School of Service Industries at Bournemouth University who had no prior knowledge of the work being carried out and were all non-vegetarians.

Method

Assessors were presented with a list of 15 foods and beverages (appendix 3) and asked to indicate, using a 10cm hedonic scale (as used by Lawless and Malone 1996), anchored by 'like extremely' and 'dislike extremely' (figure 4), the degree to which they liked or disliked the products. Included in the list of foods and beverages were the four selected foods from section 2.1 (i.e. smoked bacon, pork sausages, melted mature Cheddar cheese and boiled cabbage). One week later the assessors were presented with the odour of each of the cooked food products, using blind testing techniques. Each odour was identified by a randomly generated three digit coded number and assessors were instructed to give hedonic ratings for each, using a similar 10cm scale as shown in figure 4 (see appendix 4).

Smoked streaky bacon

Dislike Extremely ______________________________ *Like Extremely*

Figure 4 Hedonic scale used for rating of food items

Results

All twenty assessors claimed to like, to some degree, the four experimental foods listed in the initial questionnaire (appendix 3). The mean hedonic ratings given by the 20 assessors for the four foods and their respective odours are shown in table 4.

Food Odour	*Mean (food)* (0 = Dislike Extremely/ 10=Like Extremely)	*Mean (odour)* (0 = Dislike Extremely/ 10=Like Extremely)
975 (Bacon)	9.06	8.75
891 (Sausage)	8.96	6.13
254 (Cheese)	8.14	4.82
657 (Cabbage)	8.65	1.45

Table 4 Mean hedonic ratings given for the foods and their respective odours.

In line with the findings of Rozin (1982), regarding the duality of the olfactory sense (section 1.16), each assessor claimed to like cabbage but gave the odour of the coded sample a low hedonic rating. Similarly, but to a lesser extent, the odour of melted mature cheese was also given a low hedonic rating. In addition to meeting the experimental criteria, the selected stimuli (i.e. cabbage and cheese) also represented foods which possess odours regarded as unpleasant, when the foods themselves are considered to be pleasant, thus demonstrating the dual sensory modality.

To summarise, this initial stage of the empirical research established a set of four odour stimuli, representing the four quartiles of the hedonic scale, which were generic to foods claimed to be liked by all the assessors. These foods formed the fundamental part of the subsequent experiments to examine the effects of exposure to food odours on hunger perception. The assessors who took part in the profiling exercise were asked to participate in further experiments using these odours.

2.2 Experiments to measure the effects of exposure to food odours on hunger perception

It is known that physiological responses, such as the secretion of saliva and other digestive substances, may follow olfactory stimulation (section one). These physiological responses are *subconscious* reactions to olfactory cues and have been found to be related to both the palatability of the food and satiation (Klajner *et al.* 1981). The aim of this part of the investigation was to test the hypothesis that exposure to food odours leads to a *conscious* perception of a shift in hunger[14].

In order to measure this perception of hunger, an appropriate scaling technique was developed to record assessors' hunger levels.

2.21 The development of the hunger rating scale

The basic principles of scale development

Piggott (1984) defined a scale as the tool by which the size or extent of attributes of stimuli are made explicit by assessors. A number of factors needed to be considered when selecting an appropriate scale used to measure hunger levels, based on the test objective, the information required, and the methods of analysis to be applied to the data. As untrained assessors were to be used, it was important that the completion of the form was made as simple as possible in order to avoid subject frustration and measurement error. The words used to scale the responses needed to be familiar to the assessors, unambiguous and easily understood.

The scale length needed to be considered in relation to its sensitivity to differences and it was also essential to eliminate any bias which may influence the test outcome (Stone and Sidel 1992).

The hunger rating scale

Taking these factors into account, a hunger rating scale was developed using an unstructured line scale, based upon the graphic rating scale proposed by Anderson

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14 Definitions (The Chambers English dictionary. 1994)

Conscious : Aware of, and responsive to, stimuli and events in the environment.
Subconscious : Part of mind that is not fully conscious but is able to influence actions.
Unconscious : Not aware. Part of the mind not normally accessible to consciousness.

(1970, 1974). This type of scale was selected, as the limited use of words and the absence of numerical values (as used in category scales) ensured that any bias is minimised. In a comparison of four types of scaling methods, the unstructured line scale was rated as easy to understand, the fastest to complete and the least restrictive (Lawless and Malone 1986). A disadvantage of this technique is that the assessors may use the scale in a variety of different ways; as a ratio scale, an interval scale or in an undefined manner (Stone and Sidel 1992). For the purpose of this investigation, however, this would not influence the results, as the data was used for internal comparisons (i.e. within individual assessors). The emphasis for this investigation was for the assessors to be as consistent as possible, to encourage full use of the scale to express differences and to minimise end order effects (i.e. avoidance of the extremes).

The scale consisted of a 10cm, horizontal line anchored at the left hand side by 'not hungry at all' and at the right hand side by 'extremely hungry' (figure 5). Assessors marked a vertical line on the appropriate point of the horizontal line which reflected their hunger state. The scale provided an infinite number of places in which to indicate the relative hunger intensity (within the constraints of the actual length of the line) and each assessor was able to mark at whatever location on the line they felt appropriate, provided they were internally consistent. The mark was then converted into a numerical value for computational purposes by measuring the distance along the line, in centimetres, from the left hand side.

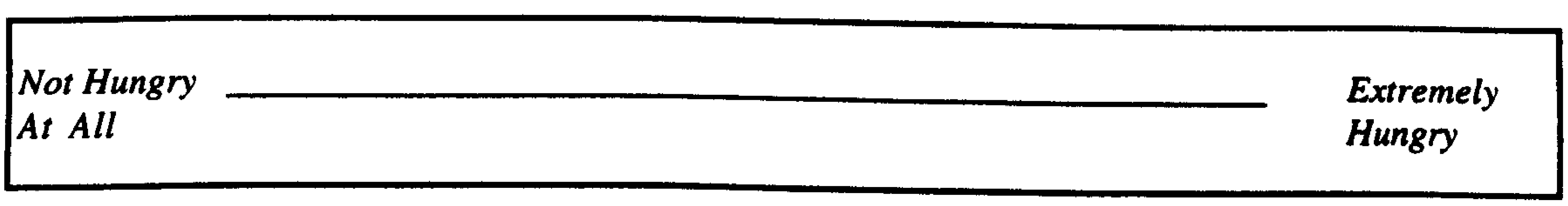


Figure 5 Example of hunger rating scale

The scale provides a quantitative, interval measurement to which most statistical procedures may be applied (Stone and Sidel 1992). The numerical responses may also be converted into ranks in order to apply non-parametric methods of analysis where appropriate.

In order to ensure continuity, where appropriate, this 10cm unstructured line scale was used throughout the investigation, by varying the anchor terms, to record hedonic information and acceptability data, etc.

2.22 Pilot study

A pilot study was conducted to investigate the effects of exposure to food odours on hunger perception. This was carried out with five of the 20 assessors who took part in the hedonic attributes exercise (section 2.14). These were two males and three female aged between 23 and 36 years (mean 30, SD ± 6). The pilot study was conducted using the odours selected in section 2.1, and was designed to assess the logistics of the experiment, the appropriateness of the time scale, and the suitability of the hunger rating scale.

Method

The study took place over a two day period. On the first day, the five assessors recorded their levels of hunger at hourly intervals between 09.00h and 12.00h using the hunger rating scale (figure 5) in their normal working environment[15]. On the second day the food odours were presented in the fume cupboard each hour, to the assessors. The odours were produced by cooking the foods as detailed in table 5 and then placing them in the fume cupboard.

Food Item	*Weight cooked on each occasion to produce odour*	*Preparation*
Smoked back streaky bacon	30g (6 rashers)	Grill for 12 minutes on full power (electric)
Pork sausages	80g (4 links)	Grill for 12 minutes on full power (electric). Slice in half length-ways.
White cabbage	500g (shredded)	Bring to boil and simmer for 20 minutes
Mature Cheddar cheese	200g (grated)	Melt under grill on low heat for 7 minutes

Table 5 Methods used to produce food odours

The cooked products were allowed to stand in the cupboard for the time indicated in table 3 to allow the odour to infuse. To minimise visual cues, the foods were masked by muslin before the assessors arrived. The muslin allowed the odour to penetrate the fume cupboard whilst preventing the assessors from seeing the foods corresponding to the olfactory cue. At 09.00h assessors were exposed to the odour of bacon, at 10.00h the odour of cabbage, at 11.00h the odour of sausage and finally the odour of melted cheese at 12.00h. On each occasion the assessors were exposed to the odour for one minute and hunger levels were recorded after each exposure.

15 Normal working environment is defined as the environment customary to each assessor in their daily routine.

Results

The results indicated that the timing of the experiment was inappropriate. Due to the availability of the assessors and times of arrival at the University, the 09.00h to 12.00h timescale was not suitable. This, therefore, was changed to 09.30h to 12.30h to enable all assessors to attend. The 10cm hunger rating scale was used successfully and it was established that individual scales (presented on a separate sheet of paper) should be used each hour in order to prevent the assessors from making direct comparisons to their previous indications. The masking of the products during exposure to the odour was also unsuitable as this distracted the assessors. In the experiments, therefore, the food items should be removed before the assessors arrive. Once the logistics of the experiment were established, the concept was then transferred into the sensory laboratory (appendix 5).

Due to the size, layout and design of the sensory laboratory, the presence of the cooking equipment and the nature of the experiments, five assessors were found to be the optimum number for each stage of this work.

2.23 Experiments to investigate the effects of exposure to food odours on hunger perception

Based on the results of the pilot study, the experimental procedures were modified and adapted for use in the sensory laboratory. Whilst the fume cupboard was suitable for the pilot study the assessors were aware that they were being exposed to an odour and the experimental conditions were not tightly controlled. Conducting the experiments in the sensory laboratory ensured that the assessors sat in individual booths, where no communication or other influences could affect the results. All assessors were exposed to an identical intensity of odour at the same time and the exposure to the odour was extended to 10 minutes.

Assessors

A further five assessors were selected from those who took part in the hedonic attributes exercise (section 2.14). These were two males and three females, age range 24 to 41 years (mean 34, SD ± 6). The assessors were instructed not to consume any food or beverages other than water, between 09.30h and 12.30h on the test days.

Materials

The four food odours selected in section 2.1 were used for this experiment. In order to infuse the odour into the sensory laboratory the food products were cooked in the laboratory using an electric grill and free standing electric hob to produce the odours. The grill was used to cook the bacon and sausages and to melt the cheese. The cabbage was brought to the boil in an adjacent kitchen and then simmered on the hot plate in the sensory laboratory.

Method

The hunger perception investigation was designed and conducted as three separate experiments. The aim of the first experiment was to establish the effect of exposure to a variety of food odours representing the four quartiles of the 10cm hedonic scale (as determined in section 2.14). The second experiment was designed to investigate the effects of repeated exposure to a food odour with a high hedonic rating and the third experiment investigated exposure to a food odour with a low hedonic rating.

Experiment one (sequential exposure to a series of odours from the four quartiles of the hedonic scale)

The five assessors recorded their levels of hunger at one hourly intervals between 09.30h and 12.30h, each day, over a period of six days using the hunger rating scale (figure 5). The experiment consisted of six test conditions each of which took place on a separate day.

In test one, assessors recorded their hunger levels between 09.30h and 12.30h at one hourly intervals in their normal working environment. In test two, assessors completed hunger rating forms in the sensory laboratory where they were exposed to a neutral odour stimulus (i.e. the odour inherent to the sensory laboratory). This was designed to allow for any effects caused by the change in orientation, i.e. changing from the normal working environment to the sensory laboratory.

Each hunger rating scale was presented on a separate sheet of paper to ensure that direct comparisons to the previous rating could not be made.

For test three, similar procedures were used as for test two but at each hour the assessors were exposed to a different food odour. At 09.30h the odour of grilled bacon was presented to the assessors, boiled cabbage at 10.30h, grilled sausages at 11.30h and finally melted cheese at 12.30h.

The food items were cooked for the time indicated in table 5 and removed from the laboratory just before the assessors arrived to record their hunger levels. No visual or auditory cues were, therefore, present in the laboratory, only the food odour. An extraction system ensured that one odour was removed thoroughly from the laboratory before introducing the next.

The assessors were exposed to the odours in the sensory laboratory for 10 minutes each hour, and no reference was made to the odour present. In order to distract the assessors from being *consciously* aware of the odour stimuli, and divert their attention from the purpose of the experiment, they were instructed to complete a series of manipulative tasks/questionnaires. One questionnaire collected details relating to the assessors' breakfast habits; whether they had eaten breakfast that day and if so, the time they had eaten and the foods and amounts consumed (appendix 6). A second questionnaire collected information regarding the assessor's usual eating/drinking habits during the morning, i.e. the time they would normally take a coffee break or have lunch (appendix 7). The data collected from these questionnaires was used in the analysis of the hunger perception results. Other written tasks included short questionnaires which were of no relevance to the experiment other than to occupy the assessors during the tests. The assessors completed the written task allocated for that hour in the presence of the food odour and then recorded their level of hunger using the hunger rating scale (figure 5).

For tests four, five and six similar procedures were followed with a varied odour presentation so that each of the four products was presented at a different time (table 6). This procedure was used to determine any order effect in exposure to the odours.

	Time	Odour Presented
Test 3	09.30h	bacon
	10.30h	cabbage
	11.30h	sausage
	12.30h	cheese
Test 4	09.30h	cheese
	10.30h	sausage
	11.30h	bacon
	12.30h	cabbage
Test 5	09.30h	cabbage
	10.30h	bacon
	11.30h	cheese
	12.30h	sausage
Test 6	09.30h	sausage
	10.30h	cheese
	11.30h	cabbage
	12.30h	bacon

Table 6 Order of odour presentation in experiment one

Experiment two (exposure to a food odour with a high hedonic rating)

The second hunger perception experiment investigated the effects of hourly exposure to a single food odour with a high hedonic rating. The odour of bacon was given the highest hedonic rating (mean = 8.75) during the hedonic attributes test (section 2.14) and hence was selected for this experiment. The same five assessors used in experiment one participated in this experiment in which they recorded levels of hunger at one hourly intervals between 09.30h and 12.30h over a three day period. The bacon was cooked, each hour, in the laboratory and removed just before the assessors arrived (table 5).

Assessors were exposed to the bacon odour stimulus for 10 minutes each hour in the sensory laboratory where they completed a written task (similar to those used in experiment one). They then recorded their hunger levels using the hunger rating scale (figure 5). A separate scale was used for each recording, as for experiment one.

Experiment three (exposure to a food odour with a low hedonic rating)

The third hunger perception experiment investigated the effects of hourly exposure to a single food odour with a low hedonic rating. The odour of boiled cabbage was given the lowest hedonic rating (mean = 1.45) in the hedonic attributes test (section 2.14) and therefore was selected for this experiment. The same five assessors took part in this investigation where they were exposed each hour to the odour of cabbage. The cabbage was simmered for 20 minutes each hour in the sensory laboratory to produce the odour and then removed just before the assessors arrived. The methodology for experiment two was then applied to this test.

Results

The hunger levels were transformed into ratings by measuring the distance, in centimetres (correct to two decimal places), from the left hand side of the scale to the vertical mark indicated on the horizontal line. The data were entered into the Statistical Package for Social Sciences (SPSS) version 6.1.2 using a 486 Opus computer. The results were recorded using an interval scale and although the sets of data being compared did not always have equal variances, the groups were of equal size. The data were treated for analysis as through they were normally distributed and were, therefore, assumed to comply with the requirements of parametric statistical analysis[16]. This is justified in analysis of data of this type and can be substantiated by numerous references (Wisniewski *et al.* 1991, Epstein *et al.* 1992, Pierson 1980, Stone and Sidel 1992). The results from each experiment consisted of two sample means, for a single dependent variable, hence t-tests for paired comparisons were used to analyse the data and test for significance[17]. The results were considered to be statistically significant when the *p*-value was less than or equal to 0.05, the value normally adopted for sensory studies of this type, for example, Christensen (1983), Greeley *et al.* (1993) and Pierson (1980).

The data collected for each experiment were initially analysed collectively for an overall difference in hunger levels, throughout the morning (09.30h to 12.30h), between each test condition and the neutral odour condition. The results were then analysed in terms of the hourly variation in hunger levels to locate any significant differences.

The hunger levels recorded in tests one and two were initially analysed to establish the effect of the change of environment. Therefore, the assessors' hunger levels recorded in their working environment (test one) were compared with those recorded in the sensory laboratory in the presence of the neutral odour stimulus (test two).

Location	Hunger Level			df	t-value	2-tail sig
	Mean	SD	SE of Mean			
Laboratory	2.64	2.43	.54	19	-1.31	.205
Work Environ.	2.98	2.55	.57			

Table 7 Aggregate variation in hunger levels between the assessors' normal working environment and the sensory laboratory.

16 As a control measure, one set of data from these experiments was subjected to non-parametric analysis using Mann Whitney U - Wilcoxon rank sum W test (appendix 8).

17 As used by Rolls, et al. (1982) and Rolls, et al. (1988a).

When analysed collectively (table 7), overall mean hunger levels recorded in the sensory laboratory were slightly lower than those in the normal working environment but this difference was not significant ($p>0.05$). The results were then analysed in terms of the hourly variation (table 8).

Exposure to the neutral odour stimulus in test two caused a slight decrease in hunger levels, each hour, for all assessors compared to test one but this decrease was not significant ($p>0.05$), (see figure 6).

Time	Location	Hunger Level Mean	SD	SE of Mean	df	t-value	2-tail sig
09.30h	Laboratory	.94	1.30	.58	4	.34	.752
	Work Environ.	.84	1.25	.56			
10.30h	Laboratory	1.68	1.67	.78	4	-1.00	.374
	Work Environ.	1.78	1.82	.81			
11.30h	Laboratory	3.28	2.50	1.12	4	- .17	.875
	Work Environ.	3.54	2.5	1.11			
12.30h	Laboratory	4.66	2.63	1.18	4	- .71	.519
	Work Environ.	5.12	2.43	1.09			

Table 8 Hourly variation in hunger levels between the assessors' normal working environment and the sensory laboratory.

The results from this table indicate that the change in orientation from the working environment to the sensory laboratory had no significant effect on the assessors hunger levels.

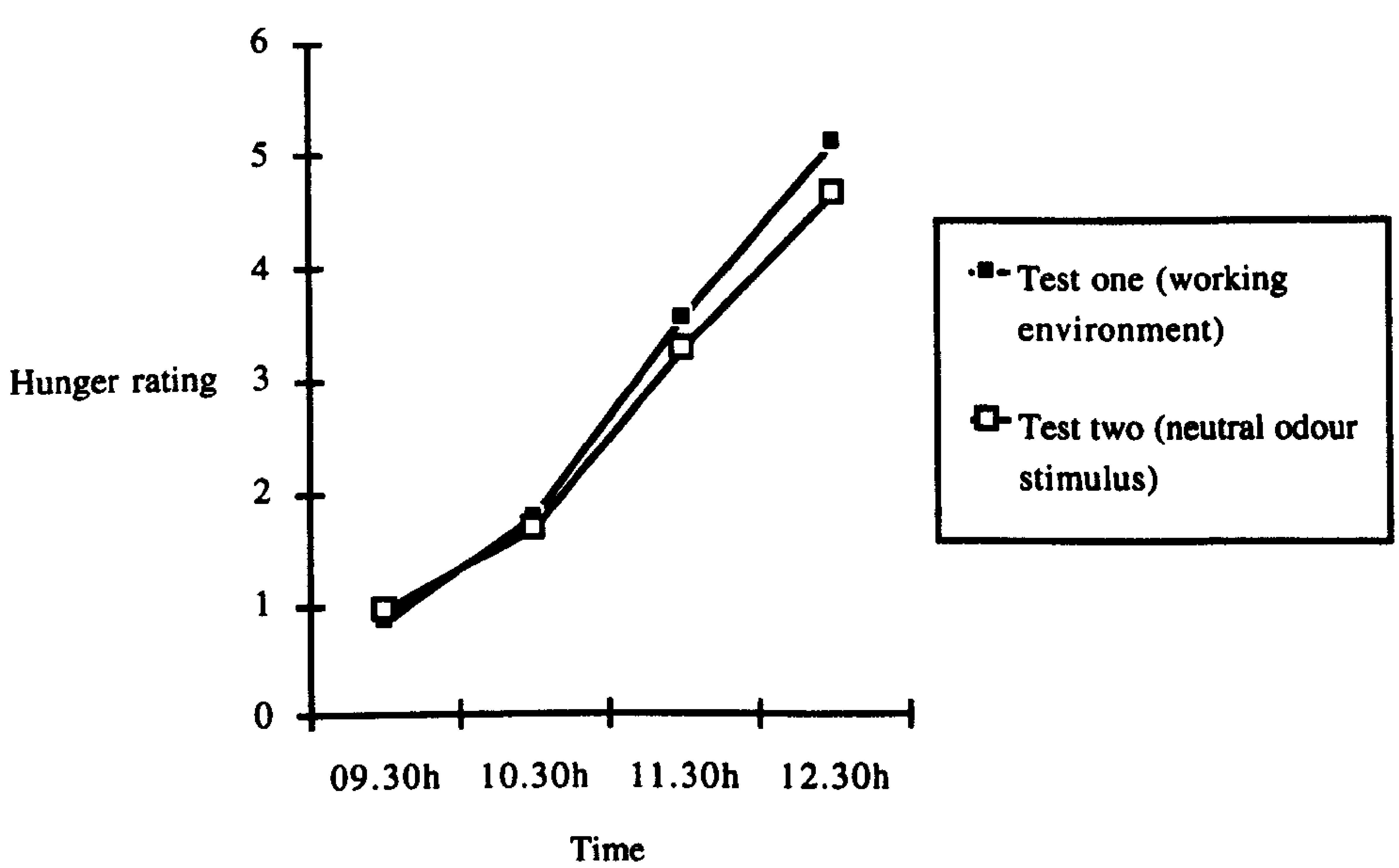


Figure 6 Results from experiment one (tests one and two) comparing mean hunger levels recorded in the assessors working environment and in the presence of a neutral odour stimulus.

From this point onwards, the hunger levels recorded in test two (exposure to the neutral odour stimulus in the sensory laboratory) were used as a baseline for paired comparisons with the hunger levels when exposed to the food odours.

Experiment one (Exposure to a series of odours from varying points on the hedonic scale)

Test three

Exposure to the food odours in test three (bacon, cabbage, sausage, cheese) caused an increase in hunger levels compared to test two for all assessors (See figure 7). The results from the t-test for paired samples for the hunger levels when analysed collectively, indicated that this overall increase was significant $p<0.05$ (table 9). When analysed for the hourly variation, however, it can be seen that the difference was only statistically significant at 11.30h (table 10).

Test Condition	Hunger Level			df	t-value	2-tail sig
	Mean	SD	SE of Mean			
Test two	2.64	2.43	.54	19	-3.22	**.004**
Test three	3.81	3.14	.70			

Table 9 Aggregate variation in hunger levels between test two and test three.

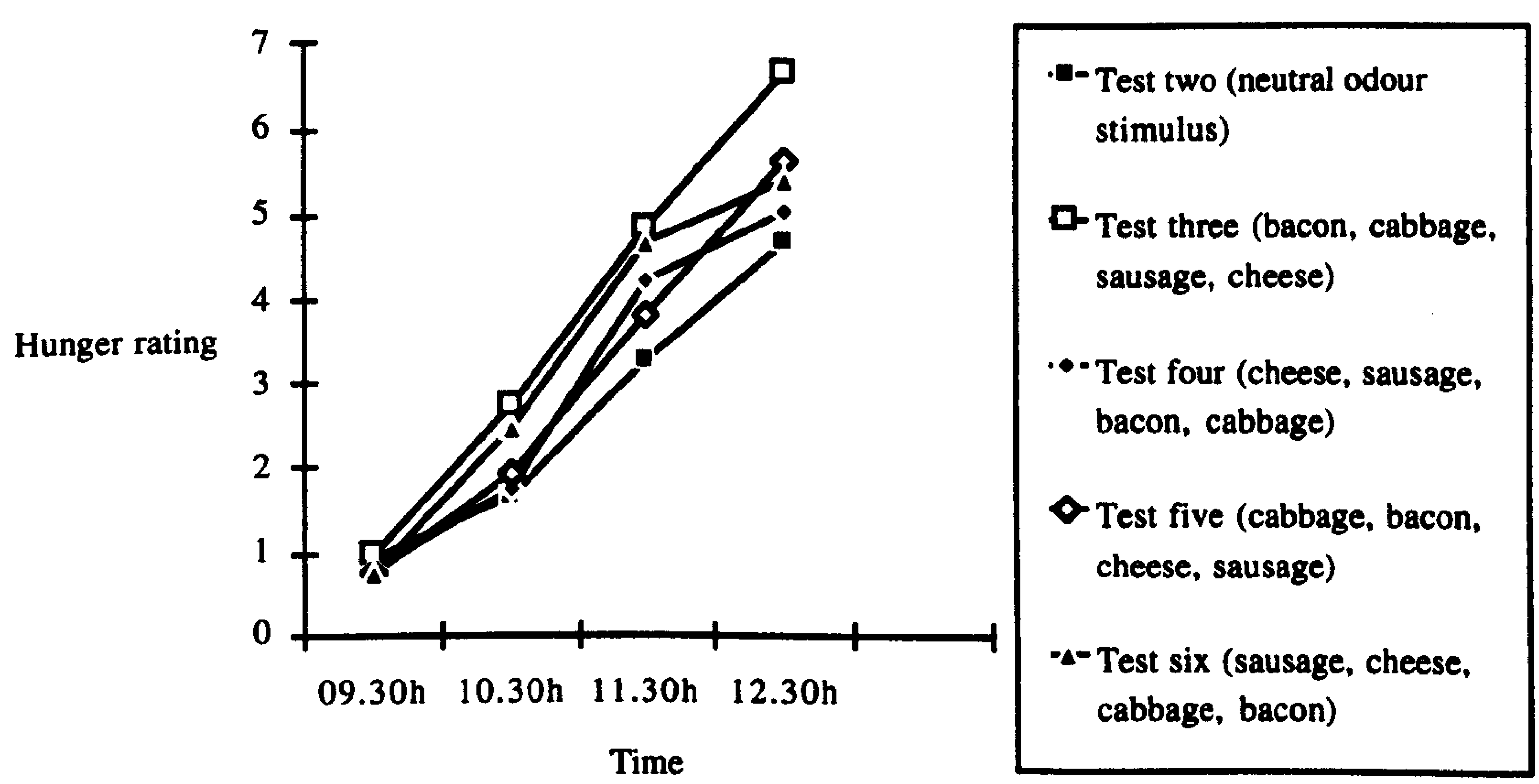


Figure 7 Results from experiment one (tests two, three, four, five and six) comparing mean hunger levels for exposure to a variety of food odours with a neutral odour stimulus baseline.

Time	Test Condition	Hunger Level Mean	SD	SE of Mean	df	t-value	2-tail sig
09.30h	Test two	.94	1.303	.583	4	-.11	.916
	Test three	.98	1.768	.791			
10.30h	Test two	1.68	1.663	.774	4	-1.46	.217
	Test three	2.72	2.397	1.072			
11.30h	Test two	3.28	2.499	1.118	4	-4.84	**.008**
	Test three	4.86	2.532	1.133			
12.30h	Test two	4.66	2.634	1.178	4	-1.83	.141
	Test three	6.68	2.910	1.301			

Table 10 Hourly variation in hunger levels between test two and test three.

Test four

The aggregate result for test 4 (cheese, sausage, bacon, cabbage) showed an increase in hunger levels which was not statistically significant ($p>0.05$) (table 11):

Test Condition	Hunger Level Mean	SD	SE of Mean	df	t-value	2-tail sig
Test two	2.64	2.43	.54	19	-1.31	.206
Test four	2.99	2.67	.60			

Table 11 Aggregate variation in hunger levels between test two and test four.

The hourly analysis of the results, however, showed a significant increase in hunger levels at 11.30h.

Time	Test Condition	Hunger Level Mean	SD	SE of Mean	df	t-value	2-tail sig
09.30h	Test two	.94	1.30	.58	4	.63	.564
	Test four	.80	1.33	.59			
10.30h	Test two	1.68	1.66	.77	4	- .21	.844
	Test four	1.76	1.25	.56			
11.30h	Test two	3.28	2.50	1.12	4	-3.30	**.030**
	Test four	4.24	2.46	1.10			
12.30h	Test two	4.66	2.63	1.18	4	- .38	.727
	Test four	5.02	2.87	2.28			

Table 12 Hourly variation in hunger levels between test two and test four.

Test five

The aggregate result for test five (cabbage, bacon, cheese, sausage) showed an increase in hunger levels which was not statistically significant ($p>0.05$) as indicated in table 13. The hourly analysis of the results also showed an increase in hunger levels which were non-significant (table 14).

Test Condition	Hunger Level			df	t-value	2-tail sig
	Mean	SD	SE of Mean			
Test two	2.64	2.43	.54	19	-1.22	.239
Test five	3.03	2.68	.60			

Table 13 Aggregate variation in hunger levels between test two and test five.

Time	Test Condition	Hunger Level			df	t-value	2-tail sig
		Mean	SD	SE of Mean			
09.30h	Test two	.94	1.30	.58	4	.72	.511
	Test five	.76	1.15	.51			
10.30h	Test two	1.68	1.66	.77	4	- 1.12	.324
	Test five	1.92	1.95	.87			
11.30h	Test two	3.28	2.50	1.12	4	-1.01	.371
	Test five	3.80	2.28	1.02			
12.30h	Test two	4.66	2.63	1.18	4	- .82	.456
	Test five	5.62	2.58	1.15			

Table 14 Hourly variation in hunger levels between test two and test five.

Test six

The aggregate result for test 6 (sausage, cheese, cabbage, bacon) showed a significant increase in hunger levels ($p<0.05$) as indicated in table 15. The hourly analysis of the results, however, showed an increase in hunger levels each hour, which was not statistically significant (table 16).

Test Condition	Hunger Level			df	t-value	2-tail sig
	Mean	SD	SE of Mean			
Test two	2.64	2.43	.54	19	-2.13	**.046**
Test six	3.33	2.83	.63			

Table 15 Aggregate variation in hunger levels between test two and test six.

Time	Test Condition	Hunger Level			df	t-value	2-tail sig
		Mean	SD	SE of Mean			
09.30h	Test two	.94	1.30	.58	4	-.72	.509
	Test six	1.66	2.32	1.04			
10.30h	Test two	1.68	1.66	.77	4	- 1.78	.150
	Test six	2.46	1.85	.83			
11.30h	Test two	3.28	2.50	1.12	4	-1.65	.175
	Test six	4.68	2.89	1.29			
12.30h	Test two	4.66	2.63	1.18	4	- .85	.442
	Test six	5.38	2.80	1.25			

Table 16 Hourly variation in hunger levels between test two and test six.

Experiment two (Exposure to a single food odour with a high hedonic rating)

Using the baseline hunger levels recorded in test two, hunger levels recorded during exposure to the bacon odour stimulus, each hour, were analysed. These results indicated a significant, aggregate increase in hunger levels ($p<0.05$) (table 17).

Test Condition	Hunger Level			df	t-value	2-tail sig
	Mean	SD	SE of Mean			
Neutral odour	2.64	2.43	.54	19	6.30	**.000**
Bacon odour	4.26	2.40	.54			

Table 17 Aggregate variation in hunger levels between the neutral odour stimulus and the bacon odour stimulus

The hourly analysis of the results for exposure to the bacon odour showed a significant increase in hunger levels each hour ($p<0.05$) and it can be seen that equivalent hunger levels shifted forward by approximately one hour (see figure 8).

Time	Test Condition	Hunger Level			df	t-value	2-tail sig
		Mean	SD	SE of Mean			
09.30h	Neutral odour	.94	1.30	.58	4	2.88	**.045**
	Bacon odour	2.02	.85	.38			
10.30h	Neutral odour	1.68	1.66	.77	4	- 3.03	**.039**
	Bacon odour	2.98	1.08	.48			
11.30h	Neutral odour	3.28	2.50	1.12	4	2.77	**.050**
	Bacon odour	5.22	2.05	.91			
12.30h	Neutral odour	4.66	2.63	1.18	4	4.34	**.012**
	Bacon odour	6.80	1.92	.86			

Table 18 Hourly variation in hunger levels between the neutral odour stimulus and the bacon odour stimulus

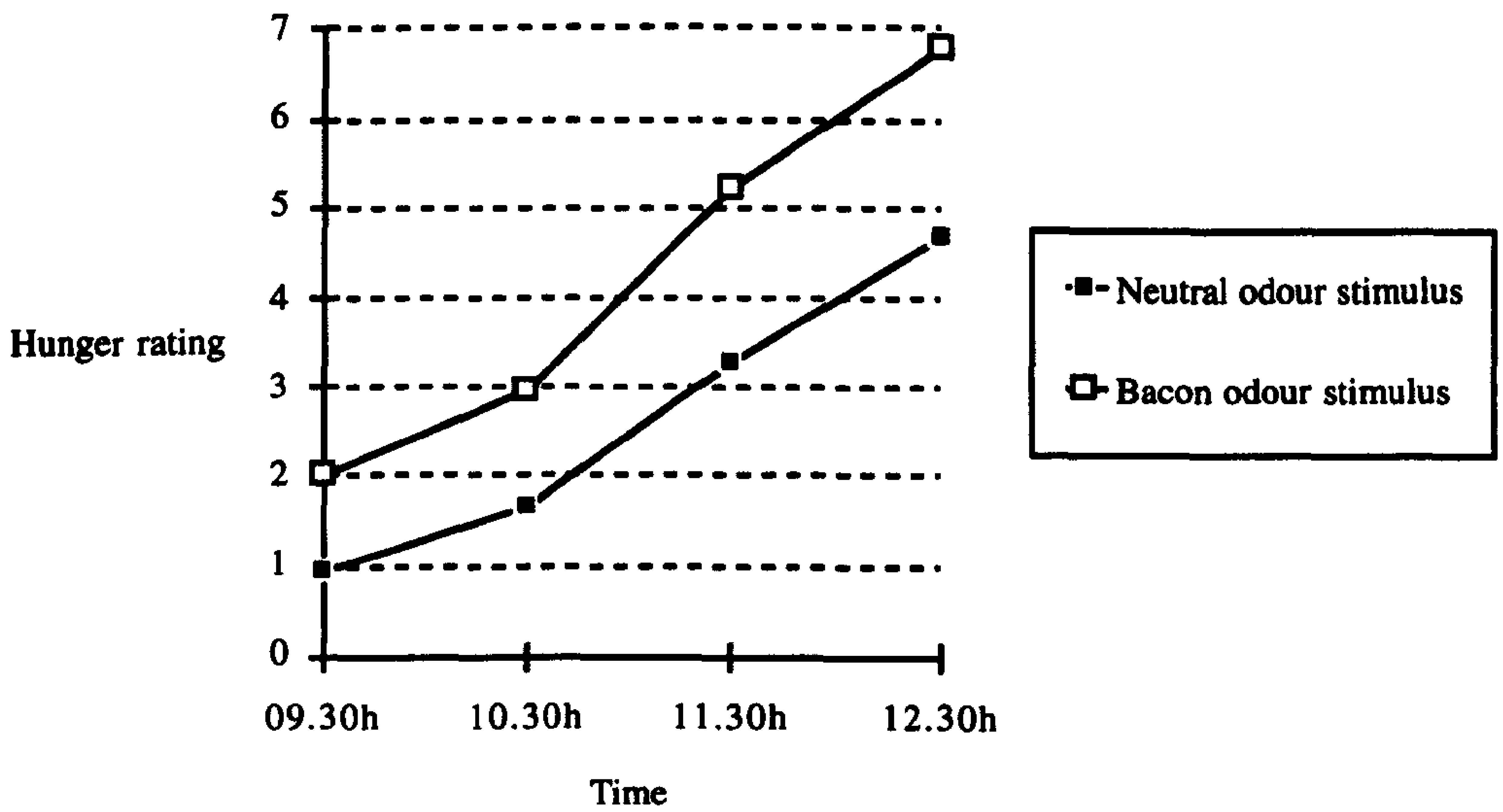


Figure 8 Results from experiment one showing mean hunger levels when exposed to a neutral odour stimulus and a bacon odour stimulus.

Experiment three (Exposure to a food odour with a low hedonic rating)

Again, using the baseline hunger levels recorded in test two, the effects of exposure to the cabbage odour stimulus each hour were analysed. The results showed an aggregate decrease in hunger levels (figure 9), but this decrease was not significant ($p>0.05$) (table 19).

This decrease was also not statistically significant when analysed hourly (table 20)

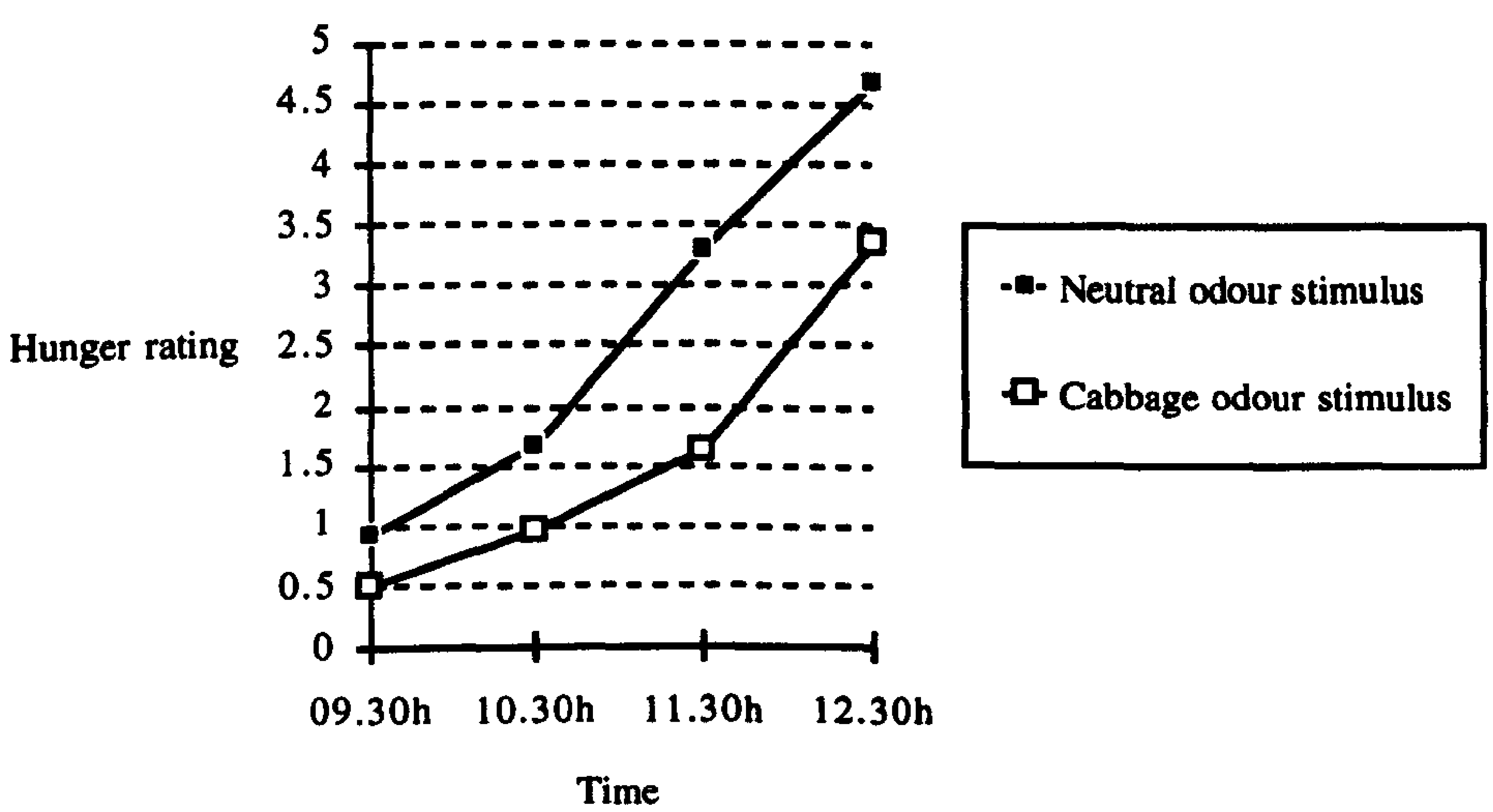


Figure 9 Results from experiment one showing mean hunger levels when exposed to a neutral odour stimulus and a cabbage odour stimulus

Test Condition	Hunger Level			df	t-value	2-tail sig
	Mean	SD	SE of Mean			
Neutral odour	2.64	2.43	.54	19	-1.65*	.116
Cabbage odour	1.62	1.51	.34			

Table 19 Aggregate variation in hunger levels between the neutral odour stimulus and the cabbage odour stimulus

Time	Test Condition	Hunger Level			df	t-value	2-tail sig
		Mean	SD	SE of Mean			
09.30h	Neutral odour	.94	1.30	.58	4	-.52	.633
	Cabbage odour	.52	.78	.35			
10.30h	Neutral odour	1.68	1.66	.78	4	- .59	.584
	Cabbage odour	.98	1.31	.58			
11.30h	Neutral odour	3.28	2.50	1.12	4	-1.03	.361
	Cabbage odour	1.62	1.28	.57			
12.30h	Neutral odour	4.66	2.63	1.18	4	-.84	.448
	Cabbage odour	3.36	1.06	.48			

Table 20 Hourly variation in hunger levels between the neutral odour stimulus and the cabbage odour stimulus

As the same set of assessors were exposed to both the cabbage and the bacon odour stimuli in these experiments, analysis of variance was conducted to compare hunger levels under the three conditions. Hunger levels when exposed to the bacon odour stimulus were significantly higher ($p<0.05$) than when exposed to the neutral or cabbage stimuli. There was no significant difference in hunger levels between the neutral and cabbage stimuli ($p>0.05$) (table 21).

	df	SS	MS	F	p
Between groups	2	70.612	35.31	7.60	**.0012**
Within groups	57	264.97	4.65		
Total	59	335.58			

Calculation of Least Significant Difference >=1.52
** (indicates significant difference)*

MEAN	*GROUP*
1.62	*Cabbage*
2.64	*Neutral*
4.26	*Bacon * **

Table 21 Aggregate variation in hunger levels between the cabbage odour stimulus and the bacon odour stimulus

The data collected from the completed questionnaires relating to breakfast consumption

* Whilst these results showed no significant difference at the 5% confidence interval, when expanded to 20% (t-value >= 1.33) a significant difference occurred.

and usual eating habits were also analysed.

Analysis of usual eating habits

Without the experimental restrictions imposed, all assessors would normally have consumed tea or coffee during the morning and some would have had a snack (for example, two biscuits or one banana). None of the assessors would normally have eaten lunch before 12.30h and therefore their lunchtime habits were not delayed by the experiments.

Each assessors' breakfast habits were consistent on all of the test days. One assessor consumed nothing at all for breakfast on any of the test days. Two assessors consumed beverages only, each day, and eight assessors consumed either toast or cereal with either tea, coffee or fruit juice on each of the test days. All assessors who consumed breakfast did so at the same time on each of the test days.

Synopsis of results

The results indicated that exposure to a variety of food odours from the four quartiles of the hedonic scale (during one test) led to non-significant increases in hunger levels and produced no evident order effect. Repeated exposure to the same odour, however, produced clearer, more well defined shifts in hunger levels. The magnitude and direction of this shift was dependent on the hedonic response to the odour. Before basing the subsequent experimental methodologies on these results, experiments two and three of the investigation were repeated with further sets of assessors in order to verify the findings.

2.24 A repeated experiment to investigate the effects of exposure to a single food odour with a high hedonic rating

This was a duplication of experiment two, section 2.23.

Assessors

Five assessors (four male, one female), age range 28 to 56 years (mean 41, SD ± 11) were selected from those who took part in the hedonic attributes exercise (section 2.14).

Materials

The bacon odour stimulus was produced as for experiment two, section 2.23

Method

The experimental methodology of section 2.23 was adhered to in order to replicate this investigation. This consisted of three test conditions each of which took place on a separate day.

In test one, hunger levels were recorded in the assessors' normal working environment. In test two, assessors were exposed each hour to a neutral odour stimulus in the sensory laboratory and in test three, assessors were exposed each hour to the odour of bacon.

Results

The results were analysed using t-tests for paired comparisons, firstly to examine the shift in hunger levels from the assessors' working environment to the sensory laboratory; and secondly between hunger levels recorded in test two (exposure to the neutral odour stimulus) and test three (exposure to the bacon odour stimulus).

As for section 2.23, hunger levels decreased slightly in the sensory laboratory compared to the normal working environment but this decrease was not significant ($p>0.05$). Exposure to the bacon odour stimulus caused a significant increase in hunger compared to test two (neutral odour stimulus) ($p<0.05$) (table 22).

Test Condition	Hunger Level			df	t-value	2-tail sig
	Mean	SD	SE of Mean			
Neutral odour	2.76	2.21	.49	19	5.02	**.000**
Bacon odour	4.92	3.20	.71			

Table 22 Aggregate variation in hunger levels between the neutral odour stimulus and the bacon odour stimulus

The analysis of the hourly observations indicated that hunger levels increased significantly at 10.30h ($p<0.05$), 11.30h ($p<0.05$) and 12.30h ($p<0.05$) but not at 09.30h ($p>0.05$), (figure 10). It can also be seen that exposure to the bacon odour caused equivalent hunger levels to shift forward by approximately two hours; i.e. for example, the hunger level reached at 12.30h in the presence of a neutral odour occurred at 10.30h when exposed to the bacon odour (table 23).

Time	Test Condition	Hunger Level			df	t-value	2-tail sig
		Mean	SD	SE of Mean			
09.30h	Neutral odour	.94	.84	.38	4	-1.51	.206
	Bacon odour	2.42	2.70	1.21			
10.30h	Neutral odour	1.80	1.48	.66	4	- 2.80	**.049**
	Bacon odour	4.08	2.24	1.00			
11.30h	Neutral odour	2.94	2.42	1.08	4	-3.36	**.028**
	Bacon odour	5.98	2.83	1.27			
12.30h	Neutral odour	4.70	2.69	1.20	4	-3.36	**.028**
	Bacon odour	7.20	3.41	1.53			

Table 23 Hourly variation in hunger levels between the neutral odour stimulus and the bacon odour stimulus.

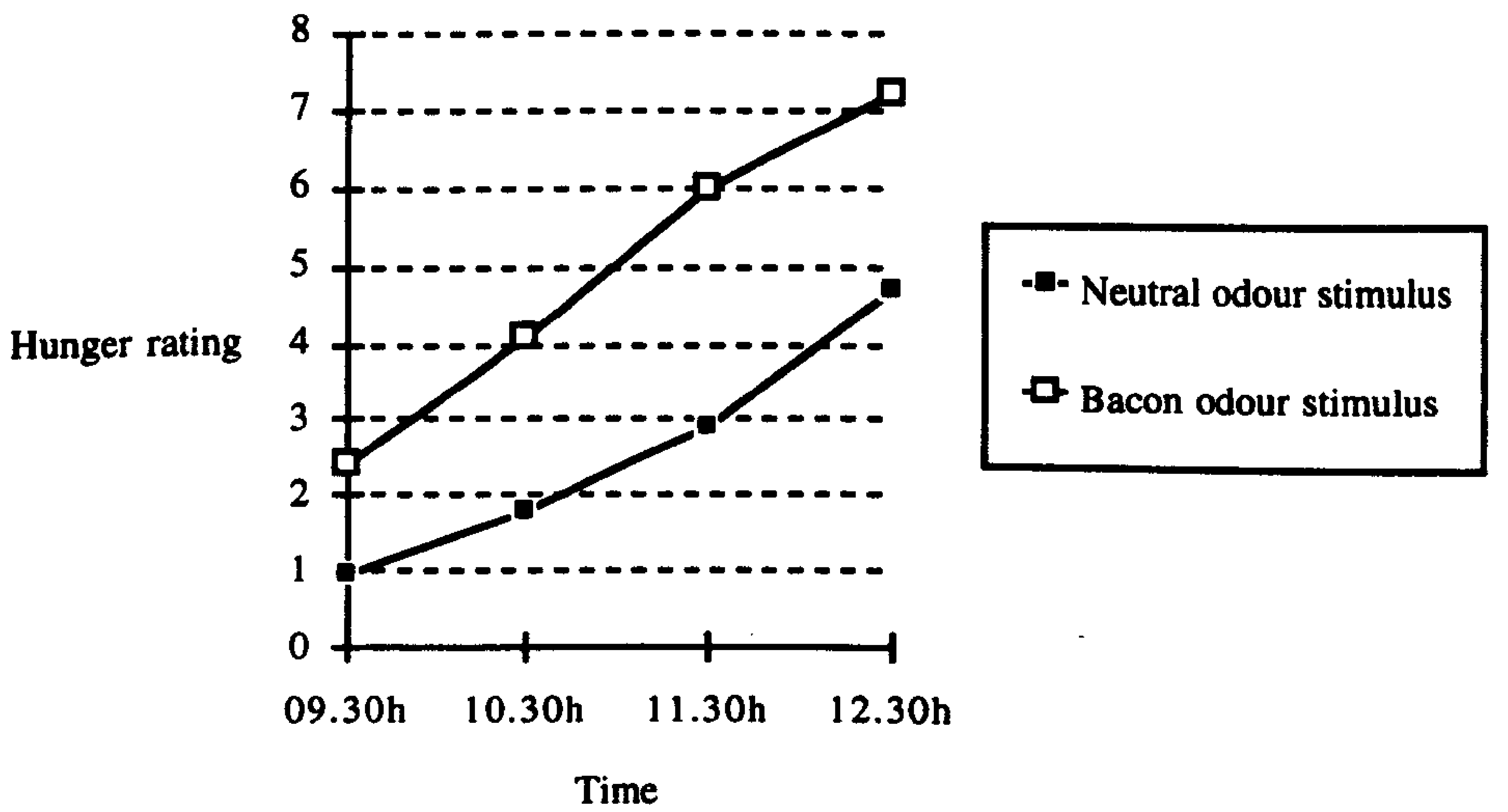


Figure 10 Results showing mean hunger levels when exposed to a neutral odour and a bacon odour stimulus

2.25 A repeated experiment to investigate the effects of exposure to a food odour with a low hedonic rating

Experiment three of the hunger perception experiments (section 2.23), was also repeated with further assessors.

Assessors

A further five assessors (two male, three female) age range 23 to 49 years (32, SD ± 10) were selected from those who took part in the hedonic attributes test (section 2.14).

Materials

The cabbage odour stimulus was produced as for experiment three, section 2.23.

Method

The methodology for experiment 2.24 was applied to this experiment which consisted of three test conditions. Conditions one and two followed the same design as experiment 2.24, and in test three, assessors were exposed to the cabbage odour stimulus.

Results

The results were analysed using t-tests for paired comparisons, firstly to examine the shift in hunger levels from the assessors' working environment to the sensory laboratory; and secondly between hunger levels in test two (exposure to the neutral odour stimulus) and test three (exposure to the cabbage odour stimulus).

As for section 2.23, hunger levels decreased slightly in the sensory laboratory compared to the normal working environment but this decrease was not significant ($p>0.05$). Exposure to the odour of cabbage caused a slight decrease in hunger compared to test two but this decrease was not was not significant overall ($p>0.05$) (table 24), nor when analysed hourly (table 25).

Test Condition	Hunger Level			df	t-value	2-tail sig
	Mean	SD	SE of Mean			
Neutral odour	3.65	2.97	.66	19	-.23	.817
Cabbage odour	3.53	3.60	.80			

Table 24 Aggregate variation in hunger levels between the neutral odour stimulus and the cabbage odour stimulus

Time	Test Condition	Hunger Level			df	t-value	2-tail sig
		Mean	SD	SE of Mean			
09.30h	Neutral odour	1.06	.948	.424	4	.00	1.000
	Cabbage odour	1.06	1.333	.596			
10.30h	Neutral odour	2.02	1.272	.569	4	.39	.717
	Cabbage odour	1.86	1.688	.755			
11.30h	Neutral odour	4.42	2.873	1.285	4	.25	.812
	Cabbage odour	4.20	3.380	1.512			
12.30h	Neutral odour	7.12	1.938	.867	4	.05	.962
	Cabbage odour	7.02	4.330	1.937			

Table 25 Hourly variation in hunger levels between the neutral odour stimulus and the cabbage odour stimulus.

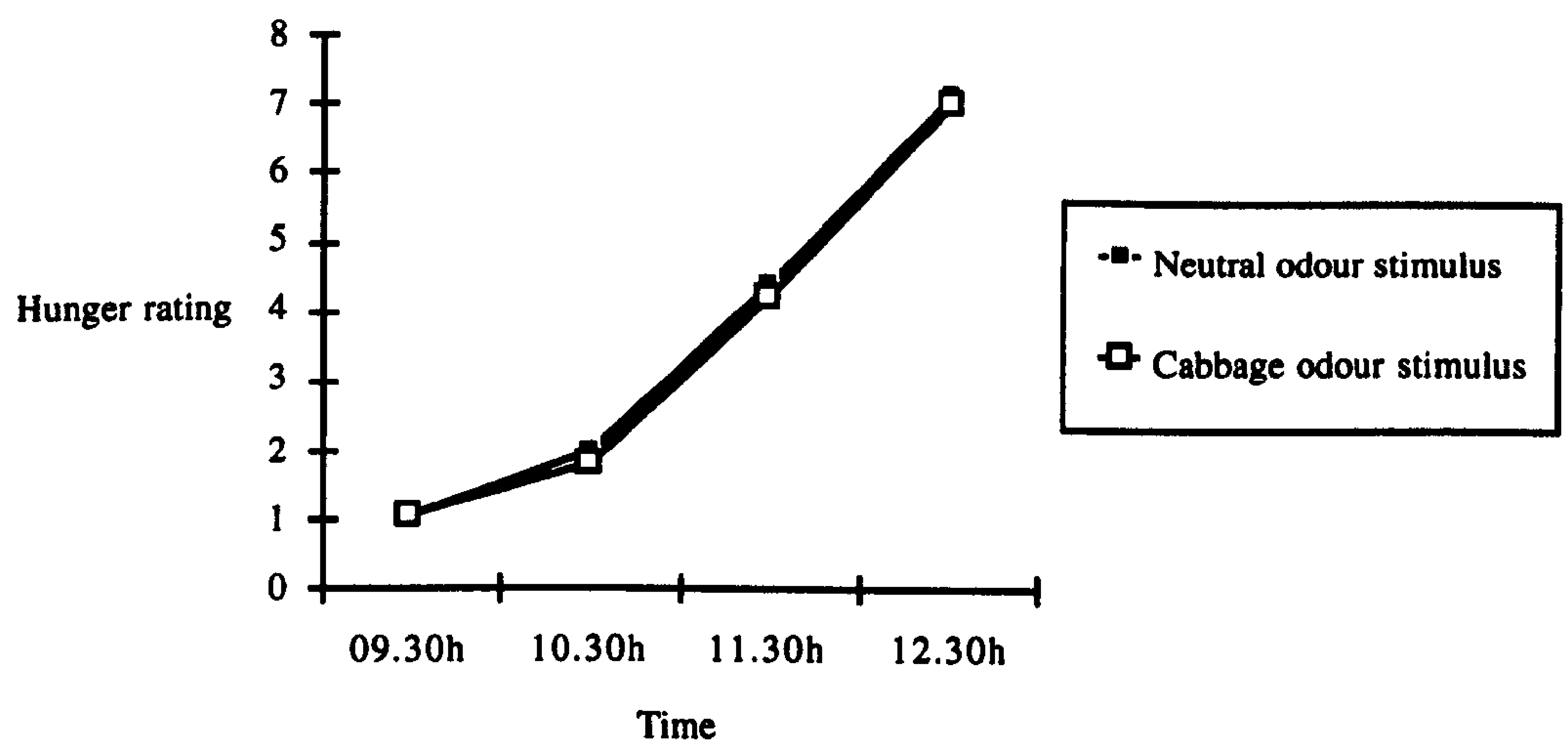


Figure 11 Results showing mean hunger levels when exposed to a neutral odour and a cabbage odour stimulus

2.26 Analysis of baseline hunger levels

To summarise, the hunger perception experiments took place in three main stages. The first stage consisted of five assessors, exposed to a series of odours from various points on the hedonic scale, followed by exposure to the odour of bacon each hour and finally exposure to the odour of cabbage each hour. The second stage involved a further five assessors who were repeatedly exposed to the odour of bacon. In the third stage, five different assessors participated in the experiment where they were repeatedly exposed to the cabbage odour stimulus. In total, fifteen assessors took part in the three stages of the experiments and therefore, three baseline levels of hunger (in the presence of a neutral odour stimulus) were recorded. As a control measure, these three sets of data were compared using one-way analysis of variance in order to determine that no significant difference had occurred for the baseline hunger levels between the three groups of five assessors. The results were as follows:

	df	SS	MS	F	*p*
Between groups	2	2.06	1.03	.2109	.8137
Within groups	9	44.06	4.89		
Total	11	46.13			

Table 26 Mean hunger levels when exposed to a neutral odour stimulus

2.27 A repeated experiment to investigate the effects of exposure to an alternative food odour with a low hedonic rating

Due to the non-statistically significant results for exposure to the cabbage odour stimulus, experiment three of this investigation was repeated using an alternative food odour with a low hedonic rating selected from section 2.1. The aim was to verify that exposure to a food odour with a low hedonic rating leads to a decrease in hunger which is not statistically significant.

Both cabbage and Brussels sprouts are cruciferous vegetables which are characterised by sulphurous odours and flavours following tissue injury or cooking. Isothiocyanates generally contribute to the desirable, pungent flavours, while methanethiol-related volatile sulphur compounds produced by cooking, cause objectionable odours in cruciferous vegetables. As both vegetables possess these similar qualities which contribute to the low hedonic rating given for their odour, Brussels sprouts were used in this follow up experiment to investigate their effects on hunger perception.

Assessors

Five assessors took part in the experiment (two male, three female) age range 23 to 56 years (mean 33, SD ± 10). As with the previous hunger perception experiments, they were instructed not to consume any foods or beverages between 09.30h and 12.30h on the test days.

Materials

The Brussels sprouts odour stimulus was produced using 500g of frozen Brussels sprouts. These were brought to the boil in a pan of water and then transferred to the hot plate in the sensory laboratory where they were simmered for 20 minutes. These were then removed just before the assessors arrived to record their hunger levels. This procedure was repeated each hour to create the odour.

Method

This experiment consisted of just two test conditions. The results from the previous experiments (sections 2.23, 2.24 and 2.25) indicated a slight, non-significant decrease in hunger levels between the normal working environment and that of the sensory laboratory in the presence of a neutral odour. Hence, it was not necessary to repeat this part of the test, as consistent results had been achieved throughout.

The experimental methodology for section 2.23 was replicated in this study which was comprised of just two test conditions. Test one consisting of the neutral odour stimulus condition in the sensory laboratory and test two the Brussels sprouts odour.

Results

The results were analysed using t-tests for paired comparisons to examine the shift in hunger levels between exposure to the neutral odour in test one and exposure to the Brussels sprouts odour in test two. Hunger levels decreased for all assessors when exposed to the Brussels sprouts odour stimulus (figure 12) but this aggregate decrease was not significant ($p>0.05$) (table 27).

Test Condition	Hunger Level			df	t-value	2-tail sig
	Mean	SD	SE of Mean			
Neutral odour	3.16	2.42	.54	19	-1.76*	.095
Brussels Sprouts odour	2.87	2.37	.53			

Table 27 Aggregate variation in hunger levels between the neutral odour stimulus and the Brussels sprouts odour stimulus

The hourly variation between exposure to the neutral odour and the Brussels sprouts odour stimuli was not found to be statistically significant either ($p>0.05$) (table 28).

Time	Test Condition	Hunger Level			df	t-value	2-tail sig
		Mean	SD	SE of Mean			
09.30h	Neutral odour	1.50	1.03	.46	4	2.72*	.053
	Brussels Sprouts odour	.54	.55	.24			
10.30h	Neutral odour	1.96	1.26	.56	4	.00	1.000
	Brussels Sprouts odour	1.96	1.27	.57			
11.30h	Neutral odour	3.72	1.88	.84	4	-.33	.757
	Brussels Sprouts odour	3.82	2.05	.92			
12.30h	Neutral odour	5.80	1.99	.89	4	1.88*	.133
	Brussels Sprouts odour	5.44	2.07	.93			

Table 28 Hourly variation in hunger levels between the neutral odour stimulus and the Brussels sprouts odour stimulus.

* Whilst these results showed no significant difference at the 5% confidence interval, when expanded to 10% (t-value >= 1.73) and 20% (t-value >= 1.33) a significant difference occurred.

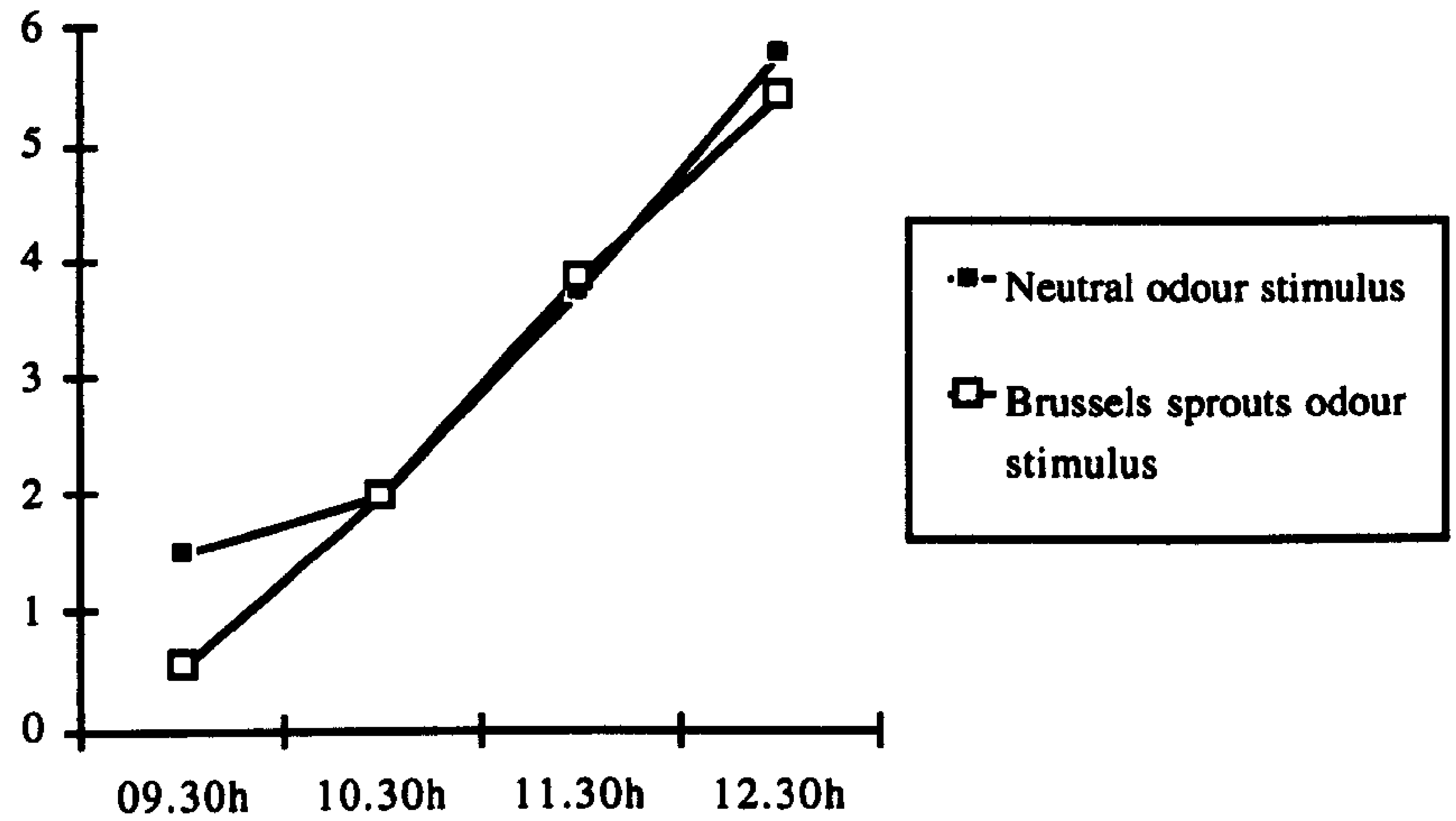


Figure 12 Results showing mean hunger levels when exposed to a neutral odour stimulus and a Brussels sprouts odour stimulus

Discussion

The first stage of this investigation established the effects of the laboratory conditions on hunger levels. The results indicated that the change in environment from the normal working situation to the sensory laboratory led to a slight decrease in hunger. This decrease, however, was not significant and may have been caused by a number of factors. In the sensory laboratory assessors had no interaction with each other and were not exposed to influences such as the sight or smell of any food or drink, which may have occurred in the work environment. The hunger recordings in the laboratory were made under controlled, experimental conditions and in a more sterile environment to that of the normal work situation, all of which may have contributed to this slight decrease in hunger.

When exposed to the four selected food odours in varying order over the following four days (tests 3 to 6), the assessors' hunger levels increased with exposure to the food odours in each of the test conditions. The results from tests three and six, however, were the only conditions in which this increase was significant overall. When analysed hourly, the increase in test three was only significant at 11.30h and the aggregate increase in test six was not significant on any individual hour.

Test three was the first test in which the assessors were exposed to any food odours which may give some explanation for this increase. The only similarity between test three and six is that the first odours presented were those of bacon and sausage, respectively, both of which had been given high hedonic ratings (Section 2.14). In tests where an odour with a low hedonic rating was presented first, the aggregate hunger increase was not significant (i.e. tests four and five). These findings suggest a modifying effect, whereby initial exposure to an odour with a low hedonic rating modified the potential hunger increase throughout remainder of the test.

Although the results from test four did not show a significant increase when analysed collectively, when analysed hourly there was a significant difference at 11.30h, as for test three. The odours presented at these times were bacon (test three) and sausage (test four), the odours which had been given high hedonic ratings. Other than this, no conclusive evidence of any order effect was observed and the results indicate that when a combination of pleasant and unpleasant odours are present, hunger levels do not always increase significantly.

In the second experiment of the hunger perception investigation, repeated exposure to the odour with a high hedonic rating (bacon), led to an overall significant increase in hunger levels. This increase was also significant each hour and the results indicated that exposure to the odour caused hunger levels to shift forward by one hour (see figure 8). The hunger levels recorded at 10.30h when exposed to the neutral odour stimulus, for example, occurred at 09.30h when exposed to the bacon odour stimulus. When this part of the experiment was repeated (section 2.24), the aggregate increase in hunger levels was significant, and the hourly increase was significant each hour except at 09.30h. As the majority of the assessors had only just consumed breakfast at this time, this may explain why the bacon odour did not significantly increase their hunger levels. As for experiment 2, section 2.23, the results indicated that exposure to the odour shifted hunger levels forward, and in this case, the shift was by more than two hours (see figure 9). The hunger level, for example, recorded at 11.30h when exposed to the neutral odour stimulus, occurred at 09.30h when exposed to the bacon odour stimulus.

In the third experiment, repeated exposure to the odour with a low hedonic rating (cabbage), led to a decrease in hunger, and although this was not significant at the 5% confidence level, hunger levels appeared to decrease by approximately one hour (figure 9). When this part of the experiment was repeated (section 2.25), a slight decrease in hunger levels occurred, but this too, was not statistically significant.

Similarly, when the experiment was conducted using the odour of Brussels sprouts, in place of cabbage, a decrease in hunger levels occurred but this, again, was not significant. This verified the results that, although exposure to an unpleasant food odour leads to a decrease in hunger, the reduction is not significant.

When the expression of significance was expanded to 10% and 20% for experiments 2.23 and 2.27 the results showed a significant decrease in hunger, however in order to maintain consistency throughout the investigation the results are not considered to be statistically significant above the 5% level.

The results showed no significant difference in baseline hunger levels (in the presence of a neutral odour stimulus) for each stage of this experiment. This provides a control measure as it indicates that factors such as the age range of the assessors, or environmental influences (such as, varying weather conditions) had no impact on the results, as baseline hunger levels remained constant throughout the various stages of the experiment between different groups of assessors.

This study demonstrated that exposure to food odours caused a shift in hunger perception which varied according to the hedonic response to the odour. There are however, a number of factors which may have affected the results of this hunger perception investigation. Firstly, the shift in hunger levels may have been depressed, due to the fact that the assessors were aware they would not be able to eat any of the foods. Wooley and Wooley (1973) found that salivary responses were attenuated when subjects did not expect to eat the food. Hence, the hunger rating of the assessors in these experiments may have been different if they had been expecting to eat the foods they could smell.

The phenomenon of sensory specific satiety, as discussed in section 1.18, may also have played a role in these experiments. In this instance, for example, if an assessor had consumed bacon for breakfast, the smell of bacon at 09.30h may not be as pleasant as it would be to an assessor who had not consumed this particular food. It has also been reported that hedonic responses to olfactory cues decline with repeated presentation and consumption of the same food (Wisniewski *et al.* 1991) and the appeal of food flavours and odours can change depending upon the internal state of repletion (Rolls 1985). In these experiments, however, the assessors did not consume any of the foods they could smell, therefore, repeated exposure to the same odour each hour would not have caused sensory specific satiety in this form. Hence, the odours maintained their hedonic ratings and the pleasant odours continued to increase hunger levels. This is supported by the results of Cabanac's work on alliesthesia, where it was found that sniffing orange syrup was pleasant to fasting subjects and remained pleasant when repeated, it was only after ingestion of a glucose load, that this olfactory stimulus became unpleasant (Cabanac 1971) .

Another factor which may have had an impact on the results, relates to the context of the odour presentations. Rozin (1982), describes affective responses to odours as being context dependent: 'The same foul odour can be pleasant if attributed to cheese, but unpleasant if attributed to decaying meat.' As the assessors could not see the products they were smelling this may well have had an effect on the pleasantness of the odour and hence an effect on their hunger levels.

As reviewed in section 1.22, pleasure or displeasure is not in the odour stimulus itself, but is part of an ecological situation involving an interaction between the individual and the odour (Engen 1988). The smell of bacon to someone brought up in a kosher environment, for example, may invoke a feeling of sickness, but to someone from a different religious background it may make them feel hungry. Individual experience will play a role such that an odour which is pleasant to most may be extremely pleasant to an individual who has experienced it in a different manner. When applying the results of this experiment, factors such as the cultural context and an individual's preference or experience may need to be taken into account.

The first part of the hunger perception experiments was designed to test for any order effect in exposure to the food odours. It was concluded from this, that the presentation order of the odours when exposed to a different odour each hour had no impact on the hunger ratings and therefore no order effect was observed. It may also be concluded that exposure to a variety of food odours (with both high and low hedonic ratings) caused hunger to increase, although not significantly.

Secondly, the experiment was designed to establish the accumulative effect of odour exposure. It was concluded that repeated exposure to a food odour with a high hedonic rating led to a significant increase in hunger compared to a neutral odour stimulus, whilst repeated exposure to a food odour with a low hedonic rating had no significant effect on hunger levels.

The overall conclusion from this stage of the investigation is that exposure to food odours led to a conscious perception of a shift in hunger. The magnitude and direction of this shift, however, was dependent on both the hedonic response to the odour and the repetition of the exposure.

A number of factors and mechanisms relating to the concept of hunger were reviewed in section 1.3, and investigations into the locations within the brain which may contribute to hunger levels, showed the hypothalamus to be closely linked to eating behaviour.

During the olfactory process, signals generated in the olfactory receptors travel through the brain to several centres including the hypothalamus (section 1.12). It is, therefore, likely that exposure to food odours will trigger reactions in the hypothalamus leading to an effect on hunger, as indicated by the results of this experiment. There is also evidence that the hippocampus (which forms part of the limbic system) acts as an autoassociation memory, in that, the network learns to recognise a pattern of inputs and produces an output for each pattern. When a similar pattern is subsequently presented, the network produces the appropriate output (see section 1.31). As olfaction is directly linked to the limbic region, causing odours to have strong connections with memories and emotion, it is possible that a food odour stimulus, representing an hedonically acceptable pattern, could be a cue producing the output of hunger.

Throughout the hunger perception experiments, other factors which have been found to effect hunger (as discussed in section 1.3), remained constant and the results from the completed breakfast questionnaires indicated that the assessors' breakfast habits were consistent on each of the test days. Any factors which may influence glucostatic effects, stomach contractions, temperature regulation and stomach distention, therefore, should have remained constant during both the neutral odour and food odour conditions. The presence of the odour cue, however, appeared to shift the hunger rating. When the hedonic rating of the odour was high, this shift was significant, causing hunger levels to shift forward by up to two hours. This effect may have occurred in two levels of the brain, either the hypothalamus or the hippocampus where the presence of the odour stimulus produced a cue to hunger.

Having found that exposure to food odours leads to a conscious perception of a shift in hunger, the next stage of the investigation was designed to examine the effects of exposure to food odours on food choice, consumption and acceptability.

2.3 Experiments to measure the effects of exposure to food odours on food choice, consumption and acceptability

This stage of the empirical research was designed to measure food consumption, following exposure to different odour stimuli. The experiment aimed to overcome the effects of expectation of eating (as identified in section 2.2) and to investigate the effects of odour exposure on the choice and relative acceptability of selected foods.

The objective was to test the hypothesis that exposure to a food odour, prior to consumption, influences food choice, consumption and acceptability. Based on the hunger perception results, the odours of bacon and Brussels sprouts were selected for this investigation. As these stimuli were found to have opposing effects on reported hunger levels (section 2.2), it is proposed that exposure to these odours may enhance and suppress eating habits (i.e. food choice, consumption and acceptability), respectively.

2.31 Experiment to investigate the effects of exposure to a food odour with a high hedonic rating on food choice, consumption and acceptability

This experiment was designed to measure both the qualitative and quantitative effects of exposure to a food odour with a high hedonic rating on food choice, consumption and acceptability. The odour of grilled smoked streaky bacon was given a high hedonic rating (section 2.14) and exposure to the odour was found to significantly increase hunger levels (sections 2.23 and 2.24). Based on these results, the bacon odour stimulus was selected for this follow-up experiment. The methodology adopted was similar to that of the hunger perception study, where assessors were exposed to the odour stimulus in the sensory laboratory. In order to measure consumption and acceptability, following exposure to the odour, the assessors were given lunch. This comprised the food item generic to the odour stimulus, along with other similar foods, to enable food choice to be measured.

Materials

Smoked back bacon was offered for consumption as part of the experiment and in order to introduce the 'choice' element, other meats of a similar nature to bacon were offered. Sausages and beefburgers were chosen as these meat products have similar nutritional values, are found in similar eating situations, and may be classified under the same meal context. As accompaniments to the meats, jacket potato, salad, French bread and water were offered for the assessors to serve themselves. These accompaniments were chosen as they were claimed to be liked by all of the assessors, were appropriate for the time of year (i.e. summer) and were suitable for 'self-service'.

The meats used were thick link pork sausages (mean cooked weight of 42g each), smoked back bacon (mean weight of each cooked rasher 15g) and beefburgers (mean cooked weight of 58g each). Smoked streaky back bacon was used to create the odour in the laboratory, as the high fat content produced a stronger odour than other bacon cuts.

Assessors

Assessors comprised 54 members of staff from Bournemouth University aged between 19 and 58 years (mean 35, SD ± 11). These were 34 females and 20 males who were selected on the basis that they were non-dieters, non-vegetarians and liked the foods which were to be used in the experiment. An initial pilot questionnaire listing nine different foods (six of which were to be involved in the experiment) was completed by volunteers to establish their liking for the experimental foods (appendix 9). Assessors who expressed a disliking for any of the foods chosen for the experimentation were eliminated at this stage from further studies.

The experiment took place over a period of six days with nine assessors taking part each day (a total of 54 participants). The assessors were divided into two samples of 27, balanced by age and sex, and labelled the control group and the experimental group.

Method

During the morning of the tests, assessors completed two written tasks in the sensory laboratory. During this time the control group were exposed to a neutral odour stimulus (i.e. the odour inherent to the sensory laboratory), whilst the experimental group were exposed to the odour of bacon.

Smoked streaky back bacon was grilled in the sensory laboratory on the experimental test days, and removed just before the experimental group arrived. No visual or auditory food cues were present in the laboratory. Assessors were instructed to complete the written tasks in silence and no reference was made, by either the assessors or the researchers, to the odour in the room.

The first written task was completed at 11.30h in the sensory laboratory. This was designed to collect details about the assessor's breakfast habits. The purpose of this questionnaire was to occupy the assessors whilst they were exposed to the odour and the information from this questionnaire was not analysed as part of the results. At 12.30h assessors returned to the sensory laboratory and completed the second written task, a 'lunch order form' (appendix 10). They were given details of portion sizes and instructed to select one of the three meats (bacon, sausage or beefburger) and to indicate the amount they would like. Whilst this questionnaire was partly designed to occupy the assessors while they were in the laboratory, its main purpose was to ensure that they selected the type and amount of meat they anticipated they could eat, exclusively in the presence of the olfactory information. The assessors had not seen the foods, heard them cooking nor been exposed to any sensory cue other than that of the odour. Assessors were exposed to the odour stimulus for 10 minutes on each of the two occasions.

The assessors then went into the restaurant (see appendix 11) where they were seated at two tables (1x5 assessors and 1x4 assessors). Each assessor was served the meat they had requested on the lunch order form. They then helped themselves to jacket potato, French bread, salad and water. During this time the experimental conditions enforced in the sensory laboratory were removed and the assessors were free to communicate with each other. Once everyone had finished their meal, a second serving of meat was offered. This time assessors were allowed to choose a different meat from their first serving if they so wished. Extra salad, etc. was also available if desired. Plate wastage and extra portion sizes were measured.

At the end of the meal, assessors completed a 'meal satisfaction questionnaire' (appendix 12) in which they were instructed to give ratings for the appearance, flavour, smell, texture and overall satisfaction of the meal. Ratings were made on a 10cm hedonic scale (section 2.14 (figure 4)). Finally, they were instructed to describe why they had chosen that particular meat.

Results

As for the experiments in section 2.2, the results were entered into SPSS and parametric methods of analysis were applied to the data. As two groups of assessors (control group and experimental group) took part in these experiments, the results were analysed using t-tests for independent samples (Hair *et al.* 1995). The data from this experiment were analysed in order to measure, firstly, the effects of odour exposure on food choice, i.e. the number of assessors who selected bacon; secondly, to measure the effects of odour exposure on food consumption and finally to analyse the assessors' satisfaction with the meal. The meat (bacon, sausage or beefburger) was the only element of the meal which was selected in the presence of olfactory cues alone, whilst the salad, jacket potato and bread were selected using visual cues. Therefore, to determine the effects of exposure to the food odour, in terms of food choice and consumption, only the meat element of the experiment was measured, whereas, for acceptability, the whole meal was assessed.

Food choice

From the control group, 10 assessors chose bacon as their first meat and when offered a second serving, four assessors selected bacon. The control group selected a total of 32 rashers (mean weight = 480g) of bacon. From the experimental group nine assessors selected bacon as their first meat with seven assessors choosing it on the second serving. A total of 38 rashers (mean weight = 570g) of bacon was selected by the experimental group. There was no significant difference between the number of assessors choosing to eat bacon nor the amount of bacon selected between the control group and the experimental group ($p>0.05$).

Consumption

Consumption was measured by the weight in grams of the meat consumed by each group. The total amount of meat consumed is displayed in table 31. These results were analysed, using t-tests for independent samples, to determine whether a significant difference existed between the amount of meat consumed by the experimental group and the amount consumed by the control group.

	Control Group	*Experimental Group*
Bacon	480g	570g
Sausage	714g	798g
Beefburger	946g	1450g
Total	**2140g**	**2818g**

Table 31 Total amount of meat consumed by the control group and the experimental group

The total amount of meat consumed by each group was analysed, the results of which are shown in table 32.

Group	Meat Consumption (g)				t-value	2-tail sig
	n	Mean	SD	SE of Mean		
Control	27	79.26	37.91	7.30	-1.80	.078
Experimental	27	104.37	61.96	11.92		

Table 32 Analysis of total meat consumption

The results indicated that the experimental group consumed more meat in total than the control group although this difference was not significant ($p>0.05$). The total meat consumption was then examined as two separate servings as shown in tables 33 and 34.

	Control Group	*Experimental Group*
Bacon	405g	450g
Sausage	546g	588g
Beefburger	714g	1218g
Total	**1665g**	**2256g**

Table 33 Meat consumption during the first serving for both groups

	Control Group	*Experimental Group*
Bacon	75g	120g
Sausage	168g	210g
Beefburger	232g	232g
Total	**475g**	**562g**

Table 34 Meat consumption during the second serving for both groups

The two separate servings were analysed, and the results indicated that during the first serving, which was selected based on olfactory cues alone, the amount of meat consumed by the experimental group was significantly greater than the amount consumed by the control group on their first serving ($p<0.05$), see table 35.

Group	Meat Consumption (g)				t-value	2-tail sig
	n	Mean	SD	SE of Mean		
Control	27	61.67	31.24	6.01	-2.19	**.033**
Experimental	27	83.56	41.55	7.99		

Table 35 Analysis of meat consumed during the first serving

When analysing the amount of meat consumed on the second serving only (table 36), no significant difference was found between the control group and the experimental group ($p>0.05$).

Group	Meat Consumption (g)				t-value	2-tail sig
	n	Mean	SD	SE of Mean		
Control	27	17.59	23.65	4.55	-.43	.672
Experimental	27	20.81	31.36	6.04		

Table 36 Analysis of meat consumed during the second serving

Acceptability

The hedonic ratings given by each assessor for the appearance, flavour, smell, texture and overall acceptability of the meal were recorded by measuring the distance, in centimetres, from the left hand side of the scale to the vertical mark indicated on the horizontal line. The mean ratings given by each group are shown in table 37.

Attribute	*Control Group*	*Experimental Group*
Appearance	5.87	6.74
Odour	6.26	6.64
Flavour	6.66	7.46
Texture	6.14	7.11
Overall	6.33	7.23
Total	**31.66**	**35.11**

Table 37 Mean hedonic ratings given for acceptability by the control group and the experimental group

The total ratings given by the two groups were initially analysed using t-tests for independent samples as follows:

Group	Hedonic Rating : Total				t-value	2-tail sig
	n	Mean	SD	SE of Mean		
Control	27	31.66	6.76	1.30	2.26	**.029**
Experimental	27	35.11	4.19	.81		

Table 38 Analysis of total hedonic ratings given for the acceptability of the meal

It can be seen that the total ratings given by the experimental group were significantly higher ($p<0.05$) than those of the control group (table 38).

The hedonic ratings were then calculated for each individual attribute; appearance, flavour, smell, texture and overall acceptability.

Group	Hedonic Rating : Appearance				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	27	5.87	1.56	.30	2.18	**.034**
Experimental	27	6.75	1.37	.26		

Table 39 Analysis of the hedonic ratings given for the appearance of the meal

The experimental group rated the appearance of the meal significantly higher than the control group ($p<0.05$) (table 39).

Group	Hedonic Rating : Flavour				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	27	6.66	1.05	.20	2.03	**.048**
Experimental	27	7.46	1.77	.34		

Table 40 Analysis of the hedonic ratings given for the flavour of the meal

The experimental group rated the flavour of the meal significantly higher than the control group ($p<0.05$) (table 40).

Group	Hedonic Rating : Odour				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	27	6.26	1.81	.35	.80	.428
Experimental	27	6.64	1.69	.33		

Table 41 Analysis of the hedonic ratings given for the odour of the meal

There was no significant difference between the hedonic ratings for the odour of the meal ($p>0.05$) (table 41).

Group	Hedonic Rating : Texture				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	27	6.14	1.55	.30	2.31	**.025**
Experimental	27	7.11	1.55	.30		

Table 42 Analysis of the hedonic ratings given for the texture of the meal

The experimental group rated the texture of the meal significantly higher than the control group ($p<0.05$) (table 42).

Group	Hedonic Rating : Overall				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	27	6.33	1.66	.319	2.19	.033
Experimental	27	7.23	1.35	.260		

Table 43 Analysis of the hedonic ratings given for the overall acceptability of the meal

For the overall acceptability of the meal, the ratings for the experimental group were significantly higher than those of the control group ($p<0.05$) (table 43).

The last part of the meal satisfaction questionnaire asked the assessors to indicate why they had chosen their particular meat (appendix 12). A variety of responses were given to this question, but only three of the assessors (11per cent) made comments relating to the odour. One person stated that they chose the bacon because they could smell it cooking. Another commented that they did not choose the bacon because it smelt as though it was smoked and a third assessor said they chose the sausages because they could smell them cooking from the sensory laboratory. This comment indicates that those who may have been aware of the odour in the laboratory may not have been able to identify it as bacon, as it was not possible to smell the odour of sausages cooking.

Accompaniments consumed and plate wastage

The accompaniments consumed by the assessors and the plate wastage were recorded as shown in tables 44 and 45. Jacket potato, salad and bread consumption was not analysed as part of the experiment as these foods were selected using visual, rather than olfactory, cues. The plate wastage, however, gave an indication of acceptability and the accuracy of the assessors anticipated consumption levels. Although the results showed no significant difference between the two groups, second servings of the accompaniments were higher for the experimental group (table 44) and plate wastage was higher for the control group (table 45).

	Experimental Group		Control Group	
	1st Serving n	2nd Serving n	1st Serving n	2nd Serving n
Jacket Potato	27	1	26	0
Salad	27	1	27	0
French bread	0	0	1	0

Table 44 Number of assessors consuming one portion of the accompaniments

The experimental group rated the texture of the meal significantly higher than the control group ($p<0.05$) (table 42).

Group	Hedonic Rating : Overall				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	27	6.33	1.66	.319	2.19	**.033**
Experimental	27	7.23	1.35	.260		

Table 43 Analysis of the hedonic ratings given for the overall acceptability of the meal

For the overall acceptability of the meal, the ratings for the experimental group were significantly higher than those of the control group ($p<0.05$) (table 43).

The last part of the meal satisfaction questionnaire asked the assessors to indicate why they had chosen their particular meat (appendix 12). A variety of responses were given to this question, but only three of the assessors (11per cent) made comments relating to the odour. One person stated that they chose the bacon because they could smell it cooking. Another commented that they did not choose the bacon because it smelt as though it was smoked and a third assessor said they chose the sausages because they could smell them cooking from the sensory laboratory. This comment indicates that those who may have been aware of the odour in the laboratory may not have been able to identify it as bacon, as it was not possible to smell the odour of sausages cooking.

Accompaniments consumed and plate wastage

The accompaniments consumed by the assessors and the plate wastage were recorded as shown in tables 44 and 45. Jacket potato, salad and bread consumption was not analysed as part of the experiment as these foods were selected using visual, rather than olfactory, cues. The plate wastage, however, gave an indication of acceptability and the accuracy of the assessors anticipated consumption levels. Although the results showed no significant difference between the two groups, second servings of the accompaniments were higher for the experimental group (table 44) and plate wastage was higher for the control group (table 45).

	Experimental Group		Control Group	
	1st Serving n	2nd Serving n	1st Serving n	2nd Serving n
Jacket Potato	27	1	26	0
Salad	27	1	27	0
French bread	0	0	1	0

Table 44 Number of assessors consuming one portion of the accompaniments

	Experimental Group		Control Group	
	n	Weight in g	n	Weight in g
Meat	0	0	0	0
Jacket Potato	0	0	3	462g
Salad	0	0	0	0
French bread	0	0	0	0

Table 45 Plate wastage for the two groups

2.32 Experiment to investigate the effects of exposure to a food odour with a low hedonic rating on consumption and acceptability

The results from the hunger perception experiments, showed the odour stimuli of both boiled white cabbage and Brussels sprouts to have low hedonic ratings and exposure to these odours led to a decrease in hunger levels for all assessors, although this was not significant ($p>0.05$), section 2.27. The Brussels sprouts odour stimulus, was selected for this follow-up experiment as it was found to be more potent, easier to produce and had a longer duration than that of the cabbage. The design of this experiment differed to that of experiment 2.31, as the assessors selected their whole meal (not just one element) in the presence of olfactory cues alone. In addition to this, the food pertaining to the odour did not constitute part of the subsequent meal, i.e. Brussels sprouts were not served as part of the lunch. The effect of exposure to the food odour was, therefore, measured in terms of consumption and acceptability and *not* food choice.

Materials

A buffet style lunch was served with a choice of sandwiches; tuna and cucumber, Cheddar cheese, ham or salad on either brown or white bread; broccoli and cheese quiche, sausage rolls, and chicken drumsticks. The sandwiches, served in quarters, had mean weights of 26g for cheese, 29g for ham, 31g for salad and 35g for tuna and cucumber. Each sausage roll had a mean cooked weight of 42g and one slice of quiche had a mean weight of 118g. The chicken drumsticks (boned out) had a mean cooked weight of 86g.

The odour stimulus was produced using 500g of frozen Brussels sprouts which were brought to the boil in a pan of water, transferred to the hot plate in the sensory laboratory and simmered for 20 minutes on each occasion.

Assessors

Forty four members of staff from Bournemouth University aged between 19 and 56 years (mean 36, SD ± 12) took part in the experiment. These were 27 females and 17 males who were selected on the basis that they were non-dieters and liked the foods involved in the experiment.

The experiment took place over a period of five days with nine assessors taking part on four of the days and eight taking part on the fifth day (a total of 44 participants). The assessors were divided into two quota samples of 22 balanced by age and sex. These were labelled as the control group and the experimental group.

Method

As for experiment 2.31, assessors completed written tasks in the sensory laboratory throughout the morning of the tests. During this time the control group were exposed to a neutral odour stimulus, whilst the experimental group were exposed to the odour of boiled Brussels sprouts.

The Brussels sprouts were simmered in the sensory laboratory on the experimental test days, and removed just before the experimental group arrived. No visual or auditory food cues were present in the laboratory. Assessors were instructed to complete the written tasks in silence and no reference was made, by the assessors or the researchers, to the odour in the room.

The methodology for experiment 2.31 was applied to this experiment. The breakfast questionnaire was completed at 11.30h in the sensory laboratory and at 12.30h assessors returned to the sensory laboratory to complete the 'lunch order form' (appendix 13). They were given information regarding the portion size of the food available and instructed to select the foods they would like, indicating the amount. This questionnaires used in this experiment served the same purpose as for experiment 2.31.

The assessors went into the restaurant where they helped themselves to the foods they had indicated on the lunch order form. As for experiment 2.31, assessors were seated at two tables (1x5 and 1x4) and the experimental controls were relaxed. During the experimental test days, the odour of Brussels sprouts was also present in the restaurant whilst the assessors consumed their lunch. This was produced by simmering 500g of frozen Brussels sprouts, on a hotplate at the back of the restaurant, out of the assessors' view.

At the end of the meal, assessors completed the 'meal satisfaction questionnaire' (appendix 12). This instructed them to give ratings for the appearance, flavour, smell, texture and overall satisfaction of the meal. Ratings were made on a 10cm hedonic scale, as used in section 2.14 (figure 4). Finally, they were instructed to make any comments they felt appropriate about the meal.

Results

As for experiment 2.31 the results were entered into SPSS and analysed using t-tests for independent samples, to measure the effects of exposure to the food odour, firstly on consumption and secondly on acceptability.

Consumption

Consumption was measured in terms of the weight in grams of the foods consumed by each assessor. The total amount of food consumed by the two groups is shown in table 46.

	Control Group (Weight g)	Experimental Group (Weight g)
Sandwiches	*3370*	*2630*
Quiche	*1008*	*882*
Sausage Rolls	*2832*	*3186*
Chicken	*2580*	*2666*
Total	***9790***	***9364***

Table 46 Consumption of food in grams for each group.

The results were analysed for significance as follows:

Group	Food Consumption (g)				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	22	445.00	226.99	48.39	.15	.880
Experimental	22	434.91	213.73	45.57		

Table 47 Analysis of food consumed by the control and experimental groups

Although the total weight of food consumed by the experimental group was less than that of the control group this difference was not significant (p>0.05).

Acceptability

The hedonic ratings given for each attribute; appearance, smell, flavour, texture and overall acceptability were measured and recorded for each group. The mean ratings given by each group are shown in table 48.

Attribute	*Control Group*	*Experimental Group*
Appearance	6.52	6.37
Odour	5.6	4.99
Flavour	6.57	6.33
Texture	6.36	6.19
Overall	6.83	6.39
Total	**31.88**	**30.27**

Table 48 Mean hedonic ratings given for the meal.

The ratings given by the experimental group were lower for each of the attributes, but this difference was not statistically significant (p>0.05) (table 49).

Group	Hedonic Rating : Appearance				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	22	6.52	1.542	.32	.24	.611
Experimental	22	6.37	2.418	.51		

Table 49 Analysis of hedonic ratings given for appearance of the meal

The experimental group ratings for appearance were lower than those of the control group but the difference was not significant (p>0.05) (table 50).

Group	Hedonic Rating : Flavour				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	22	6.57	2.04	.435	.39	.612
Experimental	22	6.33	2.02	.431		

Table 50 Analysis of hedonic ratings given for the flavour of the meal

The difference in the mean hedonic ratings for flavour was not significant (p>0.05) (table 50).

Group	Hedonic Rating : Odour				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	22	5.86	1.648	.360	1.59	.120
Experimental	22	4.99	1.947	.417		

Table 51 Analysis of hedonic ratings given for the odour of the meal

The mean difference for the odour of the meal was greater than the mean difference for any other attribute but this was not great enough to be significant (table 51).

Group	Hedonic Rating : Texture				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	22	6.36	2.48	.53	.24	.813
Experimental	22	6.19	2.28	.49		

Table 52 Analysis of hedonic ratings given for the texture of the meal

As for the other attributes, the difference between the hedonic ratings for the texture of the meal was not significant ($p>0.05$) (table 52).

Group	Hedonic Rating : Overall				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	22	6.38	1.89	.403	.74	.461
Experimental	22	6.39	2.04	.435		

Table 53 Analysis of hedonic ratings given for the overall acceptability of the meal

Similar mean hedonic ratings were given by the two groups for the overall acceptability of the meal, hence there was no significant difference ($p>0.05$) (table 53).

Plate wastage/extra portions

No extra portions were offered during this experiment. Plate wastage was measured and in total 242g of food were left by the control group and 490g by the experimental group. These weights were deducted from the consumption data prior to analysis.

Discussion

The results from experiment 2.31 indicated that exposure to the bacon odour stimulus had no significant effect on the assessor's choice of meat. A significant difference was, however, found between consumption levels for the experimental group and the control group. It is possible that the nature of the odour contributed to these effects as the odour of bacon may be described as simply a 'meaty' odour and therefore influenced *meat* consumption *in general* rather than bacon specifically. Another possible reason for the non-significant effect on food choice relates to the nature of the food product. When asked to indicate why they had chosen their particular meat, a number of assessors commented that they chose either the sausage or beefburger as it was 'more substantial' and complemented the jacket potato and salad better than bacon.

In terms of consumption, the total weights of meat consumed on the two servings were not significantly different. When analysed as two separate servings, however, the experimental group was found to have consumed significantly more meat on the first serving than the control group. Analysis of the results as two separate servings provides a more accurate comparison as the assessors selected their first serving in the presence of olfactory cues alone. They had not seen the meats or heard them cooking or had any indication of their sensory characteristics other than the odour cue. When offered a second serving in the restaurant, however, visual, auditory and textural cues were present. The assessors had seen the three meats and probably had some indication of the crispness of the bacon or the greasiness of the beefburgers, for example. Hence, it is likely that the assessors' second choice of meat was greatly influenced by visual or gustatory cues. Therefore, a comparison of the first servings only is more valid as the assessors anticipated their consumption in the presence of olfactory cues alone.

The results for consumption during the second serving showed no significant difference between the two groups. This finding also highlights the effect of the olfactory cues in isolation, as the results indicated that when other cues were present (i.e. during the second serving) there was no significant difference in consumption levels. Although consideration must be given to the fact that one serving had already been eaten, and therefore, less food would be expected to be consumed on the second serving, this factor was constant to both groups.

These results may also be interpreted in terms of *anticipated* consumption rather than *actual* consumption. The experimental group *anticipated* a significantly higher consumption level (in the presence of the bacon odour stimulus) than the control group, hence the amount of meat consumed during the first serving was significantly greater. When combined with the second serving and analysed as the total *actual* consumption there was no significant difference between the two groups. Therefore, it may be said that the food odour did not necessarily *cause* the experimental group to experience significantly greater hunger levels, it just led them to *perceive* that they were more hungry, hence causing them to *anticipate* they could consume more. When exposed to the neutral odour stimulus, the hunger perception of the control group was not increased, hence their anticipated consumption levels were significantly lower than those of the experimental group. They did, however, make up their consumption levels on the second serving leading to a total consumption which was not significantly different from that of the experimental group.

There are a number of other factors which may have had an impact on the consumption element of this experiment. As discussed in section 1.46, nutritional meaning has been found to influence decisions regarding food selection and portion size (Booth 1981). Non-dieters, however, were specifically selected for this experiment in order to minimise the influence of the nutritional value of the foods on consumption.

Social factors such as etiquette and politeness, or alternatively, greediness and gluttony may also have had an impact when selecting the amount of meat to be consumed. Assessors were, however, clearly instructed to select exactly the amount they genuinely anticipated they could eat.

As reviewed in relation to the hunger perception experiments, sensory specific satiety is likely to have had an effect on the amount of meat consumed in this study. Had the assessors only been offered a second serving of the *same* meat rather than a choice of the others, it is possible that the amount consumed during the second serving would have been less, due to sensory specific satiety.

The results for acceptability showed that the experimental group rated the meal significantly higher than the control group. This difference was significant for the total mean hedonic ratings and the mean ratings for each individual attribute (appearance, flavour, texture and overall acceptability of the meal). There was, however, no significant difference between the hedonic ratings given by the two groups for the odour of the meal. This indicates that although the presence of the odour stimulus appeared to influence consumption and enhance the acceptability of the meal for the other sensory attributes, its effect may have been subconscious rather than conscious. Had the assessors been consciously aware of the odour presence, it is expected that they would have rated the odour attribute higher. The meal satisfaction questionnaire measured the attributes of the meal *after* consumption, where the odour of the actual meal was the same for both groups. The flavour, texture and appearance of the meal also remained constant, however, but these characteristics appear to have been enhanced for those exposed to the odour. Additionally, only three assessors from the experimental group made comments relating to the presence of the bacon odour, again indicating that the effects it caused were, for the majority of assessors, subconscious.

The findings drawn from this experiment indicate that exposure to the food odour did not significantly influence food choice as there was no significant difference between the number of assessors choosing bacon ($p>0.05$). Exposure to the food odour did significantly influence food consumption, as significantly more meat was consumed on the first serving by those exposed to the odour ($p<0.05$), and exposure to the food odour significantly influenced the acceptability of the meal as higher hedonic ratings were given for the appearance, flavour, texture and overall satisfaction by the experimental group ($p<0.05$).

Finally, exposure to the odour of bacon prior to eating had both a qualitative and quantitative effect on the meal experience, as it influenced food consumption (a quantitative measure) and enhanced the acceptability of the meal (a qualitative measure).

The results from the second part of this investigation found exposure to the odour of boiled Brussels sprouts to have no significant effect on food consumption, as there was no significant difference in the amount of food consumed between the control group and the experimental group ($p>0.05$). Neither did it significantly influence the acceptability of the meal, as, although the hedonic ratings given for the appearance, smell, flavour, texture and overall satisfaction were lower for the experimental group, this was not significant ($p>0.05$). Hence overall, exposure to the food odour with a low hedonic rating did not significantly influence food consumption nor acceptability.

The overall results for the food choice, consumption and acceptability investigation are consistent with those of the hunger perception study. Exposure to the odour of bacon significantly increased hunger (section 2.23 and 2.24) and also had a significant effect on consumption and acceptability. The odour of Brussels sprouts reduced hunger levels, albeit not significantly and it also reduced consumption and acceptability, but this too was not significant.

As proposed, the odour stimuli had opposing effects on eating behaviour and food intake. These effects were significant when exposed to the odour with a high hedonic rating, but not statistically significant for the odour with a low hedonic rating. As discussed in section 1.22, the sense of smell is very idiosyncratic, and the pleasantness of an odour stimulus may be reflected by an individual's experiences and memories with which it is associated. A number of the assessors who were exposed to the Brussels sprouts odour stimulus, commented after the experiment that, although the odour itself was unpleasant, the memories of a 'home cooked Sunday lunch' with which it was often associated had pleasant connotations. Factors such as this may provide some anecdotal explanation of these empirical results, as although an odour may be regarded as unpleasant, it may not significantly reduce hunger levels due to its pleasurable associations.

The overall conclusion from this stage of the empirical research is that exposure to a food odour with a high hedonic rating significantly increased food consumption and acceptability, whilst exposure to a food odour with a low hedonic rating had no significant effect.

The next stage of the empirical research was designed to apply the experimental methodology from sections 2.2 and 2.3 to a realistic restaurant environment, thus eliminating the use of the sensory laboratory.

2.4 Experiment to measure the effects of odour exposure in a restaurant environment

The results from the previous experiments (section 2.3) indicated that exposure to a food odour prior to a meal, influenced food consumption and acceptability. The prior exposure to the odour in these experiments took place under laboratory conditions, whereas, in a restaurant environment this would not be the case as the first time a consumer would be exposed to the food odour, is on arrival at the restaurant.

This experiment was, therefore, designed to transfer the 'odour exposure' element of the meal choice and acceptability investigation *from* the laboratory *into* the restaurant.

For this investigation, the protocol of the above experiments (sections 2.31 and 2.32) was applied to the restaurant to examine the effects of exposure to a food odour on the choice and acceptability of the food being served in this environment. The results from the hunger perception experiments (section 2.2) indicated that repeated exposure to a single odour stimulus had a greater effect than when several odours were presented sequentially. The results also indicated that the accumulative effect of exposure over time had a greater effect on hunger levels than one short exposure. For these reasons, the experiment was designed using a sweet food odour, pertaining to a pudding being served, to ensure that assessors would be exposed to the odour (i.e. whilst eating the main course) before being asked to make their dessert selection. Due to this design, it was only possible to measure food choice and acceptability rather than consumption as, unlike experiment 2.31 and 2.32, it was impractical for the assessors to indicate the amount they desired. Similarly, consumption could not be measured by offering a second serving as by this stage other sensory cues may have influenced the results.

Materials

Tests were initially conducted to examine a variety of sweet food odours, in the laboratory, to determine their suitability for the experiment (table 54). Data were recorded for the intensity and duration of the odour presence in order to meet the same criteria set out in section 2.1.

Food Item	Method of Preparation	Results
Oatmeal Biscuits	Freshly made oatmeal biscuits baked in convection oven for 15 minutes.	Odour not sufficiently intense to infuse into volume of $36m^3$
Chocolate chip cookies	Frozen cookie mixture cooked in convection oven for 20 minutes.	Very intense odour, but smelt more of vanilla than chocolate and was very sweet.
Fruit odours	Artificial fruit odours (lemon, blackcurrant and raspberry[18]) Tested individually by placing two drops of each filter paper in petri dish.	Too intense and artificial.
Chocolate sponge cake	Freshly made chocolate sponge baked in convection oven for 20 minutes.	Infused odour into lab. after 15 minutes of baking. Odour persisted for further 10 minutes.
Chocolate sauce	Freshly made chocolate sauce with plain chocolate, cocoa powder, cornflour, sugar and water left to simmer on hob.	Representative odour but not sufficiently intense.

Table 54 Tests to establish suitable sweet food odours for further experiments

From the products tested, the chocolate sponge cake was found to produce the most suitable odour for the experiment. The realistic representation and intensity of the odour stimulus was optimised in the laboratory when baked in a closed convection oven for twenty minutes at 180°C and then for a further five minutes with the oven door open to allow the odour to infuse into the room.

The sponge cake was produced using the recipe shown in table 55.

Ingredient	Amount
Plain flour	740g
Cocoa powder	50g
Castor sugar	600g
Baking powder	10g
Butter	800g
Warm water	2 tablespoons

Table 55 Chocolate sponge recipe used to produce odour

The addition of the water enhanced the odour when cooking due to the production of steam which caused the odour molecules to be released and become more volatile.

As the restaurant (appendix 11) had a greater volume than the laboratory ($135m^3$), when the method was transferred from the laboratory, two convection ovens and a large

18 Blackcurrant flavouring NA (D2969)
Raspberry flavouring NA (D1542)
Lemon juice flavouring oil (D2458)

Supplied by Bush Boake Allen Ltd., Blackhorse Lane, London.

hot plate were required to infuse the odour into the room. The ovens were placed in the centre of the restaurant, and in order to maintain the odour in the room, when the sponges were cooked they were transferred to the hot plate where they were left throughout service. During service, the ovens were moved to the edge of the restaurant but continued to cook further cakes whilst the main course was being served; these ovens were masked by screens so the assessors were unaware of their presence. The temperature of the restaurant was maintained at 22°C to increase the volatility of the odourous molecules.

As the restaurant was filled with a chocolate odour stimulus, in order to measure the direct effects on the choice of a related food product, it was necessary to serve a pudding that was primarily chocolate based. Chocolate sponge pudding served with chocolate sauce was selected as this was generic to the odour in the room, and was substantial enough to be served as a pudding. As an alternative pudding, apple pie with cream was offered. This was chosen because it contained no chocolate or sponge and therefore was a contrast to the chocolate pudding but it did have similar nutritional values, was served hot with an accompaniment and was of similar portion size. The products are also common menu items which would be served in a restaurant of this type.

Main course

Jacket potatoes with a choice of tuna mayonnaise, cheese or coleslaw; or lasagne with new potatoes and salad were served for the main course. These were selected as they were deemed to be a typical, light lunchtime meal (comprising of approximately 400kcal), of similar portion size and nutritional value and contained an option suitable for vegetarians.

Assessors

One hundred and six assessors took part in the experiment overall. They were all members of staff from Bournemouth University aged between 22 and 55 years (mean 37, SD ± 10). Assessors were selected on the basis that they were non-dieters, liked at least one of the above main courses and liked both apple pie and chocolate sponge. Assessors were instructed to rate their liking for apple pie and chocolate sponge using a 10cm hedonic scale (appendix 14). Assessors who expressed an extreme liking for either of the two puddings were eliminated at this stage, and only those who had a similar liking for the two puddings were selected for further experimentation. They were divided into two samples of 53 balanced by age and sex, labelled the control and experimental groups.

Due to restrictions such as the restaurant size, availability of waiting staff and control of the test conditions, the experiments were conducted over a period of six days. This consisted of three control days, where a neutral odour stimulus was present in the restaurant, and three experimental days where assessors were exposed to the chocolate odour stimulus. Each day 17 or 18 assessors took part.

Method

In order to infuse the chocolate odour into the restaurant, the first sponges were placed in the convection ovens in the restaurant at 11.35h. At 11.55h the oven doors were opened (whilst the oven was still switched on) and the cakes were left to cook for a further 5 minutes. At 12.00h the two sponges were removed from the ovens and placed on the hotplate. A second pair of sponges were placed in the convection ovens and the procedure was repeated. At 12.25h the process was repeated for a third time, removing the sponges from the ovens at 12.43h, just before the assessors arrived in the restaurant. The convection ovens were then moved to the edge of the restaurant, masked with screens, and a final batch of sponges was cooked whilst the main course was being served. The hot plate containing the baked cakes was also masked during service.

To reduce the amount of time and labour required for the experiments, assessors were asked to select their main course on the day prior to the experiment. On each day assessors arrived in the reception area and were shown through to the restaurant, once all the assessors had arrived. This ensured that all assessors were exposed to the odour for the same period of time. The pre-ordered main courses were then served, and when all assessors had finished the main course, a choice of chocolate sponge with chocolate sauce or apple pie with cream was offered. After all of the assessors had finished eating, they completed a 'meal satisfaction questionnaire' (appendix 15). The assessors were instructed to indicate, on a series of 10cm hedonic scales, their rating of the appearance, smell, flavour, texture and overall acceptability of their chosen pudding. Finally, the assessors were instructed to describe why they had chosen their particular pudding and to make any further comments which they felt were relevant.

Results

The data were entered into SPSS and analysed as follows:

- Initial analysis to test for a significant difference in the assessors' usual liking for apple pie and chocolate sponge using t-tests for independent samples
- Chi-square test to measure food choice
- T-tests for independent samples to measure acceptability

<u>Assessors' *usual* liking for the two puddings</u>

Hedonic ratings given for the *usual* liking of the two puddings, prior to the experiment are shown in table 56. These were analysed to establish that no significant difference in liking/disliking existed within assessors nor between the two groups.

	Chocolate Sponge		Apple Pie	
	Mean	SD	Mean	SD
Control Group	7.02	1.75	7.30	1.77
Experimental Group	7.01	1.71	7.07	1.45

Table 56 Mean hedonic ratings of the assessors' *usual* liking for apple pie and chocolate sponge

These hedonic ratings were analysed in order to determine whether a significant difference existed between the liking for the two puddings within each group.

Group	Experimental Group				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Apple Pie	53	7.07	1.45	.20	.17	.864
Chocolate Sponge	53	7.02	1.71	.23		

Table 57 Analysis of hedonic ratings for both puddings by assessors from the experimental group

There was no significant difference between the hedonic ratings given for the *usual* liking of apple pie and chocolate sponge between the assessors in the experimental group (table 57), nor between the assessors in control group (table 58).

Group	Control Group				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Apple Pie	53	7.31	1.77	.24	.82	.411
Chocolate Sponge	53	7.02	1.75	.24		

Table 58 Analysis of hedonic ratings for both puddings by assessors from the control group

The results were then analysed to determine if a significant difference existed in the hedonic ratings between the two groups for each pudding. The results indicate that no significant difference occurred between the experimental and control groups' hedonic ratings for the *usual* liking of chocolate sponge ($p>0.05$) (table 59).

Group	Chocolate Sponge				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	53	7.02	1.75	.24	.02	.983
Experimental	53	7.02	1.71	.23		

Table 59 Analysis of hedonic ratings for chocolate sponge by assessors from the control and experimental groups.

Similarly, no significant difference occurred between the experimental and control groups' hedonic ratings for the *usual* liking of apple pie ($p>0.05$) (table 60).

Group	Apple Pie				t-value	2-tail sig
	Number of cases	Mean	SD	SE of Mean		
Control	53	7.31	1.77	.24	.76	.451
Experimental	53	7.07	1.45	.20		

Table 60 Analysis of hedonic ratings for apple pie by assessors from the control and experimental groups.

As no significant differences occurred for the *usual* liking of the two puddings to be served, the assessors then went on to take part in the experiment.

The data from the experiment were analysed firstly to measure the effect of exposure to the food odour on food choice, and secondly to analyse the assessors' satisfaction with the pudding.

Food choice

The data were analysed to compare the number of assessors selecting chocolate sponge and apple pie. Significantly more assessors selected chocolate sponge from the experimental group than from the control group ($p<0.05$) (table 61).

Group	Selection		
	Apple Pie	Chocolate Sponge	
Experimental group	20	33	
Control group	32	21	
Chi-Square	*Value*	*df*	*p-value*
Pearson	5.44	1	.01973

Table 61 Chi-square analysis of the puddings selected by the control group and the experimental group

Acceptability

The hedonic ratings given by each assessor for the appearance, smell, flavour, texture and overall satisfaction of their chosen pudding were measured and recorded. The mean ratings given by those who selected apple pie and those who selected the chocolate sponge are shown in tables 62 and 63.

		Appearance		Odour		Flavour		Texture		Overall	
	n	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Experimental Group	33	6.61	1.99	7.96	1.42	7.84	1.51	7.39	2.11	7.84	1.47
Control Group	21	5.33	1.64	5.88	1.65	5.73	2.09	5.20	2.30	5.35	2.54

Table 62 Mean hedonic ratings given for the chocolate sponge

		Appearance		Odour		Flavour		Texture		Overall	
	n	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Experimental Group	20	7.49	1.84	6.89	1.88	7.53	1.55	7.81	1.28	7.78	1.61
Control Group	32	7.66	2.01	7.52	1.93	7.77	2.09	6.96	2.73	7.78	2.08

Table 63 Mean hedonic ratings given for the apple pie

The data were then analysed using t-tests for independent samples to investigate a number of criteria:

- To determine whether a significant difference existed between the hedonic ratings given for each attribute of the chocolate sponge by the control group and the experimental group
- To establish if a significant difference occurred between the ratings for each attribute of the apple pie by the two groups.

The results are shown in table 64.

	Appearance		Odour		Flavour		Texture		Overall	
	t-value	2-tail sig	t-value	2-tail sig	t-value	2-tail sig	t-value	2-tail sig	t-value	2-tail sig
Chocolate Sponge	2.49	**.016**	4.92	**.000**	4.29	**.000**	3.6	**.001**	4.07	**.000**
Apple Pie	-.30	.764	-1.16	.250	-.44	.662	1.5	.561	.00	1.000

Table 64 Analysis of hedonic ratings given by the control and experimental groups for chocolate sponge and apple pie

The results indicated that the chocolate sponge was rated significantly higher by the experimental group for each attribute ($p<0.05$) but there was no significant difference between the control and experimental group ratings for any of the attributes for the apple pie ($p>0.05$).

As a control measure, the data were then analysed to determine if a significant difference occurred between the acceptability of the two types of pudding within each group (i.e. whether a significant difference occurred between the apple pie and chocolate sponge within the experimental group and the apple pie and chocolate sponge within the control group).

	n	Appearance		Odour		Flavour		Texture		Overall	
		t-value	2-tail sig	t-value	2-tail sig	t-value	2-tail sig	t-value	2-tail sig	t-value	2-tail sig
Experimental Group	53	-1.62	.112	2.35	.023	.71	.483	-.79	.434	.14	.888
Control Group	53	-4.42	**.000**	-3.21	**.002**	-3.46	**.001**	-3.80	**.000**	-2.44	**.018**

Table 65 Analysis of difference between the hedonic ratings given for apple pie and chocolate sponge by the control and experimental groups.

There was no significant difference between the experimental group ratings for chocolate sponge and apple pie ($p>0.05$). For the control group, a significant difference was evident for each attribute; the apple pie being rated significantly higher than the chocolate sponge ($p<0.05$).

Finally, the last part of the meal satisfaction questionnaire instructed the assessors to indicate why they had chosen the particular pudding. Seven assessors from the experimental group (21% of those who chose the chocolate pudding) stated that the reason for their selection was due to the odour on entering the restaurant.

Discussion

The results from the food choice element of this experiment showed that significantly more assessors from the experimental group chose the chocolate pudding. This suggests that exposure to the chocolate odour influenced the assessors to select the chocolate rather than the apple dessert. Additionally, those who chose the chocolate pudding, rated it significantly higher for appearance, smell, flavour, texture and overall satisfaction, than assessors who were not exposed to the odour prior to consumption. Of those who selected the apple pie, no significant difference was found between the control and experimental groups for acceptability. Within the experimental group, no significant difference occurred between the acceptability of the chocolate sponge and the apple pie. Within the control group, however, the acceptability of the chocolate sponge was rated significantly lower than the apple pie. This also suggests that exposure to the chocolate odour, prior to consumption, enhanced the acceptability of the chocolate pudding.

The results from the food choice element of this experiment are not consistent with those of experiment 2.31 where exposure to the odour of bacon did not significantly influence food choice. As discussed in section 2.31, this may be due to the fact that a bacon odour may simply be recognised as a general 'meaty' or 'savoury' odour. The odour of chocolate, however, may be regarded as more product specific and is unlikely, for example, to have been confused with the apple.

It was not possible to ask the assessors directly whether the odour stimulus influenced their choice of pudding as this could have introduced bias. When asked why they had chosen a particular pudding only 21% of those who selected the chocolate sponge, stated that the selection was due to the presence of the odour in the restaurant. This suggests that, although the odour appears to have affected their choice, this influence was innate and subconscious, rather than a conscious awareness of the stimulus in the environment.

It is possible that exposure to the odour stimulus produced a subliminal or subthreshold effect, whereby the intensity of the stimulus was below the threshold of conscious recognition and did not appear to generate a detection response in the majority of the assessors. The imperceptible, subliminal stimulus appeared to produce indirect but measurable effects on the experimental groups' behaviour, as it influenced the assessors' choice and enhanced acceptability of the food. Alternatively, it could be argued that the assessors were aware of the odour but did not verbalise this in the questionnaire, for reasons other than being consciously aware of the stimulus.

Investigations into the effects of subliminal stimuli indicate that the semantic properties of weak sensory information, below the level necessary for detection, are received and processed by the observer (Fowler *et al.* 1981).

The results from this research suggest that, similar to linguistic cues, olfactory cues may also produce subliminal effects on behaviour, as the stimuli may be picked up and registered by the sensory system and encoded at a level beneath conscious awareness. Schiffman (1990), however, states there is no empirical evidence that subliminal sensory input and its accompanying neural encoding have any substantial impact on one's thoughts or that it can, in any way, modify or influence behaviour. The results from this experiment indicate, however, that subliminal sensory stimuli may have had an impact on the assessors' behaviour, although it is not possible to confirm that the odour stimulus present in the restaurant was at a subthreshold level for all of the assessors.

Similarly, although the choice element of experiment 2.31 was not significantly influenced by exposure to the bacon odour, consumption and acceptability were increased. The hedonic ratings given for the odour of the meal, however, showed no significant difference, indicating that this effect may also have been subliminal. Additionally, when asked to indicate why they had chosen their particular meat, only 11 per cent of the assessors made comments relating to the odour, again, indicating that they were not consciously aware of its presence.

A number of factors may contribute to this subliminal effect. The structure of the olfactory system with its direct projection into the limbic region and indirect links to the Broca's area of the brain, may cause assessors to be aware of the odour only subconsciously, due to the difficulty in verbalising its name. Unlike visual and auditory information, odours have been found to be difficult to identify (Desor and Beauchamp 1974), suggesting that although the assessors may not have consciously identified the odour as chocolate, and consequently ordered the chocolate pudding, the odour subconsciously influenced their choice and acceptability. Kirk-Smith *et al.* (1982) found the effects of odours on moods and attitudes may be difficult to verbalise due to the fact that in humans, the auditory and visual senses predominate over the olfactory sense. This phenomenon may be applied to the meal acceptability element of these experiments. The presence of the odour stimulus appeared to enhance the acceptability of the meal, but in the meal satisfaction questionnaire the assessors did not verbalise it as being the reason for the enhancement. The acquisition of associations may, therefore, have been below the levels of verbal awareness or conscious detection (Van Toller *et al.* 1983).

The overall conclusion from this stage of the empirical investigation is that exposure to the chocolate odour stimulus, during consumption of the main course in a restaurant environment, significantly influenced the choice, and enhanced the acceptability of the pudding.

Following completion of the empirical investigation, the results from each of the experiments were synthesised, and integrated with the findings of the research reviewed in section one, in order to develop the predictive olfactory cueing model.

3.0 *The proposed olfactory cueing model*

Throughout the investigation, a number of factors have been identified, which may contribute to the role of olfactory cues. The interrelationships and relative importance of these variables will now be demonstrated in the form of a predictive olfactory cueing model, designed to predict the effect of exposure to odour stimuli on eating behaviour.

A wide variety of models prediciting attitudes and behaviour have been developed, one of the most widely applied being that of Fishbein and Ajzen (1975). More specific models, relating to eating behaviour and food preference, have also been devised (Shepherd 1989). The model derived from the findings of this investigation specialises further by focusing on one sense and demonstrating the contribution of olfaction to eating habits and dietary behaviour.

The findings from the empirical research indicated that exposure to odour cues can influence eating behaviour by effecting hunger, consumption, food choice and acceptability (Blackwell and Pierson 1995a and Blackwell and Pierson 1996). The factors contributing to these results were identified through both the empirical investigation and previous research reviewed in section one. The manipulation of these factors has been found to influence the experimental results (e.g. the hedonic rating of the odour, the length and time of exposure and the identifiable nature of the stimulus), hence these elements are defined as the independent variables of the model which influence the dependent outcome of eating behaviour. In order to facilitate the development of the olfactory cueing model, the independent variables were categorised as either stimulus variables or subject variables.

3.1 Stimulus variables contributing to the model

The stimulus variables identified during the experimentation included the hedonic rating and identifiable nature of the odour, and the time, location and concentration of exposure to the odour. Any variations in these independent conditions are likely to influence eating behaviour as the dependent variable.

3.11 Time of exposure

In section 2.24 of the hunger perception investigation, the odour of bacon was found to significantly increase hunger levels at 10.30h, 11.30h and 12.30h. At 09.30h, however, although hunger levels increased, this increase was not statistically significant. The mean time difference between breakfast consumption and exposure to the odour at 09.30h was 1.45 hours, thus it is likely that the majority of the assessors were at this time satiated. Exposure to the odour at this time, therefore, did not significantly increase their hunger levels. Consequently, the time of the odour presentation, in relation to when a meal was last consumed, is an important variable within the model.

3.12 Location and context

The experiments conducted in the sensory laboratory showed a decrease in hunger compared to that experienced in the normal working environment (section 2.23). As discussed in section 2.2, this may have been influenced by the controlled experimental conditions, whereas in a restaurant environment, the ambience is likely to be more conducive to eating. Exposure to the high hedonic food odour, under laboratory conditions, led to a significant increase in hunger, consumption and acceptability (sections 2.23 and 2.24). In an environment considered to be more conducive to eating, the effects of such exposure would, therefore, be expected to be further enhanced (as indicated in section 2.4). Similarly, the context in which an odour is presented may influence its effectiveness, as responses to odours are believed to be context dependent (Rozin 1982). The odour of mature cheese, presented in the context of a meal, may produce a different effect than when presented in the context of old socks, for example. The olfactory cueing model, however, assumes that the assessor is in an eating environment.

3.13 Concentration of exposure

The results from the hunger perception experiments showed that sequential exposure to the same odour had a greater effect on hunger levels than exposure to a series of different odours from the four quartiles of the hedonic scale. Although constant exposure to an odour is likely to lead to olfactory adaptation (section 1.17), the experimental findings indicated that short (10 minutes), but repeated exposure to the same odour had a significant effect on hunger levels.

3.14 Hedonic rating

The hunger perception study (section 2.23), indicated that the hedonic rating of the odour effected the direction and magnitude of the hunger shift. In the subsequent experiments, which measured consumption and acceptability, assessors exposed to an odour with a high hedonic rating consumed significantly more food and rated the meal significantly higher than those exposed to a neutral odour stimulus. When assessors were exposed to an odour with a low hedonic rating a decrease in consumption and acceptability was observed.

The hedonic rating of the stimulus is therefore, considered to be one of the most important factors, as the hedonic rating of the odour will determine whether food intake is enhanced or suppressed. In a restaurant environment, it is likely that an odour with a high hedonic odour will be desired, in order to increase food intake and acceptability. In situations such as weight reducing diets, an odour with a low hedonic rating may be required in order to suppress hunger and food intake (discussed further in section 4.0)

3.15 Identifiable nature of the odour

The results from experiment 2.31 indicate that the bacon odour was perceived by the assessors as a general 'meaty odour' and was not specifically attributed to bacon. Whilst exposure to this odour stimulus influenced consumption and acceptability, the effects on food choice were not statistically significant. In contrast, exposure to the chocolate odour (experiment 2.4) significantly influenced food consumption. It is likely that the chocolate odour stimulus was easier to identify and more readily attributed to the chocolate sponge being served in the restaurant.

3.2 Subject variables contributing to the model

The findings from both the literature reviewed in section one and the empirical research, indicated that olfaction is very individualistic and subjects may be effected by exposure to an odour in different ways. There are, therefore, a number of subject inputs to the model which may influence the outcome. These include the consumption of special diets, cultural or religious beliefs, individual odour preferences and experiences, the impairment of the olfactory sense, and the effects of sensory specific satiety.

3.21 Special diets

As discussed in section one, food intake is guided by a variety of factors including social, cognitive and environmental influences. For these reasons, diets may be followed which prohibit the consumption of certain foods. Individuals who follow such diets have been reported to dislike the forbidden foods and consequently dislike their associated odours (Engen 1988). A vegetarian, for example, who does not eat meat for moral reasons, may be nauseated by the odour of meat products. A vegetarian who refrains from eating meat for health reasons, however, may be positively stimulated by the presence of a meat odour in terms of hunger, consumption and acceptability. Factors such as this will play a role in the olfactory cueing model, as exposure to such an odour may produce different effects for different dietary groups.

3.22 Cultural or religious beliefs

Other factors which have been found to influence food intake include cultural and religious beliefs (section one). Similarly to section 3.21, some cultures and religions consider certain foods to be 'taboo' and prohibit their consumption. Hence the odour of the forbidden foods is often regarded as unpleasant. Those practising the Muslim religion, for example, find the odour of pork to be objectionable (Engen 1988).

In some instances, however, although the consumption of certain foods is forbidden, the odour stimulus may not necessarily be considered unpleasant and the effects of exposure to such an odour may be positive. Whilst exposure to the odour of a forbidden food may not influence food choice (i.e. the product would not be selected), it may still increase consumption and acceptability of related foods.

3.23 Individual preference or experience

As with many aspects of consumer behaviour, personal preference or experience plays an important role. As olfaction has been found to be a very idiosyncratic sense, personal preference and experience are factors which are particularly pertinent to this model. Whilst the odour of boiled Brussels sprouts, for example, may be unpleasant to most assessors, for some, it may have pleasant connotations and hence a positive effect on their hunger. Similarly, a bad experience with a food may mean an odour which is pleasant to most individuals may, for some personal reason, be unpleasant to others (section 1.22).

3.24 Acuity of the sense of smell

A major factor affecting the olfactory cueing model is the individuals' ability to detect odours. Exposure to food odours is unlikely to affect the behaviour of anyone suffering from anosmia, as discussed in section 1.15, hence this model is only applicable to subjects with a functional sense of smell.

3.25 Sensory specific satiety/Alliesthesia

An individual's internal state of repletion will have an effect on both the perceived hedonic rating of an odour and their hunger levels, due to the fact that many food odours are pleasant when hungry, but unpleasant when satiated and not wanting to eat (Duclaux *et al.* 1973). Additionally, due to the phenomenon of sensory specific satiety, exposure to a food odour which differs to that of the food causing satiation (e.g. exposure to a sweet food odour following satiation specific to savoury foods only) may lead to an enhancement of food intake (section 1.18).

3.3 The relative importance and control of the model variables

The relative importance and control of the subject and stimulus variables varies considerably. When applied to a restaurant environment, the time of exposure and sensory specific satiety are unlikely to be salient factors, as a consumer would not normally enter a restaurant if they had just eaten or were completely satiated. Sensory specific satiety, however, would play a role during the eating experience and the presence of the same pleasant odour before a meal may be unpleasant after consumption (Cabanac 1971).

The hunger perception investigations indicated that repeated exposure to a single food odour had the greatest impact on hunger levels. In a restaurant environment, therefore, it may be more effective to eliminate any other odours and concentrate on one 'optimum' odour. The length of exposure to the stimulus has also been found to be an important factor (sections 1.17 and 2.2). The odour would need to be present when entering the restaurant in order for it to take effect in time to influence food choice and consumption.

Special diets, cultural and religious beliefs may be accounted for to a certain extent, and a 'neutral' food odour selected for presentation. A sweet or non-meat savoury stimulus, for example, may be a generally acceptable odour which would not offend any particular dietary groups. The experimental findings from sections 2.2 and 2.3 showed meat odours (particularly bacon) to have a more powerful effect on hunger and consumption than vegetable or dairy odours. In a restaurant environment, however, the recent increase in vegetarianism cannot be ignored and it is important not to offend such consumers by subjecting them to odours which they find unpleasant.

The results from the experiments indicated that the hedonic rating of the odour is the most important variable, with exposure to high hedonic food odours leading to an increase in hunger and consumption, an influence on food choice and an enhancement in acceptability.

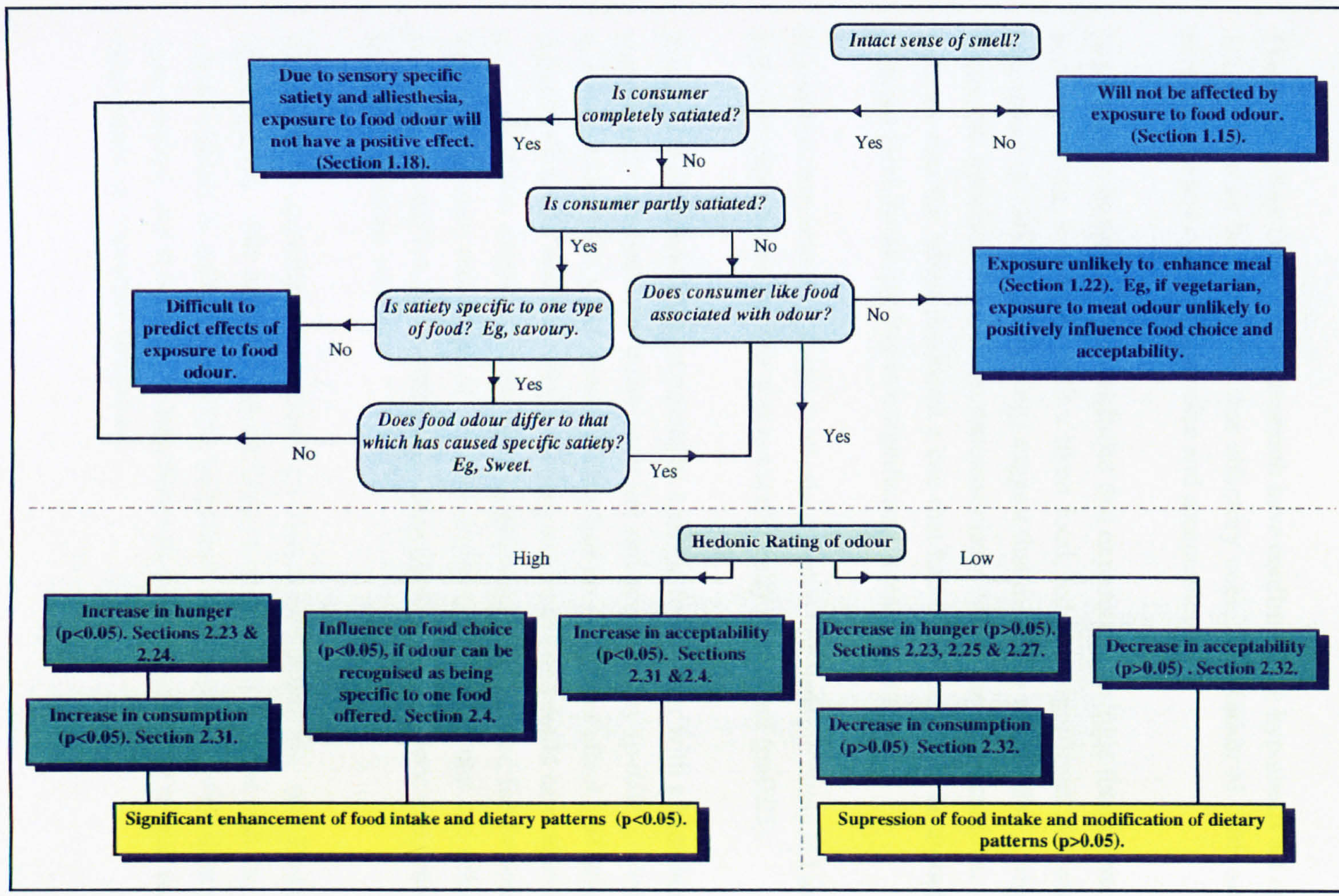
The effects of individual preference or experience are difficult to control or predict. It is important, however, not to eliminate subjects who may be offended by the presence of a particular odour. Similarly, the impairment of the olfactory system is another factor which cannot be controlled. Only a small percentage of the population suffer from permanent loss of the sense of smell. A much larger percentage, however, suffer from colds or allergies causing their olfactory abilities to be temporarily reduced.

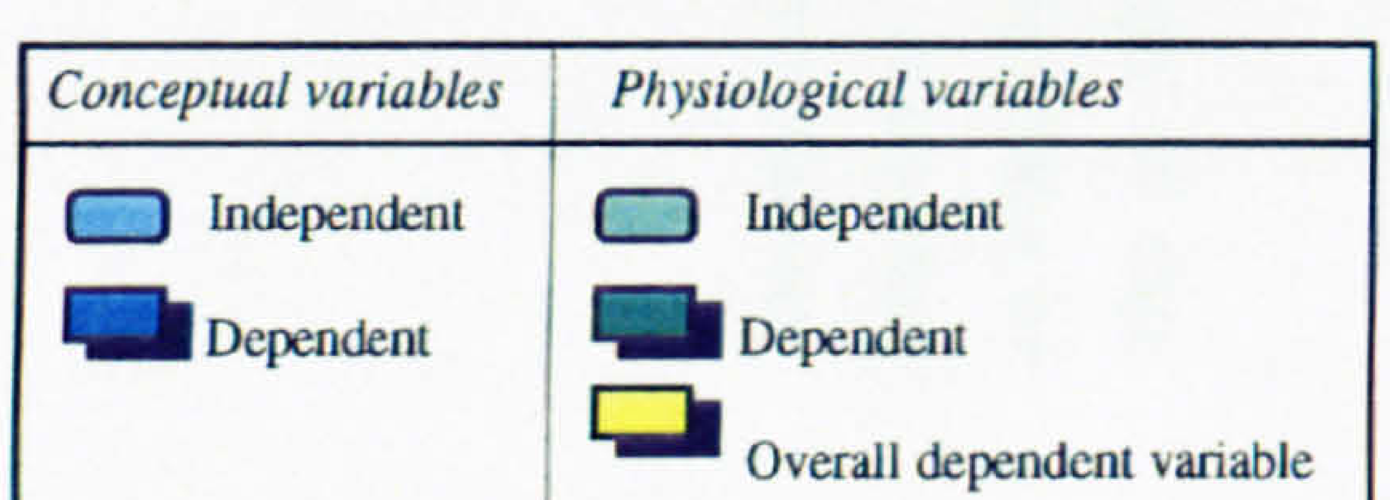
To summarise, the variables within this model which may be controlled are, most importantly the hedonic rating of the odour, which should be high in order to enhance food intake, or low if a suppression of hunger is desired. Secondly, the concentration of the stimulus should be a single odour rather than several odours at once, and finally, due to olfactory fatigue, the exposure should be short and frequent, rather than continuous.

The olfactory cueing model (section 3.4) is constructed in two sections, the first considers the conceptual inputs (indicated in blue) and the second deals with the physiological factors (indicated in green) affecting the output. Two overall dependent variables are demonstrated by the model (indicated in yellow), one being the enhancement of dietary patterns and the other a suppression of food intake.

The starting point of the model assesses the subject's olfactory ability (i.e. to ensure their olfactory system is not impaired) and continues to measure other subject variables such as their state of repletion. Assuming the subject has an intact sense of smell, is not completely satiated (or satiated to the type of food generic to the odour being presented), and expresses a liking for the food associated with the odour, the model predicts that exposure to the odour stimulus will have an effect on the subject's eating behaviour. The next stage of the model assesses the stimulus variables by measuring the hedonic rating of the odour. The model divides at this stage into two routes, one of which indicates an increase in food choice, consumption and acceptability, the other showing a decrease in food intake and acceptability, dependent on the hedonic rating of the stimulus.

3.4 The proposed model demonstrating the effects of exposure to a food odour on food choice, consumption and acceptability.





4.0 Conclusions

The results from the empirical research have confirmed the hypothesis set out in section 1.5, and it may be concluded that olfactory cues, in isolation of other sensory cues, play a functional role in food choice and acceptability.

In relation to hunger, it was concluded that exposure to a single food odour with a high hedonic rating, associated with a liked food, led to a significant increase in hunger perception ($p<0.05$). The findings suggest that the effect occurred as a trigger through either the hypothalamus, or an autoassociator cue in the hippocampus. The results indicate that the odour produced a cue that had been learned to be associated with a pleasant food, hence leading to a significant increase in hunger.

In contrast, exposure to a single food odour with a low hedonic rating led to a reduction in hunger perception, but this was not statistically significant ($p>0.05$).

It was also concluded that exposure to a single food odour with a high hedonic rating significantly increased food consumption and acceptability ($p<0.05$), whilst exposure to a food odour with a low hedonic rating had no significant effect ($p>0.05$). When the odour with a high hedonic rating was easy to identify and could be readily attributed to a specific food, exposure to the odour significantly influenced food choice ($p<0.05$). The results from this stage of the investigation suggested that the effects on food choice, consumption and acceptability, were subliminal, subconscious reactions caused by exposure to the stimulus.

There are a number of applications and implications for the findings of this investigation. The results from the empirical research indicate that the function of odour stimuli in relation to eating behaviour may extend further than a restaurant environment, and in addition to the effects on food intake, odour stimuli may influence other forms of consumer behaviour.

5.0 The application and implications of the investigation

5.1 The role of olfactory cues in eating behaviour

The findings from this investigation indicate that the presence of a food odour with a high hedonic rating, associated with a liked food, leads to an increase in hunger which in turn may increase food consumption, influence food choice and enhance the acceptability of a meal. Exposure to a food odour with a low hedonic rating, however, was found to have no significant effect on hunger levels, food consumption nor acceptability. Individual experiences, memories and associations will play a role in this relationship, with exposure to an odour leading to idiosyncratic effects for some individuals.

The results from this research have clearly indicated that the presence of a pleasant food odour enhances the overall satisfaction of a meal, in terms of its appearance, flavour and texture. This has important implications for populations who suffer from anosmia or temporary impairment of the olfactory function. It is known that odour plays a vital role in flavour perception, through retronasal stimulation, but the results from this research indicate that orthonasal stimulation also plays a functional role in determining food intake. If suffering from a loss or impairment of olfaction, therefore, other components of the eating experience, which odour cues appear to influence, (i.e. hunger, consumption, choice and acceptability) may also be effected, in addition to a reduction in flavour.

These results may also have implications for nutrition and dieting. Non-sensory, contextual cues such as being alone or watching television have been found to trigger binge eating in bulimics (Archer *et al.* 1979). The findings from this investigation, which indicate that exposure to a pleasant food odour leads to an increase in both hunger and consumption may also be a contributing factor to binge eating. Unpleasant food odours, however, were found to reduce hunger levels and consumption (although these results were not statistically significant) and it is therefore possible that the presence of an odour with a low hedonic rating may help reduce binge eating.

Similarly, dieters wishing to lose weight should avoid exposure to pleasant food odours which are likely to increase their hunger levels, whilst exposure to unpleasant food odours may lead to a reduction in consumption. In addition to enhancing dietary patterns, therefore, exposure to food odours may be used to suppress hunger and modify food intake.

This concept forms part of one of the most recent dietary aids available in America which claims to help weight loss by inhaling certain odours. Hirsch (1996) claims to have found a direct link between the frequency of inhalation of odours and weight loss. Assessors participated in trials which indicated that when exposed to a variety of chemicals odours, hunger levels were reduced (Hirsch 1996). The odours used in these trials were all described as 'pleasurable' and consisted of both food and non-food odours. The hypothesis is based on the concept of satiety, and Hirsch (1996) believes that exposure to these odours can 'trick' the hypothalamus and hence the stomach into thinking hunger has been satisfied, leading to a reduction in consumption and the elimination of hunger pangs. These beliefs and findings, however, are not consistent with the findings on alliesthesia (Cabanac 1971) or the hunger perception and consumption results of this investigation. Satiety to food odours only occurs as the food is consumed (Wisniewski *et al.* 1991), and pleasant food odours were found to significantly increase both hunger levels and consumption.

Based on articles published by Hirsch (1996) various forms of dietary aids have been developed. In the US, pens containing pleasurable odours are available for purchase. In the UK, a similar concept has been developed in the form of skin patches, impregnated with a floral odour, specifically designed to reduce chocolate cravings. Both devices are designed to be 'sniffed' at the onset of hunger. Hirsch's most recent dietary advice (Sherwell and Feger 1996) simply suggests 'sniffing' foods or food wrappers instead of eating the product.

An explanation for any correlation between odour and weight loss, however, has not yet been established. It has been suggested that the odours affect mood state and limit appetite, or act as a displacement mechanism for eating. It has also been proposed that the odours themselves satisfy cravings so the food does not have to be eaten (Sherwell and Feger 1996). Although this information is sourced from non-refereed, popular press claims, with little available supporting evidence, due to the vast amount of media attention it receives, the impact on consumer behaviour and beliefs about the relationship between food odours and diet is likely to be high.

The effects of odour and hunger may also be implicated in cases of anorexia. In very low-weight anorexics the sense of smell was found to be impaired and the olfactory function did not improve from hospital admission to discharge despite significant weight gain (Fedoroff *et al.* 1995). The findings suggest that the severe and prolonged starvation experienced by very low-weight anorexics caused or contributed to intractable deficits in the olfactory system. This in turn has implications for recovery, as the impairment of the sense of smell will not only effect the flavour of food, it will reduce sensitivity to odour cues which may be able to stimulate hunger, increase consumption or enhance meal acceptability.

In addition to eating habits, the stimulation of the olfactory sense may also influence other types of behaviour, due to the strong links between odour and emotion (section 1.24). These findings have had a great impact on the retail trade, and odours are now being used for marketing and advertising purposes, as retailers discover the ability of odours to influence feelings and behaviour (Blackwell and Pierson 1995b).

5.2 The role of olfactory cues in spending behaviour

Research has been conducted to investigate the effects of odours on spending behaviour, where various odours (mainly non-food) were pumped through the air conditioning systems of certain stores (Dodd 1992). These included filling car showrooms with the odour of new leather, suggestive of quality; infusing coconut through travel agencies to induce the desire for tropical holidays; and filling greengrocery stores with the odour of freshly cut grass to remind shoppers of summer.

Some of the odours tested above, are now available for marketing purposes. Marketing Aromatics, launched in 1992 (a subsidiary of the Swiss consultancy company, Behavioural Dynamics), offers the company's latest marketing method, 'The Smell Service'. Odours may be purchased for a variety of effects, from purifying work environments and reducing stress, to influencing buying behaviour in shops and impregnating company stationery with a 'corporate identity' aroma.

The results indicate that, not only does odour have an impact on eating behaviour, it may also influence buying behaviour. These findings are interlinked, particularly in a restaurant or food store environment, as the presence of an odour which leads to an increase in hunger, or influences food choice may, in turn, lead to increased spending.

There are, however, a number of implications of this marketing method, particularly in relation to individual preferences and experiences. As discussed throughout, the sense of smell is very idiosyncratic and personal preference and associations can lead to individualistic responses to an odourant. An individual, therefore, may avoid a certain store or restaurant if they were likely to be exposed to an odour which they regarded as offensive. Another consideration includes the population of allergy sufferers whose symptoms may be triggered by such odours.

In addition to these consumer factors, the use of odour to enhance sales has come under a considerable amount of criticism due to the subliminal, manipulative element of the marketing technique. A further implication relates to the trademark protection of odours.

5.3 The trademark protection of odours

The American Trademark Trial and Appeal Board (TTAB) has determined that arbitrary and non-functional product scents may be registered as federal trademarks (Burgunder 1991). These developments have an impact on marketing companies as it effects the range of available devices which may be used to enhance, distinguish and sell products.

There are however, a number of important issues which must be considered before extending trademark protection to an odour associated with a product or service. These issues include genericism, functionality and depletion.

5.31 Genericism

The decision to deny protection to an odour that is generic from the outset should be relatively straightforward. For example, a manufacturer of leather shoes would derive competitive benefits if it was allowed registration for the odour of leather. Other shoe makers could be disadvantaged if consumers who desire leather shoes use odour as a cue to determine the substance of the shoes. A complication of this however, occurs when odours are linked with experiences. For example, a lemon odour may be identified as smelling like spring, cleanliness or even washing-up liquid. As discussed in section 1.22, this is the evaluative dimension of odour processing (Van Toller *et al.* 1993) and in effect causes a reverse genericide where consumers identify the odour by the product.

The implications of this occur if consumers come to define an odour only in terms of a particular product, leading to confusion if that odour is applied by other producers to goods or services in different competitive markets.

5.32 Functionality

A trademark is functional when it increases the relative demand for its attendant product or service. Demand may be influenced when the trademark is desirable in its own right, either because it affects the utility or the aesthetic appeal of the product or service.

Some odours may be demanded by consumers, not because they make the product more aesthetically pleasing, but because they allow the product to achieve its purposes better. For example, if a particular odour was noxious to rodents, it would be unfair to allow a company marketing rodent repellents to have trademark rights for this odour. It is not always clear however, when odours affect utility, or whether it is something of which consumers are consciously aware.

Research has shown that certain odours may produce subconscious physiological affects; apple-spice may be relaxing, while peppermint increases attentiveness. This would mean complications with regard to the competitive consequences if trademark protection were allowed for the apple-spice odour of a blanket, or the peppermint aroma of a pen. If the research about these odours is verified, such protection would raise inappropriate barriers to competition. The blanket company would now have the most restful product on the market and the pen manufacturer would be selling the most productive pen.

5.33 Depletion

Colours and sounds (i.e. combinations of sounds such as the NBC chimes) have been registered for services, and the debate has questioned how many single visual or auditory cues may be distinguished by purchasers in the marketplace. Studies show that the average observer can distinguish approximately 125 colours, but believe this number is substantially less under marketplace conditions and may be as low as eight (Cooper 1948). For odours, although individual abilities differ greatly, studies show that there may be as many as 10 thousand which are individually distinguishable (Benderley 1988). Hence, it would appear that depletion is unlikely to be a concern for odours, although the number which might be distinguishable under purchasing conditions will be substantially lower.

5.34 Product categories

Three main categories have been identified with regard to the protection of product fragrances. One group includes perfume odours where the feature to be protected is the primary or sole motivation for purchase. Another set of products includes those in which odour is just one of possibly several important reasons for purchase, for example laundry detergents. It is believed that such detergents are purchased as much for their scent as their ability to clean (Burgunder 1991). The final category of products are those in which scent is a factor for purchase, but one that is very minor. For example a screwdriver which may be marketed with a particular unnatural scent. This is a case of 'aesthetic functionality', the feature is not an important aspect of the purchase decision.

There are, therefore, a number of unresolved issues stemming from genericism and depletion, and in the light of research demonstrating the effects of odour on human behaviour, functionality is also an important issue. The implications of these legal developments for this research are unknown. The odour in this case, however, may be classed as part of the ambience of a restaurant and the odours present would be generic to the products being served.

5.4 The application of olfactory cues in the retail industry

The use of odour as a marketing technique has been adopted by a number of retailers in the USA. Some non-food examples include Disney, The Knot Shop and Its Really One Dollar. Seafirst Bank, Seattle is also planning to use the technique; one idea being, to scent the money in its Automatic Transaction Machines (ATM's) by applying a mint odour to the money so that it will 'seem fresher' than money from *other* ATM's (Miller 1993).

In the food industry, Melmarkets Inc., a small chain of 16 supermarkets claim their customers buy twice as many groceries as the typical supermarket customer. The stores give the customer the feeling that the establishment is redolent of good food, with the odour of roasted chickens from the delicatessen and freshly baked bread from the on-site bakery, present in the store (Schifrin 1992).

In the United Kingdom, the supermarket chain Sainsbury's adopted this marketing method approximately five years ago when they pumped the odour of freshly baked bread from the bakery, through the air conditioning to the front of the stores. This procedure, however, is no longer used by Sainsbury's as they believed it to be an 'unfair' marketing method which was unnecessary (Abrahams 1994). More recently, Del Monte have used this marketing technique to promote a new drinks range called Batik. An advertisement for the 'Citrus Twist' variety was placed at a London bus stop with an infra-red sensor attached to the ceiling. On entering the shelter, the sensor was activated releasing a fine, scented haze of the lemon odour generic to the drink. When interviewed about the odour, however, many shoppers claimed to have either not noticed it at all or described it as very unpleasant (Young 1996).

These comments indicate that the context in which the stimulus was presented, led to the odour being perceived as unpleasant, as it is likely that if asked to rate the odour of the drink in its appropriate context, the hedonic rating would be much higher.

5.5 Recommendations for further research

The findings from the investigation show that exposure to food odours influenced eating behaviour and dietary patterns. The results also suggest that this may be a subliminal or subthreshold effect rather than a conscious awareness of the stimulus in the environment. This investigation could not confirm this subliminal effect, however, as by questioning the assessors about the odour stimuli would have introduced bias. Further research, therefore, would include experiments to determine the psychological effects of odour exposure which have been suggested by these results.

The investigation concentrated on the effects of food odours on hunger and dietary behaviour. Recommendations for further research would include the effects of non-food odours, particularly in relation to the modification and suppression of food intake. This may involve odours such as cleaning materials (disinfectant, antiseptics, etc.) or other medicinal odours that are believed to be one of the factors contributing to the suppression of food intake for hospital patients (Maller *et al.* 1980). Similarly, the effects of pleasant non-food stimuli, such as floral odours (as used by Hirsch 1996), on food choice and acceptability may be studied.

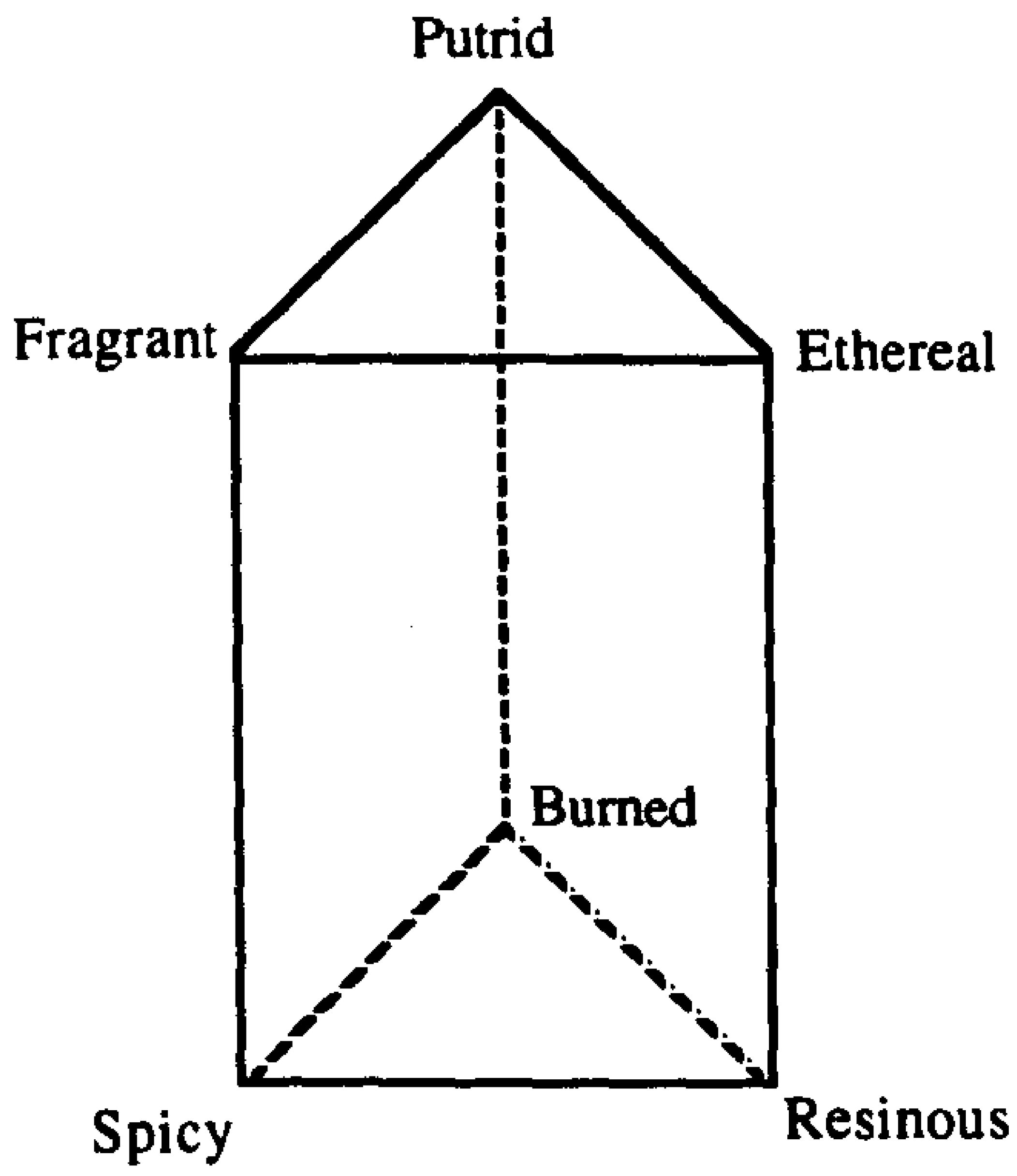
The findings from this investigation indicate that olfactory cues play a functional role in food intake and dietary behaviour. An extension of this study may be to investigate the implications of olfactory deficits for eating behaviour. Significant olfactory deficiencies have been found in both anorexics and patients suffering from schizophrenia, and these findings, along with other information, indicate the involvement of the olfactory system with psychiatric disorders (Kopala *et al.* 1994). Further research would aim to establish links between the role of olfactory cues in food intake and the effects on such psychiatric disorders.

Appendices

List of appendices

Appendix 1

Smell prism devised by Henning (1916)



Source: Matlin and Foley (1992)

Appendix 2

Primary odours suggested by Amoore (1970)

Odour	*Chemical Example*	*Familiar Substance*
Camphoraceous	Camphor	Moth Repellent
Musky	Muskone	Musk Oil
Floral	Geraniol	Roses
Peppermint	Menthone	Mint Sweets
Ethereal	Dichloroethene	Dry-cleaning Fluid
Pungent	Ethanoic Acid (Acetic Acid)	Vinegar
Putrid	Butylmercaptan	Skunk Odour

Source: Matlin and Foley (1992)

Appendix 3

Food preference questionnaire

Name ______________________________ *Ext. No.* __________

Please indicate your liking/disliking for each of the foods listed by placing a mark on the appropriate point of the scale below :

Chicken

Dislike Extremely ______________________________ *Like Extremely*

Pork sausages

Dislike Extremely ______________________________ *Like Extremely*

Pork

Dislike Extremely ______________________________ *Like Extremely*

Smoked back bacon

Dislike Extremely ______________________________ *Like Extremely*

Turkey

Dislike Extremely ______________________________ *Like Extremely*

White cabbage

Dislike Extremely ______________________________ *Like Extremely*

Brussels sprouts

Dislike Extremely ______________________________ *Like Extremely*

Carrots

Dislike Extremely ______________________________ *Like Extremely*

Sweetcorn

Dislike Extremely ____ *Like Extremely*

Mature Cheddar cheese (melted)

Dislike Extremely ____ *Like Extremely*

Fish (cod, haddock, etc.)

Dislike Extremely ____ *Like Extremely*

Orange juice

Dislike Extremely ____ *Like Extremely*

Coffee

Dislike Extremely ____ *Like Extremely*

Milk

Dislike Extremely ____ *Like Extremely*

White bread

Dislike Extremely ____ *Like Extremely*

Appendix 4

Odour ratings

Name ______________________________ ***Date*** ___________

Please indicate the pleasantness of the following odours by placing a mark on the appropriate point of the scale below.

657

Like Extremely ____ *Dislike Extremely*

891

Like Extremely ____ *Dislike Extremely*

254

Like Extremely ____ *Dislike Extremely*

975

Like Extremely ____ *Dislike Extremely*

Appendix 5

The sensory laboratory

The sensory laboratory, used throughout this investigation, consists of nine white individual booths with draughtsman's chairs. The design and layout of the laboratory ensures the assessors are isolated both from each other, and any outside influences, during experiments. Each booth is equipped with a set of coloured lights (red, blue, green and white), a computer monitor and keyboard. For the purpose of this investigation only the white light was used. The coloured lights and computer system did not form part of any of the experiments. The laboratory has positive air pressure, a neutral, clean decor, and is maintained at 20-21°C. External noise is minimised to avoid distractions.

Appendix 6

Breakfast questionnaire

Name ________________________ ***Date*** ______________

Did you have breakfast this morning ?

Yes	No

If yes, please indicate the time at which you ate :

06.30 - 07.00	07.00 - 07.30	07.30 - 08.00	08.00 - 08.30	08.30 - 09.00

What did you eat/drink and how much?

For Example : *Two slices of white toast with butter and jam. One cup of coffee.*

Appendix 7

Eating habits survey

Name ________________________ ***Date*** ______________

1. On an average weekday, would you normally drink tea/coffee during the morning at work ?

Yes	No

If yes, please indicate the time(s) you would normally drink at :

09.30 - 10.00	10.00 - 10.30	10.30 - 11.00	11.00 - 11.30	11.30 - 12.00	12.30 - 13.00

2. On an average weekday, would you normally eat a snack during the morning at work ?

Yes	No

If yes, please indicate the time(s) you would normally eat at :

09.30 - 10.00	10.00 - 10.30	10.30 - 11.00	11.00 - 11.30	11.30 - 12.00	12.30 - 13.00

What would you normally eat as a snack ?

____

____

3. On an average weekday at work, what time would you normally eat lunch ?

11.30 - 12.00	12.00 - 12.30	12.30 - 13.00	13.00 - 13.30	13.30 - 14.00	After 14.00

What would you normally eat ? (eg. Sandwiches, cooked meal, etc.)

____

____

Appendix 8

In addition to the parametric tests conducted on the hunger perception data, as a control measure, non-parametric tests were also applied. The responses from experiments one and two (section 2.2) were converted to ranks, and the Mann Whitney U - Wilcoxon rank sum W test was used to analyse the results.

Test Condition	n	Mean Rank	Sum of Ranks	U	W	Z	2-Tailed P
Neutral odour	20	16.3	326.0	116.0	326.0	-2.2738	**.0230**
Bacon odour	20	24.7	494.0				

Table 29 Mann Whitney U - Wilcoxon rank sum W test for exposure to the neutral odour stimulus and the bacon odour stimulus in experiment one.

Test Condition	n	Mean Rank	Sum of Ranks	U	W	Z	2-Tailed P
Neutral odour	20	22.75	455.0	155.0	365.0	-1.2191	.2228
Cabbage odour	20	18.25	365.0				

Table 30 Mann Whitney U - Wilcoxon rank sum W test for exposure to the neutral odour stimulus and the cabbage odour stimulus in experiment two.

As for the parametric analysis, exposure to the bacon odour caused a significant increase in hunger levels (p<0.05), whilst exposure to the cabbage odour had no significant effect (p>0.05).

Appendix 9

Food preference questionnaire

Name ______________________________ *Ext. No.* __________

Please indicate your liking/disliking for each of the foods listed by placing a mark on the appropriate point of the scale below :

Chicken

Dislike Extremely ____ *Like Extremely*

Pork sausages

Dislike Extremely ____ *Like Extremely*

Jacket Potato (Baked in the skin)

Dislike Extremely ____ *Like Extremely*

Smoked back bacon

Dislike Extremely ____ *Like Extremely*

Salad (tomato, lettuce, cucumber, etc.)

Dislike Extremely ____ *Like Extremely*

Beefburgers

Dislike Extremely ____ *Like Extremely*

French bread

Dislike Extremely ____ *Like Extremely*

Fish (cod, haddock, etc.)

Dislike Extremely ____ *Like Extremely*

Appendix 10

Lunch order form

Name ________________________________ ***Date*** ___________

Lunch will be served in the Thomas Hardy Restaurant at 12.45pm. You will be able to help yourself to jacket potato and salad with a choice of ***one*** of the following meats.

Please indicate below the type of meat you would like and the amount (ie. number of sausages *or* rashers of bacon, etc.).

Type of Meat **(Select One)**	Bacon	Sausage	Beefburger
Amount			

Appendix 11

The Thomas Hardy restaurant

The University training restaurant consists of two sections, one serving a full Table d'hote menu, seating up to 70 covers; the other serving a 'grill room' style menu seating up to thirty covers. For the purpose of experiments 2.31, 2.32 and 2.4, the grill room section (9m x 5m) of the restaurant was used. This was appropriate is it was of the right size for the number of respondents taking part and had an atmosphere conducive to the type of food served in the experiment. For experiment 2.4, which involved the application of the odour exposure into a restaurant environment, the Thomas Hardy Grill Room was also ideal as the layout of the restaurant enabled the odour to be infused into the room unobtrusively.

On the days in which these experiments took place, the restaurant was closed to the general public and was used solely for the purposes of this research.

Appendix 12

Meal satisfaction questionnaire

Name ________________________________ ***Date*** ____________

Please indicate your opinion of the meal by placing a mark on the appropriate point of the scale below, for the following attributes :

Appearance

Dislike Extremely ____ *Like Extremely*

Smell[1]

Dislike Extremely ____ *Like Extremely*

Flavour

Dislike Extremely ____ *Like Extremely*

Texture

Dislike Extremely ____ *Like Extremely*

Overall satisfaction with meal

Extremely Dissatisfied ____ *Extremely Satisfied*

If you have any comments you would like to make about today's lunch please do so in the space provided below :

____

[1] Term used for odour, to simplify understanding for consumer assessors

Appendix 13

Lunch order form

Name ________________________________ *Date* ___________

A buffet lunch will be served in the Thomas Hardy restaurant at 12.45pm. A selection of sandwiches, sausage rolls, cheese and broccoli quiche and chicken drumsticks are available.

Please select the product(s) you would like to eat and indicate the amount on the form below.

Sandwiches	Amount (Brown Bread)	Amount (White Bread)
Cheese		
Ham		
Salad		
Tuna		

	Amount
Sausage Rolls	
Quiche (Cheese & Broccoli)	No. of slices
Chicken Drumsticks	

Appendix 14

Questionnaire to establish assessors usual liking for the puddings to be served in experiment 2.4.

Food preference questionnaire

Name _______________________________ ***Date*** ___________

Please indicate your liking *in general* for both Apple pie and Chocolate sponge pudding using the following scale:

Apple Pie

Dislike Extremely ____ *Like Extremely*

Chocolate Sponge

Dislike Extremely ____ *Like Extremely*

Appendix 15

Meal satisfaction questionnaire

Please indicate in the space below which pudding you selected today (if any).

____

Please indicate your opinion of the *Pudding* by placing a mark on the appropriate point of the scale below, for the following attributes :

Appearance

Dislike Extremely	____	*Like Extremely*

Smell[1]

Dislike Extremely	____	*Like Extremely*

Flavour

Dislike Extremely	____	*Like Extremely*

Texture

Dislike Extremely	____	*Like Extremely*

Overall satisfaction with pudding

Extremely Dissatisfied	____	*Extremely Satisfied*

Please explain in the space below why you chose the pudding you had today and make any other comments you feel may be relevant.

____

____

[1] Term used for odour, to simplify understanding for consumer assessors

Appendix 16

Experimental Data

Data from Experment 2.14

(Bacon odour/Bacon Food/Cabbage Odour/Cabbage Food/Sausage Odour/Sausage Food)

	bacod	bacfood	cabod	cabfood	sausod	sausfood	cheeod	cheefood
1	7.60	10.00	2.00	8.00	6.10	7.00	3.00	8.00
2	8.00	9.00	.00	7.70	5.50	10.00	3.90	7.00
3	7.90	9.90	1.10	8.90	5.60	10.00	4.00	8.90
4	7.90	8.90	1.40	7.00	5.10	9.90	5.50	8.00
5	8.80	8.80	4.30	9.00	5.50	8.00	4.10	7.60
6	8.90	10.00	.00	10.00	5.30	8.80	4.70	7.00
7	7.60	7.90	.00	9.70	7.10	7.00	6.00	7.70
8	8.90	8.80	2.20	10.00	6.20	8.60	6.60	10.00
9	9.70	9.00	2.10	7.60	6.60	9.50	4.10	8.70
10	10.00	8.80	3.00	9.00	7.90	10.00	4.20	7.50
11	9.70	10.00	2.30	8.60	7.20	9.90	3.80	9.00
12	9.90	10.00	1.00	8.50	5.10	8.00	6.00	9.00
13	8.60	8.70	1.90	8.80	5.00	9.00	6.10	10.00
14	8.80	8.80	1.10	9.00	6.00	9.10	5.00	7.80
15	8.90	9.10	.00	9.60	6.20	9.80	4.60	7.00
16	10.00	9.70	2.00	9.90	8.10	7.90	3.00	7.90
17	7.70	7.90	2.90	8.20	5.90	8.00	4.40	7.70
18	6.80	8.00	.00	7.60	6.90	9.00	5.00	9.00
19	9.30	8.00	.00	8.40	5.10	9.80	7.00	8.10
20	10.00	10.00	1.70	7.60	6.20	10.00	5.40	7.00

Data from Experiment 2.23

	Test1	Test2	Test3	Test4	Test5	Test6	Bacon	Cabbage
1	0.00	0.50	0.00	0.00	0.00	0.00	1.40	0.30
2	0.40	0.70	0.70	0.70	0.90	0.70	1.50	0.30
3	1.20	0.00	0.00	0.20	0.20	0.10	1.50	0.00
4	3.10	3.00	4.10	3.10	2.70	3.20	3.40	0.10
5	0.00	0.00	0.10	0.00	0.00	0.00	2.30	1.90
6	0.00	0.00	1.40	0.80	0.50	2.20	2.40	0.40
7	1.00	1.00	0.80	1.70	0.70	1.20	1.60	1.10
8	3.70	4.20	3.20	2.40	4.60	5.10	4.30	0.00
9	3.20	3.20	6.70	3.50	3.40	3.40	3.80	0.20
10	0.50	0.50	1.50	0.40	0.40	0.40	2.80	3.20
11	2.20	2.20	2.90	4.20	3.50	3.80	6.70	1.10
12	1.50	1.50	3.00	2.10	2.20	3.80	2.90	1.90
13	6.30	6.80	8.40	7.40	7.50	9.70	7.10	0.40
14	5.60	5.60	6.70	6.70	4.10	3.90	6.30	1.00
15	0.80	4.80	3.30	1.60	1.70	2.20	3.10	3.70
16	3.40	6.30	1.90	4.80	4.10	4.90	7.00	4.80
17	1.30	1.80	6.60	3.20	6.00	3.90	3.80	3.60
18	7.80	7.20	9.50	10.00	9.90	9.90	8.40	2.70
19	6.80	7.00	8.40	4.00	4.70	5.70	8.50	2.00
20	4.00	3.30	7.00	3.10	3.40	2.50	6.30	3.70

Data from Experiment 2.24, 2.25, 2.26 and 2.27

	neutral1	bacon	neutral2	cabbage	neutral3	bsprouts
1	1.20	.20	1.20	2.20	2.20	.20
2	3.70	4.40	3.70	3.40	3.90	3.50
3	6.30	8.50	6.30	9.20	6.20	6.80
4	7.80	10.00	7.80	10.00	9.30	9.00
5	.00	2.20	.00	.00	2.70	1.50
6	.70	5.20	.70	.00	2.60	3.20
7	1.50	7.00	1.50	1.60	2.90	3.90
8	5.00	10.00	5.00	10.00	4.40	4.50
9	.40	.40	2.20	2.80	.00	.20
10	.50	.50	3.00	3.50	1.10	1.10
11	1.70	1.70	4.50	3.30	1.10	1.00
12	2.20	2.20	5.60	4.60	5.50	5.50
13	.90	2.40	.20	.20	1.30	.40
14	1.30	3.80	1.50	.20	1.10	1.00
15	2.10	4.60	1.70	1.00	4.20	3.70
16	4.70	5.20	7.30	.50	4.90	4.10
17	2.20	6.90	1.70	.10	.20	.00
18	3.00	6.50	1.20	2.20	1.10	1.00
19	4.50	8.10	8.10	5.90	2.80	2.80
20	5.60	8.60	9.90	10.00	5.80	4.00
21	.	.	.	.	.	.
22	.	.	.	.	.	.
23	.	.	.	.	.	.
24	.	.	.	.	.	.
25	.	.	.	.	.	.
26	.	.	.	.	.	.
27	.	.	.	.	.	.
28	.	.	.	.	.	.
29	.	.	.	.	.	.
30	.	.	.	.	.	.
31	.	.	.	.	.	.
32	.	.	.	.	.	.

Data from Experiment 2.31 (Consumption)

(Control group - meat consumption 1st serving/2nd serving/total)
(Experimental group - meat consumption 1st serving/2nd serving/total)

	c.meat1	c.meat2	c.total	e.meat1	e.meat2	e.total
1	25.00	30.00	55.00	20.00	15.00	35.00
2	.00	10.00	10.00	5.00	30.00	35.00
3	20.00	10.00	30.00	20.00	60.00	80.00
4	30.00	60.00	90.00	5.00	40.00	45.00
5	5.00	30.00	35.00	.00	10.00	10.00
6	20.00	20.00	40.00	.00	60.00	60.00
7	20.00	40.00	60.00	.00	40.00	40.00
8	.00	60.00	60.00	.00	10.00	10.00
9	.00	30.00	30.00	10.00	25.00	35.00
10	.00	25.00	25.00	.00	20.00	20.00
11	.00	30.00	30.00	.00	5.00	5.00
12	.00	40.00	40.00	.00	20.00	20.00
13	.00	60.00	60.00	.00	80.00	80.00
14	.00	30.00	30.00	5.00	60.00	65.00
15	.00	30.00	30.00	5.00	60.00	65.00
16	30.00	15.00	45.00	30.00	40.00	70.00
17	5.00	10.00	15.00	.00	60.00	60.00
18	.00	10.00	10.00	5.00	60.00	65.00
19	.00	15.00	15.00	.00	80.00	80.00
20	5.00	60.00	65.00	55.00	15.00	70.00
21	.00	60.00	60.00	50.00	90.00	140.00
22	.00	10.00	10.00	20.00	120.00	140.00
23	.00	60.00	60.00	.00	90.00	90.00
24	.00	60.00	60.00	30.00	30.00	60.00
25	30.00	10.00	40.00	.00	60.00	60.00
26	30.00	30.00	60.00	.00	90.00	90.00
27	5.00	60.00	65.00	.00	30.00	30.00
28	.	.	.	.	.	.
29	.	.	.	.	.	.
30	.	.	.	.	.	.
31	.	.	.	.	.	.
32	.	.	.	.	.	.

Data from Experiment 2.31 (Acceptability)

(group 1 = Control group/group2 = Experimental group)

	appearan	smel	flavour	texture	overal	total	average	group
1	9.20	7.30	7.40	3.30	5.00	32.20	6.44	1.00
2	8.10	7.70	7.50	5.10	8.00	36.40	7.28	1.00
3	6.40	7.00	8.60	8.10	7.70	37.80	7.56	1.00
4	5.40	4.90	9.80	8.30	7.00	35.40	7.08	1.00
5	5.70	7.00	7.80	8.60	7.10	36.20	7.24	1.00
6	5.60	6.60	8.10	8.20	8.60	37.10	7.42	1.00
7	6.60	7.40	6.80	6.90	8.10	35.80	7.16	1.00
8	6.50	6.90	6.80	6.40	5.80	32.40	6.48	1.00
9	6.90	8.80	8.20	7.20	9.00	40.10	8.02	1.00
10	8.40	8.50	7.00	5.70	4.20	33.80	6.76	1.00
11	9.30	8.70	5.50	8.20	4.60	36.30	7.26	1.00
12	6.20	8.40	7.40	3.90	6.10	32.00	6.40	1.00
13	7.80	9.00	9.50	9.50	9.00	44.80	8.96	1.00
14	9.20	9.30	9.30	9.20	9.20	46.20	9.24	1.00
15	5.60	3.30	7.70	8.10	6.80	31.50	6.30	1.00
16	7.20	6.50	7.00	9.00	8.40	38.10	7.62	1.00
17	6.50	3.80	7.20	7.30	7.50	32.30	6.46	1.00
18	7.50	4.80	8.20	8.30	8.30	37.10	7.42	1.00
19	6.70	5.00	6.00	6.50	5.50	30.70	6.14	1.00
20	6.00	4.30	6.00	6.90	5.80	29.00	5.80	1.00
21	3.30	7.00	8.30	8.30	8.80	35.70	7.14	1.00
22	7.30	4.60	5.60	7.00	6.60	31.10	6.22	1.00
23	5.50	4.80	6.20	6.50	6.60	29.60	5.92	1.00
24	7.10	8.10	7.90	6.10	8.10	37.30	7.46	1.00
25	6.70	7.00	7.10	7.10	7.30	35.20	7.04	1.00
26	2.70	3.20	3.30	5.00	1.60	11.30	2.26	1.00
27	5.80	6.40	7.30	7.30	7.40	34.20	6.84	1.00
28	5.10	5.30	8.00	7.60	5.00	31.00	6.20	2.00
29	4.20	4.70	6.00	4.30	4.90	24.10	4.82	2.00
30	6.20	5.80	6.20	6.00	5.60	29.80	5.96	2.00
31	6.10	5.40	5.40	5.40	6.10	28.40	5.68	2.00
32	1.70	2.00	4.20	5.90	5.00	18.80	3.76	2.00
33	7.50	8.90	9.10	9.00	8.80	43.30	8.66	2.00
34	4.20	3.50	5.40	3.20	4.70	21.00	4.20	2.00
35	7.20	6.80	9.00	8.50	7.70	39.20	7.84	2.00
36	6.90	7.00	8.70	8.70	8.70	40.00	8.00	2.00
37	5.60	5.00	5.10	5.70	4.30	25.70	5.14	2.00
38	7.50	7.30	7.40	7.40	7.40	37.00	7.40	2.00
39	9.30	9.20	6.50	5.10	8.60	38.70	7.74	2.00
40	5.10	6.00	6.70	6.60	5.50	29.90	5.98	2.00
41	6.20	6.20	9.10	9.20	8.70	39.40	7.88	2.00
42	9.00	8.90	8.20	7.50	9.00	42.60	8.52	2.00
43	6.70	7.90	8.50	4.90	7.40	35.40	7.08	2.00
44	5.20	7.50	8.50	6.90	6.20	34.30	6.86	2.00
45	6.90	8.40	7.30	6.40	7.40	36.40	7.28	2.00
46	5.50	5.60	5.40	5.60	5.70	27.80	5.56	2.00
47	5.40	5.90	6.00	4.20	5.10	26.60	5.32	2.00
48	4.10	5.90	3.30	3.20	4.40	20.90	4.18	2.00
49	5.10	5.20	5.20	5.10	5.10	25.70	5.14	2.00
50	5.40	6.30	6.30	5.80	6.10	28.50	5.70	2.00
51	5.40	8.10	8.10	6.90	7.50	35.60	7.12	2.00
52	7.00	7.30	7.30	6.30	6.90	35.00	7.00	2.00
53	5.10	2.50	2.50	5.10	2.60	30.50	4.10	2.00
54	5.00	6.40	6.40	6.20	6.40	29.30	5.86	2.00

Data from Experiment 2.32

(Control group consumption/Experimental group consumption (in grams)

	c.total	e.total
1	316.00	760.00
2	320.00	298.00
3	305.00	284.00
4	356.00	435.00
5	620.00	674.00
6	834.00	632.00
7	183.00	361.00
8	478.00	408.00
9	326.00	310.00
10	540.00	388.00
11	513.00	325.00
12	194.00	144.00
13	988.00	260.00
14	958.00	478.00
15	376.00	484.00
16	464.00	712.00
17	447.00	139.00
18	184.00	417.00
19	302.00	171.00
20	296.00	335.00
21	416.00	980.00
22	374.00	573.00

Data from Experiment 2.32 (Acceptability)

(c = Control group/e = Experimental group)

	c.appear	c.odour	c.flavou	c.text	c.overal	e.appear	e.odour	e.flavou	e.textur	e.overal
1	6.20	4.90	5.80	2.30	3.90	7.80	6.00	7.20	6.70	7.10
2	2.90	4.20	3.20	2.30	2.70	3.40	4.90	3.20	2.70	3.30
3	6.10	5.10	5.60	4.60	5.20	8.10	5.30	7.90	8.20	7.00
4	6.05	5.35	6.00	4.70	5.80	5.50	4.10	5.90	3.30	3.50
5	3.80	4.40	9.10	9.00	9.40	5.10	6.40	6.70	6.70	5.90
6	6.60	4.30	3.10	2.90	4.30	5.00	5.00	6.20	3.50	6.20
7	6.70	6.90	8.10	8.70	7.80	2.90	4.60	4.30	5.40	4.20
8	6.20	4.30	3.00	1.40	4.50	5.00	5.10	6.40	7.20	5.80
9	10.00	10.00	10.00	10.00	10.00	8.60	1.90	7.00	7.70	7.60
10	7.30	7.60	8.80	9.10	8.90	7.50	4.90	6.70	6.90	7.60
11	4.88	4.30	6.70	5.97	6.80	9.60	5.00	8.60	8.50	8.60
12	7.40	5.70	8.50	8.30	8.40	8.50	5.10	7.50	7.30	8.60
13	6.50	5.00	8.50	8.80	8.90	7.70	5.00	7.40	7.70	7.70
14	5.50	.	7.10	7.00	8.00	10.00	.00	9.90	9.80	9.70
15	5.40	5.10	7.00	6.90	7.80	9.00	9.00	8.90	8.80	8.60
16	8.40	8.50	6.50	4.90	7.90	4.50	4.50	3.70	5.40	3.70
17	7.70	7.80	4.10	7.10	7.50	6.60	2.70	4.20	6.90	5.00
18	7.20	5.50	6.20	7.80	7.00	3.20	7.70	7.70	5.70	4.40
19	6.10	4.80	7.00	5.90	6.30	2.80	4.20	4.20	3.10	8.00
20	8.60	7.40	8.70	8.60	6.20	2.70	4.90	1.70	.60	2.70
21	6.80	4.70	4.40	6.50	6.10	8.40	8.50	7.50	7.50	8.10
22	7.10	7.30	7.10	7.10	6.90	8.30	4.90	6.50	6.50	7.30
23	.	.	.	.	.	.	.	.	.	.
24	.	.	.	.	.	.	.	.	.	.

Data from Experiment 2.4

(Assessors usual liking for apple pie and chocolate sponge - control and experimental groups)

	apple.co	choc.con	apple.ex	choc.exp
1	9.70	9.40	7.60	6.00
2	8.40	8.40	7.30	4.80
3	8.20	8.50	9.45	6.45
4	9.40	9.40	7.40	7.25
5	8.20	7.50	6.30	4.00
6	6.40	5.45	4.70	3.70
7	8.90	7.80	7.50	5.90
8	9.90	10.00	8.00	6.60
9	9.50	7.00	7.95	6.40
10	6.40	5.30	6.40	7.30
11	8.90	8.80	6.20	5.20
12	8.90	6.50	9.70	9.40
13	9.00	8.90	9.70	9.70
14	7.90	7.40	6.80	4.20
15	6.00	4.40	7.70	4.20
16	7.80	6.60	8.00	4.65
17	9.80	9.80	8.40	7.30
18	7.50	5.00	4.50	2.30
19	6.40	4.90	10.00	7.80
20	8.90	8.60	6.00	4.80
21	8.00	6.40	6.45	8.00
22	7.80	6.20	6.60	8.00
23	5.40	3.50	8.55	8.00
24	8.40	6.00	8.90	9.00
25	6.20	4.50	8.60	8.60
26	9.10	8.50	5.60	7.90
27	8.40	6.90	8.10	8.40
28	5.30	3.20	5.30	6.60
29	7.70	6.40	6.60	6.90
30	6.00	5.80	7.20	8.60
31	8.30	8.60	6.50	7.60
32	6.90	7.85	4.75	4.70
33	5.40	7.40	6.30	8.15
34	9.05	8.20	7.70	6.15
35	5.75	8.40	6.15	8.80
36	5.30	5.40	8.50	8.50
37	7.00	8.40	5.70	7.15
38	7.60	8.90	4.90	6.80
39	8.70	7.90	6.80	6.70
40	3.50	7.30	5.20	7.50
41	6.70	5.40	6.20	6.30
42	6.00	6.20	5.85	7.85
43	3.60	4.00	5.10	6.10
44	7.00	7.90	8.55	6.60
45	7.20	5.90	6.20	7.90
46	3.70	3.75	7.00	9.00
47	9.30	9.40	6.00	8.40
48	8.25	8.40	7.20	9.10
49	4.70	7.70	9.20	8.15
50	7.05	8.80	7.50	9.70
51	2.50	5.00	9.10	9.70
52	8.80	7.50	4.70	6.30
53	6.50	6.90	8.00	6.70
54	.	.	.	.
55	.	.	.	.
56	.	.	.	.
57	.	.	.	.
58	.	.	.	.
59	.	.	.	.
60	.	.	.	.
61	.	.	.	.
62	.	.	.	.
63	.	.	.	.
64	.	.	.	.

Data from Experiment 2.4 (Acceptability for Chocolate Sponge)

(e = Experimental group/c = Control group)

	e.appear	e.odour	e.flavou	e.textur	e.overal	c.appear	c.odour	c.flavou	c.textur	c.overal
1	10.00	10.00	10.00	7.60	10.00	6.20	6.80	7.80	7.50	7.70
2	4.85	10.00	10.00	7.50	10.00	5.00	6.25	8.05	8.00	9.00
3	8.30	9.10	9.10	9.10	9.00	6.60	6.85	6.85	6.85	8.80
4	9.55	9.45	9.40	9.45	9.45	4.90	5.00	8.20	7.90	6.70
5	5.40	6.50	7.00	7.00	7.00	5.70	5.10	5.20	4.20	5.10
6	8.90	9.30	7.50	8.80	8.50	6.50	6.50	6.50	2.30	6.30
7	3.55	8.20	7.60	7.50	7.10	4.50	3.20	4.80	2.20	2.90
8	6.40	7.00	7.15	7.70	7.80	5.90	8.40	5.80	2.70	3.90
9	6.50	6.60	5.30	5.05	5.75	6.10	5.20	2.60	7.50	2.10
10	6.50	8.95	8.00	8.00	8.00	6.10	7.30	4.10	3.30	4.10
11	6.60	9.20	9.20	8.90	8.70	1.70	8.80	3.30	2.60	3.90
12	4.50	7.10	4.40	1.50	4.40	3.10	2.70	1.80	1.30	.30
13	1.50	8.60	8.55	8.50	7.30	4.60	4.90	5.40	4.00	7.80
14	6.35	4.30	5.40	5.45	5.05	2.25	4.80	9.90	4.80	4.30
15	3.70	7.50	7.75	9.15	8.10	7.40	6.30	2.20	2.90	1.25
16	7.10	8.30	8.20	8.30	8.20	3.90	5.10	6.30	5.90	4.80
17	4.30	6.30	7.55	6.80	7.55	5.20	5.20	6.90	7.00	7.00
18	7.35	7.80	6.60	7.80	7.00	8.70	7.00	5.90	6.80	7.20
19	7.40	8.00	7.70	4.50	7.60	5.90	5.80	6.50	6.60	5.90
20	6.10	7.40	7.90	8.00	7.80	5.20	3.80	5.10	6.40	4.10
21	9.15	9.70	9.70	9.70	9.50	6.50	8.50	7.20	8.50	9.30
22	9.10	9.10	9.30	9.35	9.10	.	.	.	.	.
23	5.30	7.90	4.20	4.10	4.70	.	.	.	.	.
24	7.95	7.80	7.50	9.05	7.95	.	.	.	.	.
25	9.00	9.20	9.20	8.90	9.40	.	.	.	.	.
26	7.50	7.50	7.00	7.50	7.70	.	.	.	.	.
27	5.50	5.50	7.50	9.40	7.90	.	.	.	.	.
28	4.60	9.20	6.45	2.70	5.30	.	.	.	.	.
29	8.25	5.80	8.80	7.15	8.40	.	.	.	.	.
30	7.20	9.90	9.80	9.50	9.45	.	.	.	.	.
31	5.00	6.15	7.45	3.60	7.80	.	.	.	.	.
32	7.90	7.25	8.40	8.10	8.15	.	.	.	.	.
33	7.00	8.15	9.00	8.40	9.10	.	.			

Data from Experiment 2.4 (Acceptability for Apple Pie)

(e = Experimental group/c = Control group)

	e.appear	e.odour	e.flavou	e.textur	e.overal	c.appear	c.odour	c.flavou	c.textur	c.overal
1	8.60	6.40	8.40	9.00	9.00	7.85	7.85	8.90	5.10	8.10
2	6.90	7.45	6.10	7.75	6.70	7.50	7.65	7.50	8.00	8.00
3	9.40	8.90	8.85	9.00	9.15	6.50	6.80	5.70	5.90	6.75
4	7.15	4.60	4.80	5.80	6.55	7.80	7.90	6.60	5.80	6.50
5	9.10	9.35	9.30	9.50	9.40	9.30	9.00	8.00	9.25	8.80
6	7.20	7.20	8.10	7.95	7.80	8.60	9.40	9.50	9.80	9.30
7	4.10	5.55	7.50	7.45	5.30	9.70	9.80	9.80	9.80	10.00
8	8.00	5.60	8.60	8.35	8.90	10.00	10.00	10.00	10.00	10.00
9	4.00	4.45	4.50	6.90	6.15	8.30	8.00	9.00	9.20	9.20
10	7.35	8.75	7.85	7.85	8.00	8.80	8.70	9.40	8.70	9.40
11	9.35	9.45	7.40	7.40	9.35	9.20	8.30	5.60	5.20	7.20
12	10.00	9.80	9.40	9.40	9.50	8.40	8.40	6.80	6.85	7.00
13	8.10	8.80	9.00	9.00	9.30	8.20	8.00	9.20	9.60	9.50
14	8.30	4.60	7.90	7.90	7.80	8.40	8.30	8.60	8.70	9.50
15	8.30	4.20	5.10	5.10	7.60	7.50	7.40	7.45	6.70	7.85
16	7.40	7.60	7.70	7.70	4.50	9.50	8.20	9.50	9.40	9.40
17	6.75	6.70	6.80	6.80	8.40	9.30	7.70	9.60	9.50	9.50
18	4.30	6.30	6.40	6.40	5.50	8.10	8.10	1.60	1.50	1.70
19	10.00	7.60	10.00	10.00	10.00	4.20	6.80	2.40	3.30	2.30
20	5.60	4.50	6.90	6.90	6.70	2.10	.00	5.70	1.90	4.70
21	.	.	.	.	.	1.85	10.00	10.00	1.50	6.90
22	.	.	.	.	.	8.20	6.90	9.20	8.50	9.10
23	.	.	.	.	.	6.30	5.50	4.50	1.15	5.05
24	.	.	.	.	.	9.60	9.30	9.40	6.50	8.80
25	.	.	.	.	.	8.50	5.50	8.60	8.80	9.00
26	.	.	.	.	.	9.40	8.40	8.90	9.30	9.50
27	.	.	.	.	.	6.90	7.00	7.00	5.85	6.30
28	.	.	.	.	.	8.20	5.30	8.10	8.90	8.70
29	.	.	.	.	.	8.45	8.10	9.20	8.30	9.00
30	.	.	.	.	.	4.40	4.20	7.00	6.70	6.80
31	.	.	.	.	.	6.80	7.00	8.60	8.70	8.90
32	.	.	.	.	.	7.35	7.25	7.25	4.40	6.20

Glossary of terms

ISO 5098. British Standard Glossary of Terms relating to sensory analysis of food (1975)

Acceptance	An hedonic assessment of adequacy within a specified range
Appearance	The visual attributes
Aroma	An odour with a pleasant connotation. *Not the equivalent of the French term 'arome'
Assessor	Any person taking part in a sensory test
Attribute	A perceived characteristic
Auditory	Pertaining to the sense of hearing
Consumer	A person who purchases or uses a product
Control	An example selected as a reference point
Flavour	The combination of taste and odour. It may be influenced by sensations of pain, heat and cold (eg. spices, horseradish and menthol) and by tactile sensations
Gustatory	Pertaining to the sense of taste
Hedonic	Relating to like or dislike
Odour	1. The sensation perceived via the olfactory organ from certain volatile substances 2. Quality of this particular sensation due to these substances
Olfactory	Pertaining to the sense of smell
Perception	The awareness of the effects of stimuli
Reference point	A selected value against which samples are assessed
Sensory fatigue	Sensory adaptation in which a decrease in sensitivity occurs
Sensory	Relating to the use of the sense organs
Smell	To test for sensation by use of the olfactory organ
Stimulus	That which can excite the receptors of a sense organ
Tactile	Pertaining to texture
Taste	1. The sensation perceived via the taste buds resulting from the presence of certain soluble substances

2. Quality of this particular sensation due to these substances

Texture	Attribute of sample resulting from a combination of physical properties and perceived by the sensed of kinesthesis, touch (including mouthfeel, sight and hearing). The physical properties may include size, shape, number, nature and conformation of constituent structural elements

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