Influences on Consumers' Decision Making and Recognition Memory: An Investigation using fMRI, EEG and Behavioural Methods

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Declaration

I declare that, to the best of my knowledge, no portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university, or other institute of learning.

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Abstract

Neuromarketing utilizes a variety of neuroimaging technologies, such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI), to deeply understand consumers' neurological responses to marketing stimuli. For this research, a behavioural study was first performed based on consumers' preferences for different models of cars, in order to find out whether advertisements presented in different formats will have any influence on this. The obtained results of this behavioural study were unexpected, and there was a difference in the opposite direction to that predicted. The mean value of rating of preference for the plain images was higher than the one of the same car image in a car magazine and fashion magazine. Furthermore, the fashion magazine image had slightly higher preference ratings compared to the car magazine. The strongest predictor in a binary regression was the car model itself, independent of context: thus cars were a heterogeneous product for these consumers even for models within a single car body shape and price band. In the second study, Functional magnetic resonance images (fMRI) were acquired while subjects (n=20) made choices during a stimulated purchase decision experiment, which was designed to assess the effect of brand sales volume and pricing information. The behavioural data indicated that the pricing information of packaged and branded snack products influenced decisions. The increased fMRI activations in left and right insula, frontal pole, putamen, and visual cortex were related to brand sales volume. However, the neural correlates of pricing information did not reach to significant levels of activation in factorial ANOVA of fMRI data. The data were interpreted as showing that the sales volume of products -as aggregate market measure - influences brain areas associated with emotional processing during a purchase decision task. This effect might be based on cultural familiarity or prior exposure to products, or it might be based on feelings about the products or brands induced through social influences including advertising. Therefore, the third experiment was an EEG experiment using an old/new recognition task developed from the fMRI experiment, to test the effect of sales volume of product and pricing information on recognition memory.

The experiment was replicated in two participant groups under encoding conditions of products sales volume alone and with pricing information. The results showed that greater positivity to hits over left frontal electrodes and greater positivity to correct rejections over right frontal electrodes. In addition, smaller FN400 amplitudes to true recognition than false recognition was elicited in both groups. On top of that, a greater positivity for high sales volume items was found in the recognition interval in comparisons of high and low sales volume items in the comparisons of time course and scalp topography. It was concluded that products with higher sales volume elicited a frontal familiarity effect (FN400), but the results were also strongly influenced by the inclusion of flavour variants which acted as "lures" because of similarity of packaging to "old" items. The results confirm the hypothesis that effects on recognition memory are a possible cause of the neural and behavioural correlates of market-aggregate statistics of higher-selling products.

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Abbreviation

μV	Micro voltage
AB	Attitude toward performing the behaviour
ANOVA	Analysis of variance
BA	Brodmann area
BI	Behavioural intention
BOLD	Blood oxygenation level-dependent response
C	Car magazine
CR	Correct rejection
dB	Decibel
DC	Direct current
DLPFC	Dorsolateral prefrontal cortex
EBM	Engel-Blackwell-Miniard model
EEG	Electroencephalogram
ERP	Event-related potentials
F	Fashion magazine
f	Flavours
fMRI	Functional magnetic resonance imaging
FoV	Field of view
FP	False alarm

FWE	Familywise error
FWHM	Full-width half-maximum
GLM	General linear model
GRAPPA	Generalized auto calibrating partially parallel acquisitions
H	Higher sales volume products
h	Hits
HP	Higher sales volume products with original price displayed
HRF	Hemodynamic response function
Hz	Hertz
I	Plain image
iPAT	Integrated parallel acquisition technology
L	Lower sales volume products
LP	Lower sales volume products with discount price displayed
LPN	Late posterior negativity
M	Misses
MEG	Magneto-encephalography
mm	Millimetre
MNI	Montreal Neurological Institute
MPFC	Mesial prefrontal cortex
ms	Milliseconds
MVPA	Multi-voxel pattern analysis
n	Number of samples
NAcc	Nucleus accumbens
NIRS	Near infrared spectroscopy

No_H	“no” response from participants for higher sales volume products
No_HP	“no” response from participants for higher sales volume products with original price displayed
No_L	“no” response from participants for lower sales volume products
No_LP	“no” response from participants for lower sales volume products with discount price displayed
PET	Positron emission tomography
PMM	Probabilistic mental model
R	Decision making rating
ROI	Regions of interest
s	Second
sACC	Subgenual anterior cingulate cortex
SDT	Signal detection theory
SN	Subjective norm related to performing the behaviour
SPM	Statistical parametric mapping
SPSS	Statistical package for the social science
Std	Standard deviation
TE	Echo time
TMS	Transcranial magnetic stimulation
TR	Repetition time
TRA	Theory of reasoned action
Yes_H	“yes” response from participants for higher sales volume products
Yes_HP	“yes” response from participants for higher sales volume products with original price displayed
Yes_L	“yes” response from participants for lower sales volume products

Yes_LP	“yes” response from participants for lower sales volume products with discount price displayed

Nomenclature

c	Criterion value
d’	Measure of memory sensitivity in signal detection theory
df	Degree of freedom
F7	Left frontal
F8	Right frontal
k	Cluster size
p	Probability value
P7	Left parietal
P8	Right parietal
t	Test statistic
W	Empirically derived weights
β	Response bias
η2p	Partial eta-squared effect size

Chapter 1 Introduction

1.1 The background of neuromarketing

Neuroscience and marketing have recently come together in a wide range of studies and have provoked an interest, as well as a desire for knowledge, leading to the birth of a new concept: "Neuromarketing" (Marcel et al., 2009). Nowadays, neuromarketing is defined as an interdisciplinary field that is a combination between marketing and neuroscience, which, it is claimed, would be more beneficial to marketers, business and consumers compared to the employment of a traditional marketing investigation for improvement of sales. It has already been adopted gradually in the field of marketing by marketers who consider that a better and more objective and accurate measurement and observation are provided by neuroimaging. Above all, neuroimaging methods, in many cases, allow us to get closer to understanding what really happens in the consumer's brain in responses to marketing stimuli, and in marketing relevant situations. The goal of neuromarketing is that it is going to help explain and predict consumers' behaviour in order to provide a higher and more precise quality service than it was before for consumer and also develop the markers in the future.

A recent Scopus search (29/03/2017) returned 254 publications with the keyword "neuromarketing" in the title, abstract or keywords, the earliest being 2004 and the latest 2017. Of these, 140 were journal articles, 40 conference papers, 33 book chapters, 18 were reviews and 5 books. The largest subject area classification for these publications was "Business, Management and Accounting" (85 articles), whereas "Neuroscience" was fifth ranked, with 43 articles. A total of 42 articles contained the words "neuromarketing" and "future", so there may be some truth in the criticism that to date there is more hype than hard data and that the promise of neuromarketing is yet to be fulfilled. The aim of this thesis is to test some of these basic ideas underlying neuromarketing by experimental neuroscience methods.

In contrast to the relatively modest amount of peer-reviewed research on neuromarketing and consumer neuroscience, neuromarketing has a substantial global presence within the marketing industry. The website of the Neuromarketing Science and Business Association (2017) lists 144 companies with a neuromarketing interest and a functioning website, located in 43 countries worldwide, ranging alphabetically from Algeria to Venezuela. Of these 144 companies just over half offer recognisable neuroscientific techniques, and the remainder offer consultancy which may or may not be informed by neuroscientific claims or evidence. The most frequently mentioned technique is EEG (60) followed by eye tracking (46), facial coding or facial expression analysis (30), "biometrics" (24), EDA/GSR (17), and fMRI (13). Most of those companies also employ behavioural methods and computerised testing, the most frequently named technique being tests of implicit association.

The breakthroughs in neuroscience have already had an influence on marketing. Neuroscience technology as a tool for developing neuromarketing has offered a great advantage in the way that it is potentially capable of predicting human being's behaviours by studying brain's response to marketing stimuli. There is no fundamental difference in the neuroscience methods used with marketing stimuli and scenarios and the mainstream neuroscience methods used to study perception, memory, emotion and decision making.

The notion of using neuroscientific methods in marketing research has been becoming more and more established in the last few years. In daily practice of marketers classical explicit (meaning consciously accessible to the participant) market research techniques, such as focus groups and surveys, and other methodologies that require explicit response, are commonly used to provide answers to questions, such as which of three different advertisements is going to be successful on the market. The use of implicit (meaning non-consciously accessible to the participant) neuroscientific methods in contrast, such as electroencephalography (EEG) focusing on event related potentials (ERPs) or functional magnetic resonance imaging (fMRI) measuring the so-called blood oxygen level dependent (BOLD) effect in the brain still seems relatively quite rare in comparison to mainstream market research.

In the market, with the explosion of brands and product choices, marketers often struggle to find the answer to the question: why did a consumer choose one brand over another? Moreover, neuroscience offers physical evidence of how the brain processes the information behind purchase decision, providing another perspective on consumer decision making.

The basic set of techniques employed to generate neuroimaging is electroencephalography (EEG), magnetoencephalography (MEG), positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). In applying these techniques, neuromarketing uses information about brain functions and mechanisms to help marketer explore consumer behaviour on the basic of neurological findings, such as, testing advertising effectiveness; testing product appeal; celebrity endorsements; logo or brand selection; media selection; undetected advertising influence; risk assessment, immediate gratification and future benefits; delivering the right sensory elements at just the right time; the role of satisfaction (Fugate, 2007). For example, fMRI researchers and neuroscientists have started to comprehensively examine the location of neuronal activity in various tasks, and neuromarketers may interpret this data in order to help gain insight into consumers' needs. Moreover, it would be extremely helpful to capture and explain some hidden patterns in human behaviours that conventional marketing tools, such as surveys or interviews can't explain.

One such example of an fMRI study (McClure et al., 2004) was relevant to the story about New Coke, which was introduced in 1985 after comprehensive market research which involving focus groups, field tests and surveys. The new formula was launched in response to these market researches uncovered some negative responses. However, within three months, the company was forced to reintroduce their original formulation as "classic Coke" after public (and particular most loyal Coke customers') outrage emerged. Traditional marketing data such as focus groups and taste tests indicated both preference and intention to purchase. The failure of the new Coke launch illuminated that neuroscience may be helpful for improving behavioural prediction in decision making using brain data rather than only focus groups and surveys as in traditional market research. Through carrying out the fMRI experiment, researchers were able to find out consumer' responses to taste and more in deeply uncover the unconscious emotional attraction and loyalty to brand. McClure et al. (2004) showed much stronger fMRI activation of brain areas associated with emotion and motivation when participants were cued with the "Coke" brand – even though both cups contained the same drink. Neuroimaging in this way can help because it is an implicit measure.

Therefore, neuromarketing has a great potential not only to reduce marketing failures but also to increase marketing successes. Neuromarketing should be considered as a legitimate area

for present as well as future research, both of which will allow us to more fully understand human behaviour in an extremely important context. Moreover, applying neuroimaging to marketing research problems should allow us to understand far more clearly and precisely to the impact of marketing techniques, as well as gain insight into key problems concerning business relationships, answers to which have previously remained elusive (Lee, Roderick, & Chamberian, 2007).

1.2 Motivation of the research

Large portions of the current research have been strongly focusing on how consumer preferences for certain products influence on their final decisions. Perhaps the most common decisions that we make on a daily basis are purchases. Traditional marketing strategy based on consumer preference and cost is now being analysed through functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) which are opening a new world of observation. By applying these cutting edge methods, the new breed of neuromarketers' hopes to understand what the consumer wants without worrying that the consumer is lying or feeling pressured by social bias.

The present research applied fMRI, EEG and behavioural techniques to identify the elements effecting on consumers' simulated purchase decisions, and explored what was happening inside of the consumers' brain while making these decisions. In the area of decision making, most researchers have paid great attention to the role of emotion and rational factors. Neuromarketing studies have demonstrated that emotional and rational thinking co-exist, in fact, are co-dependent (Fugate, 2007). Neuroimaging techniques potentially can provide images that document both rational and emotional responses to marketing stimuli (Fugate, 2007). My research aims to explore these two main elements of decision making, what are the brain processes underlying purchase decision about food products, and what is the extent to which they implement emotional or rational processes. To address this question, a simulated purchase decision experiment was implemented in which the effect of the sales volume of different packaged and branded snack products and the effects of price discounting were investigated, using functional magnetic resonance imaging (fMRI). On top of that, the effect of cultural familiarity (sales volume) and recent recognition memory (old/new) of products and the pricing information on the memory recognition of branded products was explored by EEG methods.

1.3 Significance

The current research builds upon research on decision making, cognitive psychology, consumer behaviour, neuroeconomics and neuromarketing by employing the commercially available tools of both functional magnetic resonance imaging (fMRI) and electroencephalograph (EEG). First, a behavioural experiment was carried out to test how the magazine context influences on the purchase decision making of cars. This is the first research to study the effect of different magazine contexts – professional car magazine displayed car advertisement and fashion magazine displayed car advertisement: does this have any different effect on the final purchase decision of consumers? Secondly, an fMRI experiment was applied to test the emotional aspect and rational aspect of purchase decision, in line with dual process theories of decision making (Chaiken et al., 1999). The experiment manipulated the condition of sales volume of products and the pricing information as two effective elements. Therefore, an EEG experiment was carried out based on controlling these two conditions as experiment variables, in order to test the effect of the sales volume of products and pricing information on the recognition memory.

1.4 Thesis outline

The thesis is the overview of my research process and contains six chapters.

Chapter 1 introduces the background of neuromarketing and clarifies the motivation and the potential significance of this research.

Chapter 2 reviews the theories and research using traditional methods in the fields of decision making and consumer behaviour, followed by the overview the neuroscientific methods, especially on the fMRI and EEG methods. Last but not the least, this chapter reviews the relationship between the neuromarketing and neuroeconomics.

Chapter 3 reports on a behavioural study of some key elements of consumer decision making. It measured the influence of the magazine context of car images of different car models on a "desire to purchase" decision. The research is relevant to investigating how advertisements in the different formats impact on consumers' decision making regarding car preferences.

Chapter 4 studies the effect of cultural familiarity (in terms of sales volume) and price on decision making regarding branded and packaged food-related products, based on the fMRI technique. The fMRI technique is helpful for exploring the participants' brain activity during the process of decision making rather than just the behavioural result elicited. This aim of this study is find out the effect of sales volume and price offer on decision making underlying the purchase of food products.

With the understanding gained from the studies described in Chapter 4, and Chapter 5 I developed an experiment using the EEG technique, which is another fine technique of neuroscience that can be used to explore the cognitive processes of human beings, and in this case, to test how recognition memory is influenced by the sales volume of the product and the pricing information.

In the last Chapter 6, this provides a summary of the research, which points out the present research contributions and conclusions, analyses the research limitations and makes suggestions for further research.

Chapter 2 Literature Review

2.1 Decision making and consumer behaviour

2.1.1 Decision making

Nowadays consumers' product and service preferences are constantly changing, so it is essential for the future success of retail and service industries to have a deep understanding of consumer decision making processes which have long been of interest to research. With decisions linking everything we do in our daily life, there are large numbers of decision making theories and related researches which could potentially improve the decisions we make. Decision processes and behaviour are the core characteristics of decision making phenomena, which involve both the process of human thought, and actions and reactions in the external world. Also, decisions are considered as responses to situations and may include three aspects. First, there might be more than one possible course of action under consideration. Second, decision makers could form expectations concerning future events that are often described in terms of probabilities or degrees of confidence. Last but not the least, consequences associated with possible outcomes could be assessed in terms of reflecting personal values and current goals (Oliveira, 2007).

2.1.1.1 Rational decision making

In a review of rational decision making models, Oliveira (2007) stated that "descriptive and normative decision making theories possess distinct characteristics and follow different specific methodologies for choosing a course of action". Thus decision making is explained by using cognition in descriptive models, whereas rationalistic components that indicate how

a decision should be decided by decision makers belong to normative theories (Oliveira, 2007).

'Expected utility theory' is the theory that for choices with uncertain outcomes, people will assess the possible outcomes by multiplying the probability of that outcome by its value. This is a rational theory in that it is based on a consistent and logical set of axioms that make sense, (Busemeyer, 2015) and it is a normative theory in that it describes an ideal decision making behaviour. It is not surprising therefore that it has become perhaps the most prevalent model in economics and consumer behaviour and this theory proposes that choices made by consumers are potentially based on the expected outcomes of their decision. Von Neumann and Morgenstern developed the definitive mathematical formulation of the theory and conducted a case study that demonstrated it is possible to derive numbers that represent personal values, namely as utilities, when decision makers adopt rational methodologies (Von Neumann & Morgenstern, 1944). Consequently, according to the magnitude of their expected utility or value, alternatives with probabilistic consequences should be selected.

Rationality may be defined as the compatibility between choice and value. Rational behaviour seeks the optimization of value of outcomes, focusing on the process of selection instead of emphasizing another alternative. "In classical or perfect rationality, methods of decision analysis are used to attach numerical values or utilities to each of the alternatives during the 'choice' phase. The alternative is determined due to the highest utility or maximum subjective expected utility" (Turpin, 2004, p144). However, in order to employ the rational model in this circumstance, it is assumed that the decision makers would be in an impossibly good position where they are capable of knowing of all possible alternatives, knowing the consequences of implementing each alternative, having a well organised set of preferences for these consequences and having the computational ability to compare consequences as well as determine which is preferred (Kreitner & Kinicki, 1997). According to Busemeyer (2015), utility theory is the computational goal of the rational decision maker as defined by Marr (1982): it does not describe how the decision maker actually arrives at that goal. That is the function of the other two levels in Marr's hierarchy: the algorithmic level describes the processes whereby the decision maker arrives at the goal, roughly equivalent to cognitive processes, and the implementation level describes how those cognitive processes are implemented in the brain (Marr, 1982).

A major challenge to expected utility theory as a descriptive theory of decision making under risk was launched by Kahneman and Tversky (1979) who identified several ways in which human decision making under risk deviates from utility theory (Kahneman & Tversky, 1979). For example, people show a "certainty effect": when an outcome is certain, they value it more highly. So they would rather accept a lower outcome, if it was certain, than a better scenario (based on the sum of utilities x probabilities) with a small but finite degree of risk. Their formulation was known as prospect theory, and successfully modelled departures from rational utility theory observed in actual decision making. However, like utility theory, it was still based on probability weights and values "as if" these are actually calculated by the decision maker.

Later psychologists, including Kahneman and Tversky themselves, took the departures from expected utility theory as indicating that something radically different from the calculation of statistical probabilities and monetary values were going on in the thought processes of decision makers. This took the form of identifying "heuristics" which are able to give a good approximation to rational decisions in some circumstances, but may lead to strong departures from rationality in other circumstances. A heuristic is defined as "a simple procedure that helps find adequate, but often imperfect, answers to difficult questions" (Kahneman, 2011, p98). Some examples of heuristics in decision making are given below.

2.1.1.2 Fast and frugal decision making

The fast and frugal heuristics approach first proposed by Gigerenzer and his colleagues in 1996 is an alternative to rational choice models that has greater psychological plausibility, particularly when we consider that many decisions are taken under time pressure or when there are competing demands on cognitive resources. Hence it has achieved great popularity and has been applied to an enormous number of case studies cross a wide range of scenarios in which judgment and decision making occurs (Gigerenzer & Goldstein, 1996). These fast and frugal heuristics are applied when we make decisions in order to simplify decision making, and they refer to simple, task-specific strategies that people use to solve judgement and decision making problems. These advantages enhance the usefulness of heuristics is not only limited to laboratory research but also well adopted in real practices and daily life to

make decisions. The fast and frugal heuristics approach includes several simple rules as given below.

2.1.1.2.1 Ecological rationality

Ecological rationality is the idea that the rationality of an act or a decision depends on the circumstances in which it takes place. Ecological rationality challenges rational choice theory because choices that are rational in some conditions may be irrational in others. Thus Gigerenzer (2008) argued that decisions based on heuristics can be the best in the circumstances. Moreover, heuristics can exploit structures that allow general conclusions about the match between cognitive processes and environments (Gegerenzer, 2008). Fast and frugal heuristics are obeyed by neglecting much or all of the information in naturally occurring environments but taking account of the most important predictor variables, due to the fact that those variables are capable of boosting a decision to be made. Moreover, it isn't uncommon that relevant pieces of information are neglected by fast and frugal heuristics. As an example, the tallying heuristic (Gigerenzer & Goldstein, 1996) ignored the weighting of predictor variables and dealt with them in an equal manner in such a way that it made a count of the number of positive features and simply selected the highest scoring one eventually. That means that which heuristic is ecologically rational to use therefore heavily depends on the specific properties of the decision environment.

2.1.1.2.2 Recognition heuristics

Fast and frugal decision making is rooted in evolved psychological capacities such as memory and the perceptual system. These evolved capacities are of critical importance to the heuristics approach and vice versa. For example, the recognition heuristic is the tendency, given a choice between two objects one of which is recognised and one not, to attribute higher value to the recognised object. However, the mere observation that people often pick a recognized object does not in itself mean that they are using the recognition heuristic, as opposed to a rational decision making approach, as additional cues are often correlated with recognition and a consideration of this knowledge could thus lead to the same prediction as a non-compensatory mechanism based on recognition.

2.1.1.2.3 The Take-The-Best heuristic

In a study of the decisions made by professional burglars, police officers and novices as to which of two residential properties was most vulnerable to burglary (Garcia-Retamero & Dhami, 2009) the professional burglars' and police officers' decisions were most consistent with noncompensatory strategies such as the Take-The-Best heuristic (Gigerenzer & Goldstein, 1996). The "Take-The-Best" algorithm, as shown in Figure 2.1, based on the theory of probabilistic mental models (PMM) tested by Gigerenzer and Goldstein in 1996 demonstrates a good illustration on the cognitive mechanism of fast and frugal heuristics. As a matter of fact, the Take-The-Best simplifies decision making and it is a simplified approach that people may apply when selecting amongst alternatives for decision making. It is purely based on a single reason decision rule that is considered as the most dominant factor, by ignoring all the other influencing factors or cues (Gigerenzer & Gaissmaier, 2011).

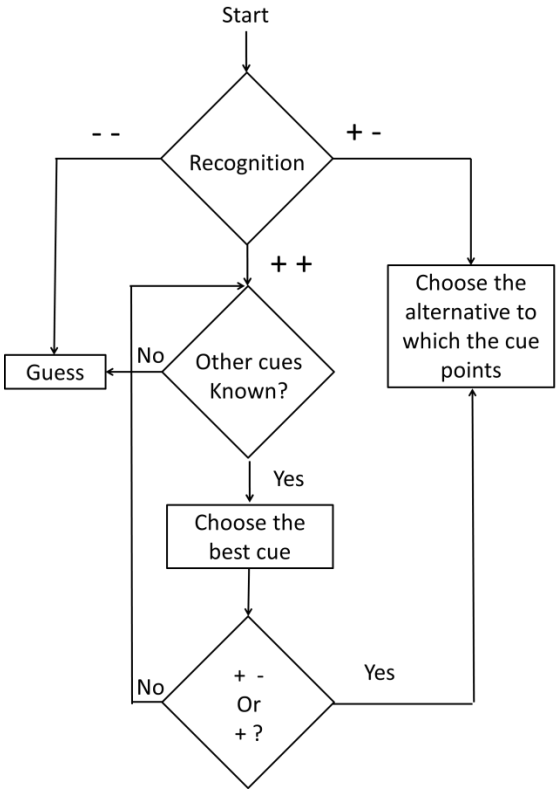


Figure 2.1 – Flow diagram of the Take-The-Best algorithm

Take-The-Best algorithm simply complies with 'take the best ignore the rest' policy. According to the validities of cues, the Take-The-Best algorithm assumes a rank ordering of these cues based on subjective opinions and feelings, and then decision maker will choose the highest ranking cue (also known as the best cue). There are five steps according to the Take-The-Best algorithm theory as below.

Step 1: Recognition Principle, if only one of the two objects is recognised, and then chooses the recognised object. If neither of the two objects is recognised, then choose randomly to the next step.

Step 2: Search for Cue Values, use ones memory to retrieve the cue values of the highest ranking.

Step 3: Discrimination Rule, one must decide whether the object has a positive cue value and the other does not.

Step 4: Cue – Substitution Principle, if the cue discriminates, then stop searching for cue values. If not one must go back to step 2 and continue until discrimination is found.

Step 5: Maximising Rule for Choice, one should choose the object with the positive cue value. If no cue discriminates, then choose randomly.

Moreover, the features of the Take-The-Best algorithm are: (a) search extends through only a portion of the total knowledge in memory and is terminated timely once the first discriminating cue is found; (b) the algorithm does not attempt to integrate information but uses cue substitution instead; and (c) the total amount of information processed in contingent on each task and varies in a predictable way among individuals with different knowledge. Furthermore, this algorithm is an example of bounded rationality than of classical rationality.

2.1.1.3 Psychological decision making models

Normative, or rational, theories of decision making are derived from fundamental axioms. If these well-established principles can be generally accepted, then it would be possible to derive a normative theory of choice, or indeed, a computational theory of choice that characterises the computational goals of decision making (Busemeyer, 2015). However, the process of reaching a final decision is influenced by the importance of psychological elements that are highlighted through descriptive or psychological paradigms (Oliveira, 2007).

Decisions are also not generally taken by an individual in isolation but by a person or persons in a social context. Stein et al. (1997) discussed whether decisions that leaders face in foreign policy making, including decisions about war and peace, are made based on rationality assumptions. Stein et al. highlighted that well documented cases of foreign policy decision

making coincidentally prove that leaders make decisions with inadequate information or even significant errors most of the time, which means this decision making process is almost never rational. Moreover, deviations from rational actor assumptions about judgment, estimation and choice are explained by cognitive psychology based on analysing the simple rules or heuristics people use when handling sophisticated and poorly structured dilemmas (Stein et al., 1997). To give a perfect example, the Korean War began when North Korea invaded South Korea, followed by the United Nations, with the United States as the principal force, coming to the aid of South Korea and China with the Soviet Union's assistance coming to the aid of North Korea. The key argument in this war which even led to further multi-country involvement was primarily due to the fact that there was a lack of information about whether United States could cross the Yalu River or not, the border with China, to invade China.

Although neither a single cognitive theory of choice nor a dominant decision rule can prevail (according to Stein, et al., 1997), they found the existence of filters and simplifying mechanisms (or heuristics) through which people process information and interpret their surrounding environments. Additionally, these filters and simplifying mechanisms play a pivotal role in decision making process; however, their impact is strongly dependent on circumstances, which means the existence of variations from context to context and from individual to individual. Therefore, the deviations introduced by these modifying factors might result in conflicting expectations about the link between judgment and behaviour, which have not been adequately explained by any of the decision theories so far. Nowadays, cognitive psychology, which can be defined as the scientific investigation of human cognition, plays an extremely important role in explaining the reasons why people may deviate from rational behaviours, as well as offering a general and compatible decision making theory; however, it has not formed a factual challenge to rational models due to the numbers of external influencing factors, such as culture or principles that are based on people's set of beliefs, and either or both might influence and distort the information being processed rationally. For instance, Adler studied many examples of differences in rationality relative to culture, and the resulting difficulties in communicating across cultural barriers: something that affects all international business activity (Adler, 1991). In contrast, Hofstede's five value dimensions pointed at the values of a dominant culture within a nation instead of co-cultures (Hofstede, 1997).

2.1.1.4 Neural computations involved in decision making

Rangel et al. (2008) proposed a framework for taking many ideas about decision making into account, setting out what would be required to develop a neurocognitive model of decision making based on probabilities and values, like expected utility theory or prospect theory (Rangel, Camerer, & Montague, 2008). It divides decision making computations into five fundamental processes; second, it shows that there are multiple types of valuation system; and finally, it incorporates modulating variables that affect the different valuation processes. Figure 2.2 shows that value-based decision making can be divided into five fundamental processes based on theoretical models of decision making in economics, psychology and computer science. The first process in decision making involves the construction of a representation of the decision problem, which entails identifying both internal and external states, as well as potential courses of action. In the second process, the value assigned to the different actions, termed as valuation, needs to be considered in order to make appropriate decisions. Besides this, those chosen values have to be reliable predictors of the benefits that are likely to result from each action. The third and fourth processes are related to the selection of one of the actions on the basis of the previous valuation and brain measurement of the desirability of the outcomes after implementing the decision, respectively. Finally, these outcome evaluations, act as feedback for the achievement of self-learning in a closed loop system, are used to update the other processes, and are seen as an ideal learning source to make the improvement or even optimisation of the quality of future decisions.

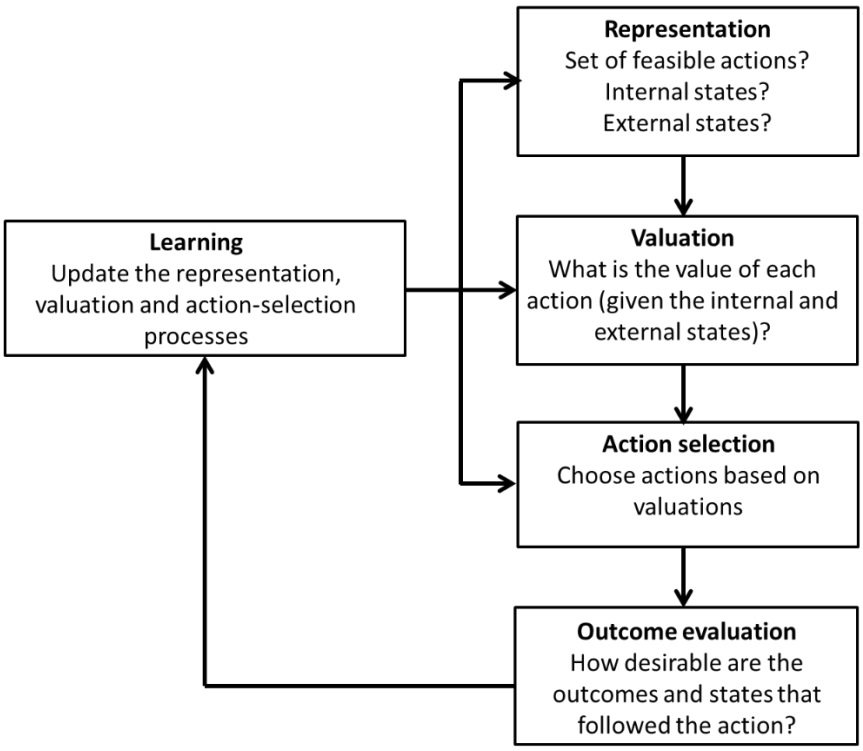


Figure 2.2 - Basic computations involved in decision making (Rangel, Camerer, & Montague, 2008)

Rangel et al. (2008) also proposed which known neural systems might implement each of these basic computations. For example, they reviewed fMRI studies that are consistent with expected value signals in the striatum and medial frontal cortex, and with risk signals in the striatum, insula and lateral orbitofrontal cortex (Preusechoff et al., 2006; Tobler et al., 2007; McCabe & Redoute, 2007; Dreher et al., 2006; Preuschoff et al., 2008).

2.1.1.5 Somatic marker hypothesis

The somatic marker hypothesis (Damasio, 1996) proposed a neurophysiological basis for processes of human reasoning and decision making. Damasio (1996) explained that the decision making process should be based on a system-level neuroanatomical and cognitive framework. The key point of this hypothesis was that the decision making is a process influenced by marker signals at multiple levels of operation which are triggered from bioregulatory processes, including processes that express themselves in emotions and feelings. Furthermore, the influence can be operated both at conscious and non-conscious levels.

The key idea for somatic marker hypothesis is that processing emotional stimuli can be affected by previous experiences with those stimuli, and the reactivation of signals to related previous individual contingencies can be carried out via the 'body loop' and the 'as if body loop'. The 'body loop' describes an anatomical system that an appropriate somatic is actually re-enacted in the body proper, and signals from its activation are then relayed back to subcortical and cortical processing structures (Bechara & Damasio, 2005). Damasio (1996) also believed that the 'body loop' is the original mechanism, however it has been superseded by the 'as if body loop'. Somatic marker hypothesis stated that activate some neural regions in ventromedial prefrontal cortex and amygdala (regions involved in triggering of somatic states), somatosensory cortices (the region can receive signals from soma) , basal ganglia (the region can mediate responses from ventromedial cortices by acting on somatomotor structures) (Tranel & Damasio, 1993), and also some regions are involved in working memory, such as dorsolateral prefrontal cortex so that a particular representation is strengthened or weakened.

Damasio et al. (1996) tested the somatic marker hypothesis by a series of experiments measuring skin conductance responses: a) somatic responses to emotionally charged stimuli; b) the gambling experiment; c) the psychophysiological dimension of the gambling experiments. Damasio's theory emphasises the importance of emotion in decision making, and he opposed "Descartes' error": a dualistic split between emotion and rationality (Damasio, 1994). Moreover, one of the findings suggested that patients with a lesion of ventromedial frontal cortex who maintained normal intellect but showed a defect in judgement and decision making in the personal and social realm, no longer had a normal ability to generate somatic responses to stimuli with an emotional component, and this might be the cause of a weakness in supporting processes, such as attention and working memory.

2.1.2 Consumer behaviour

Consumer behaviour is defined as activities people undertake when obtaining, consuming, and disposing of products and services (Blackwell et al., 2001). The core of the scientific study of marketing is the insight into consumer behaviour, which also means how consumers make decisions about almost every product they buy and use. Theories of consumer behaviour are also employed to address issues of the role of emotions in purchasing decisions, post purchase attitudes, the role of object utility and so on.

2.1.2.1 Theory of reasoned action

This theory of reasoned action (TRA) was developed by Martin Fishbein and Icek Ajzen in the late 1960s and has been summarized into a flow chart and a formula as shown in Figure 2.2 and equation (2.1), respectively (Fishbein & Ajzen, 1975). From another perspective, TRA can be considered as a model of decision making applicable to consumer behaviour.

The aim of the theory of reasoned action is to explain the relationship between attitudes and behaviours within human action, based on the analysis of the importance of individuals' pre-existing attitudes and behavioural intentions in the decision making process. As a matter of fact, the behaviour intention was added later on to improve the theory, demonstrating that attitude toward the behaviour as shown in Figure 2.3, considered here as the act of buying, is measured rather than simply the attitude toward the object. The fundamental principle of the theory of reasoned action would hypothesize that consumers' behaviour, to a certain extent, is strongly linked with their intention to create or receive a particular outcome. In this respect it is similar to expected utility theory. According to this analysis, consumers are considered to be rational actors who make a final decision based on in their best interests.

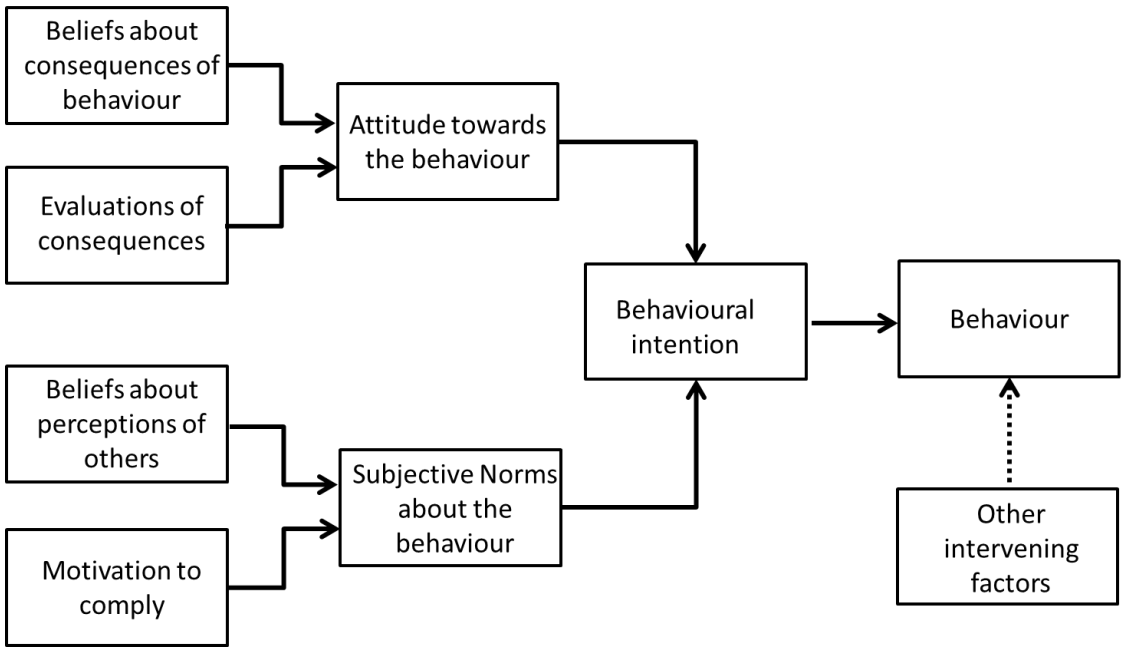


Figure 2.3 - Theory of reasoned action (Fishbein & Ajzen, 1975)

$$BI = (AB)W_2 + (SN)\,W_2 \quad (2.1)$$

Where, BI is behavioural intention; (AB) is one's attitude toward performing the behaviour; W is empirically derived weights and SN is one's subjective norm related to performing the behaviour.

Specificity is of critical importance to decision making process according to theory of reasoned action. Most of the time, an equally specific outcome will be expected when a specific action is implemented by a consumer based on pre-existing attitudes or similar prior experience or even both. Moreover, from the time the consumer decides to act to the time the action is completed, the consumer retains the ability to change his or her mind and decide on a different course of action.

When it comes to empirical tests and applications of the theory of reasoned action, although a strong correlation of attitude toward behaviour and subjective norms to behavioural intentions were found, some studies proposed that the predefined causal relationship between behavioural intention and actual behaviour is simplistic because of circumstantial limitations or inadequate information and other affect factors, such as culture, cost and quality of products, communication or even moral obligation (Oliver & Berger, 1979; Sheppard, Hartwick, & Warshaw, 1988). For example, consumer behaviour that deviated from behavioural intention could be due to the fact that brand, coupon usage or promotion draws greater attention from consumers than the functional attributes and quality of products. Weak correspondence between purchase intentions and subsequent behaviour is usually found to be due to cross-brand comparisons, outperforming of other products and so on, which leads to a strong motivation to produce additional adjustments based on valuable information that is collected from interviewing brand switchers, assessing behavioural intention based questionnaires and surveys, and comparing marketing approaches across firms, in order to mediate between intentions and behaviour (Warshaw, 1980). However, there are limitations of the above methods in practical application, such as no scientific way to tell how truthful a respondent is being, not easy to judge how much through a respondent has put in, difficult to correspond what people say about their intentions with their actual motivations. As a result, the questionnaire and survey based methods could inevitably introduce inaccurate, unreliable or even invalidate measurement results. Therefore, this being one of the reasons why neuromarketing explained in detail in later sections is considered to have great potential to reveal consumers' motivations towards a product.

2.1.2.2 Engel, Kollet, Blackwell (EKB) model

This consumer decision model, also well known as Engel-Blackwell-Miniard (EBM) Model, was originally developed by Engel et al. in 1968, but since then, it has been revised a good number of times in an attempt to provide a comprehensive information-processing account of consumer decision making. As Figure 2.4 shows, the overall structure of consumer decision model is comprised of four processes – input, information process, decision process and variables influencing the decision process (Engel et al., 1968).

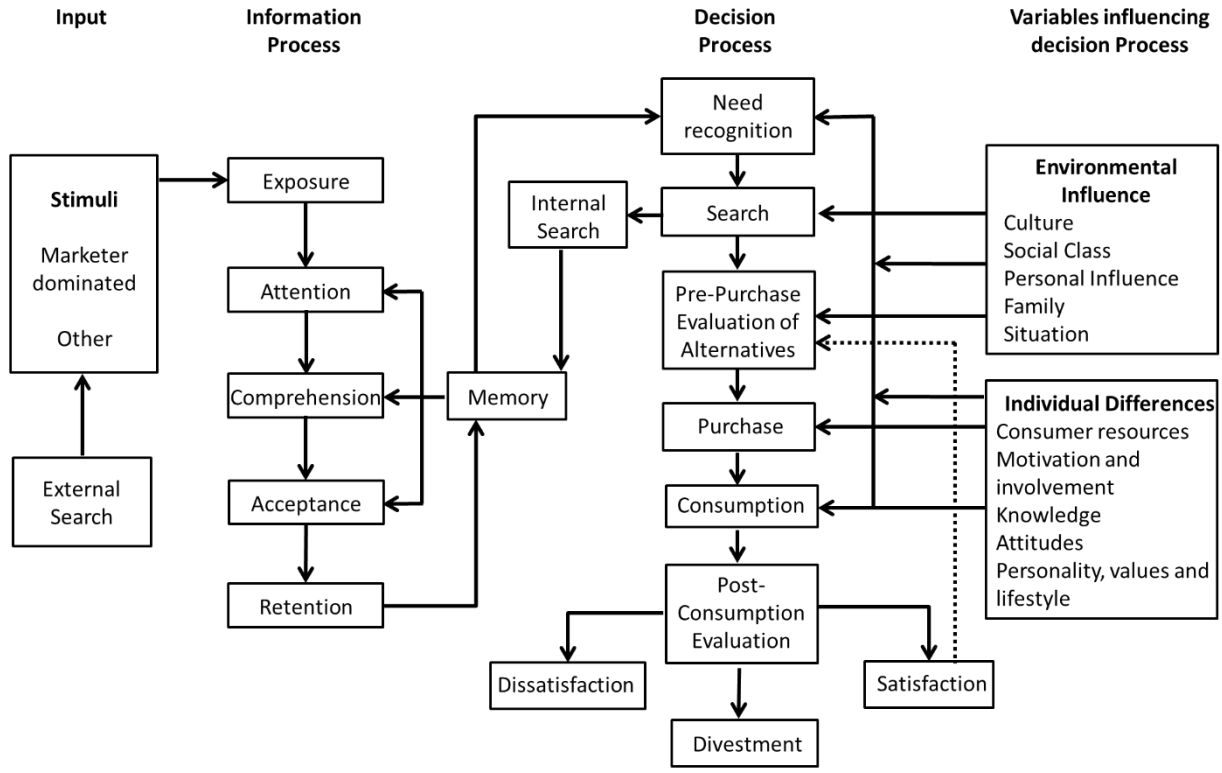


Figure 2.4 – Consumer decision model (Engel et al., 1986)

Figure 2.4 shows that the core of the model, the decision process is comprised of seven consecutive stages, which include need recognition, internal search from memory, pre-purchase evaluation of alternatives purchase and consumption and following by post-consumption and divestment. Once need recognition occurs, consumers start searching for information and solutions to satisfy their unmet needs; moreover, searching may be internal by retrieving knowledge from memory or perhaps genetic tendencies; or it may be external by collecting information from most of the marketing materials they see on television, newspapers or online, as well as, from peers and families, shown in Figure 2.4. Followed by pre-purchase evaluation of alternatives, consumers in this stage focus on evaluating and

choosing from a variety of products or services, in order to help them answer fundamental questions, such as what options are available, and which one is the best. The next stage of the consumer decision process is purchase; and it is strongly dictated by individual differences that include consumer resources, motivations and involvements, knowledge attitudes, personalities, values and lifestyles. Once the previous stages are satisfied by consumers, consumption can occur, which means the points at which consumers use the product they purchased. After consumption, the next stage of consumer decision making is post-consumption evaluation, in which consumers experience a sense of either satisfaction or dissatisfaction. It is not difficult to understand that satisfaction occurs when consumers' expectation is met, and vice versa. Post-consumption is followed by divestment that is defined as the last stage to outright disposal, recycle, or remarket products they purchased.

One simple example is given here to demonstrate consumer behaviour based on the decision process explained by the consumer decision model in Figure 2.4. Suppose that Mrs Li thinks that she would need a mommy bag in a near future that can be used to carry her new born baby's nappy, milk bottom as well as her makeups and other stuffs when she goes shopping with the baby (1st stage: need recognition). Then, she remembers that there are few famous brands selling a variety of mommy bags in internet (2nd stage: search). She looks at what style, brand, quality and price of the mommy bags is most suitable to her (3rd pre-purchase evaluation of alternatives), followed by payment to the chosen one in Internet (4th purchase). Once the mommy bag is delivered, Mrs Li will try to carry what both needed most initially whenever they go shopping (5th consumption); however, she notices that the space inside the mommy bag is spacious and the layout is well designed to carry everything they need (6th post-consumption evaluation). She would assume that it is worthwhile donating it when it is not needed in the future (7th divestment).

Prior to the decision making process in the input stage, consumers will process the information resulting from external search, or internally search previous experiences in their memories. In other words, the external and internal searches are two main factors to have influence on decision making process. Moreover, the internal search is dictated by either environmental influences or individual difference; the former includes culture, social class, personal influence, family and situation, while the latter includes consumer resources, motivation and involvement, knowledge, attitudes, personality, values and lifestyle (Engel et al., 1968).

The information process is elaborated as five stages that include exposure, attention, comprehension, acceptance and retention (Engel et al., 1968). The input of the decision process is based on individual need recognition, which reflects that a discrepancy is acknowledged by consumers between their current status and desirable alternatives. First, information and persuasive communication must reach to consumer to activate one or more of the senses and initiate preliminary information processing in exposure stage. The next stage known as attention is to allocate or not allocate information processing capacity to the incoming information; moreover, consumers often neglect commercial persuasion and only focus on selective attention. After attention is attracted, the information is further analysed against the past experience stored in the memory and following by either is dismissed as unacceptable or accepted, defined as comprehension and acceptance respectively. In the final retention stage is to store this new piece of information in the memory for future use if needed.

2.2 Neuroscience and neuroimaging

Diverse fields have recently adopted the prefix neuro - including neuroaesthetics, neurotheology, neuromarketing and neuroeducation, which have evoked a kind of "neuroculture." The surfacing of a neuroculture helps to translate brain-based narratives regarding to personal identity, responsibility, and causation into palpable information (Frazzetto & Anker, 2009).

Consumer decision making has joined the neuroculture, and been proved to be one of the more culturally popular subjects for neuroscience research, attracting interest in the commercial as well as the academic world. In some circumstances, it is claimed, neuroscience is capable of providing a measure of hidden preferences and of implicit processes through analysing neuroimaging data which can be used to reveal preferences for public goods, and which can't be readily elicited from behavioural data (Krajbich, Camerer, Ledyard, & Rangel, 2009). Neuroimaging has been widely used in affective, cognitive, and social neuroscience, thus generating a large scientific literature within which the neuroscience of consumer decision making can be situated.

2.2.1 A brief introduction to neuroscientific methods

Nowadays, there are a variety of neuroscientific methods being used to capture the brain's electrical activities and metabolic activities, including functional magnetic resonance imaging (fMRI: e.g. Fehse et al., 2017); electroencephalography (EEG: e.g. Vecchiato et al., 2011); facial encoding (Lewinski et al., 2014); eye tracking (Gidlöf et al., 2017); positron emission tomography (PET: e.g. Smith et al., 2001), magneto-encephalography (MEG: e.g. Vecchiato et al., 2011). , and transcranial magnetic stimulation (TMS: e.g. Camus et al., 2009).

Commercially available advanced neuroscientific tools, such as MRI scanners make it possible to analyse brain responses to brands, products and marketing communications while people carry out specific tasks, in order to investigate and understand how conscious and nonconscious brain processes interact during perception and decision making. If these brain activations can be reliably interpreted, they could provide a window into consumer decision making, without using verbal feedback or even market questionnaires. Moreover, those neuroscientific methods, are considered by many researchers to promise a more accurate and objective approach to predicting consumer behaviour as well as capturing important subconscious influences as opposed to traditional market research tools that strongly rely on explicit consumer responses (Ariely & Burns, 2010; Mostafa, 2014).

Neuroscience tools now offer potential insights into the role of emotion in decision making. Emotional measurements may correlate with the following market indicators, such as purchase intent, emotionally salient features, pricing strategy, strength of brand reputation, and compatibility with brand.

There are advantages and limitations that characterize every technique, and researchers and practitioners in neuromarketing need to know which tool is best suited to answer a particular marketing question. The following list describes the introduction of four major techniques used to study the human brain:

Functional magnetic resonance imaging (fMRI) uses an MRI scanner involves the detection of magnetic changes in the brain when haemoglobin in the blood is reduced to deoxyhaemoglobin. fMRI has superior spatial and temporal resolution to PET, but provides only an indirect measure of neural activity (Eysenck, 2009), fMRI detects changes of the blood oxygenation level-dependent response (BOLD) which in turn responds to local changes

in energy consumption due to neural activity. In general, fMRI is currently the mostly frequently used functional brain imaging technique.

Electroencephalography (EEG) is a useful technique for capturing brain activity in real-time because it has a very high temporal resolution (milliseconds) and therefore is capable of detecting brief neuronal events. EEG uses multi-channel electrodes applied to the outer surface of scalp and is able to measure changes in the electrical field in the brain region underneath to get readout of the different brain waves. Because a skull disperses the electrical field, this leads to a relatively low spatial resolution from EEG measurements; however, the spatial resolution is also dictated by the number of electrodes, and very often the greater the number of electrodes are used, the better the spatial resolution can be achieved (Belden, 1990).

Magneto-encephalography (MEG) measures the magnetic fields produced by the electrical brain activities. Like EEG it provides fairly detailed information at the millisecond sampling intervals, typically 1000 sample/second, about the time course of cognitive processes, which is similar to the rate at which the brain works. In practice, MEG can provide a reasonably good spatial resolution compared to EEG due to the fact that the magnetic field is less distorted by the skull than is the electrical field (Eysenck, 2009). In other words, MEG is an expensive cousin of EEG, however it is not as good as fMRI at localizing, where, precisely in the brain, activity is taking place (Belden, 2009).

Transcranial magnetic stimulation (TMS) uses an iron core, often in the shape of a toroid wrapped in electrical wire, is placed close to the participant's head and a large, very brief pulse of current is run through it. This produces a short-lived magnetic field, inhibiting processing in the brain area affected (Eysenck, 2009). TMS can be used as a single pulse, paired pulse or repetitive stimulation. As one of research tools, TMS has been used to study the causal role of specific brain regions in particular tasks by temporarily taking them 'offline' (Ariely & Berns, 2010). Moreover, TMS also has been sued to prove that the dorsolateral prefrontal cortex (DLPFC) plays a causal role in the computation of values during decision making (Camus et al., 2009).

2.2.2 An overview of functional magnetic resonance imaging (fMRI) method

Of all commercially available advanced neuroscientific methods, fMRI, implemented on an MRI scanner as shown in Figure 2.5 offers the most comprehensive evaluation of brain processing because it is the only technique that can accurately monitor activity in deep brain structures involved in functions, such as memory encoding and reward processing. It can also expose the neural networks involved in a various number of different cognitive and emotive processes, such as craving, disgust, self-relevant processing, trust, pain, and pleasure (Calvert & Brammer, 2012).

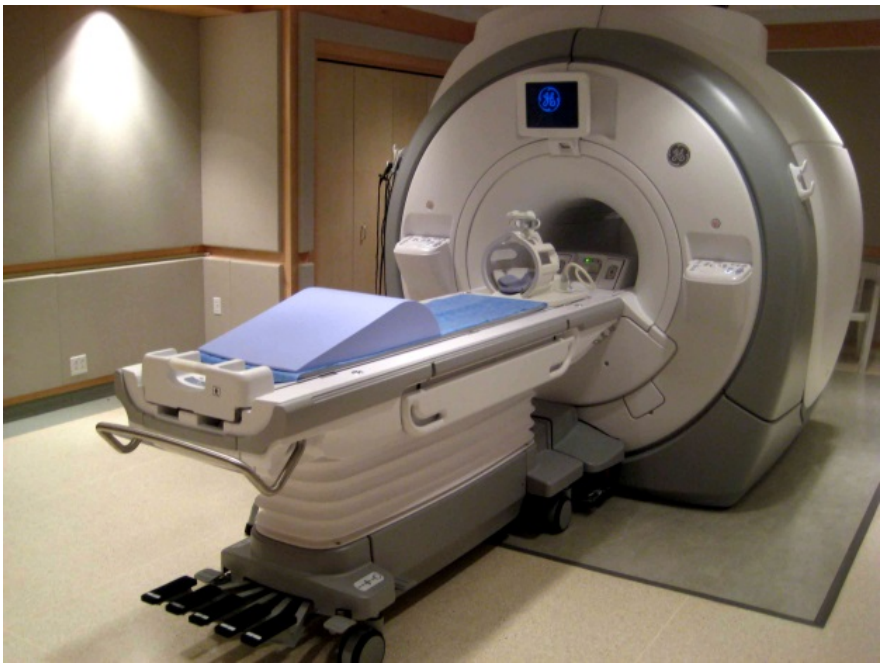


Figure 2.5 - fMRI equipment

fMRI, as a neuroscientific method, is used in neuromarketing research amongst universities across the world, when aiming to apply neurological findings to consumer behaviour such as the impact on consumer choice of different types and designs of packaging (Stoll, Baecke, & Kenning, 2008). Although the use of fMRI in companies is significantly less widespread than universities, but there are some companies that employ it for commercial activities. For example, Neurosense Limited specialise in uncovering these hidden triggers of consumer purchasing behaviours using fMRI and behavioural methods (Neurosense, 2017). A case study from Neurensics (2016) was to generate a positive effect on the activation of the consumer's buying intention based on the obtained fMRI results (Neurensics, 2016).

Moreover, Innerscope Research was acquired by Nielsen in 2015 to create the "world's largest consumer neuroscience organisation" (Nielsen News Center, 2015). Nielsen has added fMRI to the range of available technologies and has a team of "nearly 20 PhD and MD neuroscientists" who have authored "more than 550 peer reviewed articles" (Nielsen Consumer Neuroscience, 2017). FKF Applied Research founded by Bill Knapp and Dr. Joshua Freedman focuses on brand marketing and advertising to gain rich insights from massive amounts of data obtained by using fMRI scan, in order to better understand human choice and decision making deeply and accurately (FKF-Applied Research, 2017). Furthermore, The Neuromarketing Labs work together with Neurensics in Germany using fMRI to measure up to 12 relevant emotions, that including expectation, value, trust, anger, fear, involvement, familiarity, danger, disgust, novelty, attention, desire and lust (The Neuromarketing Labs, 2016).

Moreover, in commercial aspects of the medical field, neuroscience methods have been used to facilitate the development of medical products including drugs, Imanova Lmited established since 2011, was formed in an innovative alliance between the UK's Medical Research Council and Imperial College London, King's College and University College London. It specialises in the utilisation of state of the art magnetic resonance imaging (MRI) to provide advanced structural and functional information in a variety of applications, such as the study weight loss due to visceral fat loss or subcutaneous fat loss, and the study of brain activity when using electronic cigarettes as substitutes for real ones. In 2017 Imanova was acquired by Invicro, a leading American imaging and data management company (Imanova, 2017).

It has been argued that using fMRI as a tool to investigate the areas of consumers' brain activated in response to a specific marketing stimulus can provide a much more honest and objective indicator of their cognition compared to traditional marketing research tools such as focus groups and questionnaires (Senior, Smyth, Cooke, Shaw, & Peel, 2007). This is because unlike conventional marketing research methods, neuroimaging data are much less susceptible to social desirability and "interviewer effect" (Mast & Zaltman, 2005).

Currently, fMRI is also the most prevalent neuroimaging technique for academic neuroscience research. It is a technique for measuring brain activity and produce activation maps, showing which parts of the brain are involved in a particular mental process. It works by detecting the changes in blood oxygen level dependent (BOLD) which varies by

measuring the changes in blood oxygenation and flow that occur in response to neural activity. The fMRI divides the brain into a large number of small cubic volumes (also known as voxels) and monitors the BOLD signals when neurons fire in response to marketing stimuli. It can pinpoint where these neurons are firing in the brain. When a brain area is more active, it will consume more oxygen and to meet this increased demand blood flow increases to the active area (Nuffield department of clinical neurosciences, 2017).

When it comes to fMRI data analysis, the general linear model (GLM) approach, as expressed in equation (2.2), is commonly applied to reveal task-related brain areas by searching for linear correlations between the fMRI time course and a reference model. However, one major limitation of the GLM approach is the assumption that the covariance across neighbouring voxels is not informative about the cognitive under examination. Whereas, compared with the GLM approach, multi-voxel pattern analysis (MVPA) based on analysis and comparison of distributed patterns of activity with high sensitivity has become a powerful technique to analyse neuroimaging data and to identify the neural substrates of cognitive functions ranging from visual perception to memory processing. Moreover, a unique feature of MVPA is to search for highly reproducible spatial patterns of activity that differentiate across experimental conditions, and it is also capable of analysing a set of data in a joint manner within a region. Furthermore, MVPA is able to read brain activities; more specifically, the relationship between specific mental states and spatial patterns of fMRI activity can be established in some certain circumstances after carrying out a training or learning phase, which is well known as machine learning in this context.

$$Y = X\beta + \epsilon \tag{2.2}$$

where $Y = \left[y_1, \cdots y_f\right]^T$ is the dependent variable and is a column vector containing the BOLD signal at a single voxel; $\epsilon = \left[\epsilon_1, \cdots \epsilon_f\right]^T$ is the error vector whose elements are independent and identically distributed normal random variables with zero mean and variance $\sigma^2, \epsilon \sim N(0, \sigma^2 I). \beta = \left[\beta_1, \cdots \beta_f\right]^T$ is the column vector of model parameters where P is the number of model parameters; X is J X P is design matrix which is a near-complete description of the model.

Compared with other neuroscientific methods, fMRI has provided several significant advantages. First, fMRI is non-invasive and radiation free, making it extremely safe for the subject. Second, it has excellent spatial and good temporal resolution. Last, fMRI can offer

spatial resolution of 1-10 mm and temporal resolution of 1-10 s. However, fMRI is very sensitive to subject movement since a head movement of more than 2 mm in the scanner causes blurred and unusable images (Koller, 2010).

2.2.3 An overview of EEG method

The Electroencephalogram, shorten as EEG, is to measure electrical activities (brainwaves) which are generated by neurons producing currents spreading through the head. Moreover, these tiny electric currents also reach the scalp, and hence resulting in voltage differences on the scalp. Since there are billions of neurons in the brain, their activities are combined to produce electrical potentials that are large enough to be able to detect these activities at the surface of skull. Figure 2.6(a) shows the 64-channel EEG apparatus in Brunel University London's EEG Laboratory. It utilizes a cap that contains 64 electrodes, disk-shaped and covering half the size of a 1penny piece, that is fitted as closely as possible to the scalp where the electrodes are capable of detecting and measuring electrical signals from the entire head as well as skin activities, muscles activities, blood and eyes activities (Pinel, 1996). Figure 2.6(b) shows a participant undergoing an EEG wearing a cap equipped with 64 electrodes. Beside the cap with 64 electrodes, the other essential components of the EEG apparatus include connecting cables, data acquisition channels, amplifiers, a computer control module and a display device, as shown in Figure 2.7. Compared with fMRI, some of the advantages of EEG are more compactness, simpler in use, less cost and more portability. Moreover, the unique feature of portability allows that EEG is capable of recording brain activities in many circumstances, such as supermarket (Morin, 2011). Therefore, there are a quite number of companies who employ EEG for their commercial activities. For example, Mindlab International Limited specialise in advertisement effectiveness, brand identity, unconscious behaviour and so on through employing mobile EEG (Mindlab International, 2014). Moreover, HCD Research uses EEG to gain a better understanding of the consumer and their experience with stimuli (HCD Research, 2017). Innerscope Research has also used EEG for understanding consumers' non-conscious and conscious emotional responses, memory activations and attentional patterns, empowering them to better navigate the increasing complexity of modern consumer behaviour. Some companies using EEG for commercial activities as listed in Table 2.1.

Table 2.1 – Companies employ EEG for commercial activities

Company names	EEG commercial activities
Mindlab International Limited	Advertisement effectiveness, brand identity, unconscious behaviour (Mindlab International, 2014)
HCD Research	Consumer and their experience with stimuli (HCD Research, 2017).
Innerscope Research	Consumers' non-conscious and conscious emotional responses, memory activations and attentional patterns
MerchantMechanics Lmited	Consumer decision making, emotion and motivation, behaviour, brand affinity (MerchantMechanics, 2016)
Institute of Sensory Analysis	Consumer's unconscious behaviour used for press and television advertisements, packaging layout, product placement, computer games, fragrance compositions, rebranding (Institute of Sensory Analysis, 2017)
Forebrain Limited	Consumer's attention, motivation and memorization used for branding test, advertising test, sensorial test and packaging test (Forebrain, 2017)
Alpha-Active Limited	Unconscious behaviour for sports, therapy, games applications (Alpha-Active, 2016)
Brain Vision UK	Cognitive, branding and emotion applied for case studies of dancing, football, movie and so on. (Brain Vision UK, 2017)
The Neuromarketing Labs	Attention, emotional engagement, memory encoding and wakefulness used for price optimisation, advertising test and product success prediction (The Neuromarketing Labs, 2016)

(a) (b)

Figure 2.6 - (a) EEG apparatus and (b) a participant undergoing an EEG wearing a cap equipped with 64 off electrodes

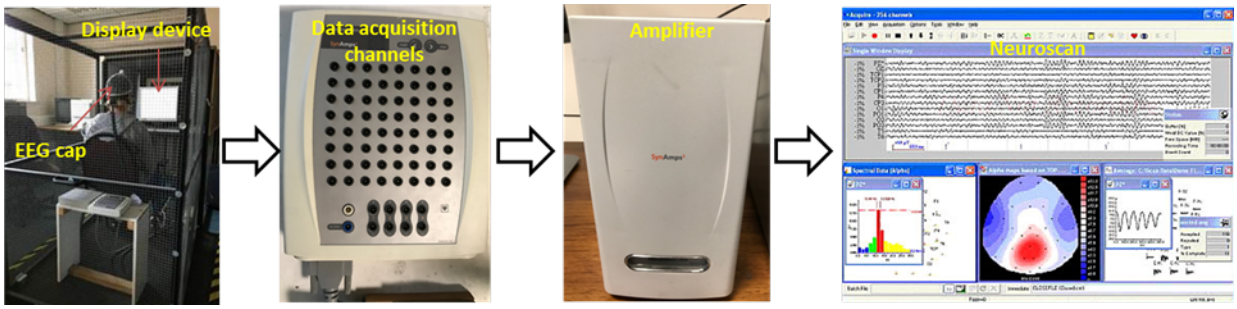


Figure 2.7 – An EEG signal flow diagram

EEG recordings are based on the difference in voltage between each exploring electrode and a designated reference electrode or the common reference, which is the average of voltage at all other electrodes. The movements of eye and jaw can cause fluctuating electrical fields across the scalp, known as noise; as a result, subjects are requested to remain still and to and try their best to minimise eye blinks and head movements. Eye movement activity (electrooculogram: EOG) is also recorded with the EEG so that trials on which there are gross movements can be eliminated or corrected from the analysis.

Nevertheless, EEG also brings along limitations such as a low spatial resolution and inverse problem which means it can't precisely locate where the neurons are firing in the brain, especially in deeper structures. The low spatial resolution is attributable to the electrodes on the scalp which can't pick up electrical signals that reside much beyond the cortex (Morin, 2011). Although EEG has poor spatial resolution compared to fMRI, EEG has a far superior temporal resolution. As a result, EEG is well adopted in neuromarketing to understand time-sensitive questions rather than spatially located questions. In general, EEG is a technique of measurement of voltage fluctuation at surface of scalp, it has a good temporal resolution and relative low equipment cost. However, EEG has very limited potential for locating brain areas which are responsible for voltage fluctuations.

Event-related potentials (ERPs) are presented as significant voltage fluctuations resulting from evoked neural activity by a stimulus. The same stimulus is presented repeatedly, and the pattern of electrical brain activity recorded by several scalp electrodes is averaged to produce a single waveform. This technique allows us to work out the timing of various cognitive processes. By making maps of the ERPs at different times after the stimulus event, the relative times at which certain brain areas become active in processing information can be determined.

ERPs are triggered by a stimulus, a response, or a physiological event (Bickford, 1987), and ERPs provide a suitable approach for studying the aspects of cognitive processes of both normal and abnormal nature; for example, in neurological or psychiatric disorders (Picton et al., 2000). Moreover, ERPs are capable of capturing mental operations with processing time ranges in the order of tens of milliseconds, this includes those involved in perception, selective attention, language processing and memory.

Contrasted with spontaneous EEG components, the amplitudes of ERP components are often much smaller, so they are not capable of being recognised easily from raw EEG traces. They are extracted from set of single recordings by digital averaging of epochs (recording periods) of EEG time-locked to repeated occurrences of sensory, cognitive, or motor events (Gevins, 1987). The spontaneous background EEG fluctuations, which are random relatively to time point when the stimuli occurred, are averaged out, leaving the event-related brain potentials. These electrical signals reflect only that activity which is consistently associated with the stimulus processing in a time-locked way.

2.2.4 The issue of reporting neuroimaging

Neuroscientific applications of brain imaging generally pose questions about the relationship of brain and behaviour in one of two directions - forward or reverse inference.

The approach well adopted even up to date by the neuroimaging research, namely 'forward inference' by Henson (Henson, 2006). Forward inference related studies examine the anatomical, neural correlates of a given mental operation and are often used to investigate localization questions - that is activations in different conditions are compared and regions that show differences in activation between those conditions are inferred to take part in corresponding mental process (Aguirre, 2014).

Neuroscientific studies also examine the relationship between brain and behaviour in the "reverse" direction. Reverse inference related studies leverage knowledge about the neural correlates of particular mental states to learn something about an imperfectly understood behaviour. One begins by assuming that neural activity in a particular area of the brain is a marker of the presence of a particular mental state and no other (Aguirre, 2014).

Reverse inference has been increasingly employed to analyse neuroimaging data to infer mental process in neuroeconomics and cognitive neuroscience. However, it reflects the logical fallacy of affirming of consequent. Such claims are deductively true if only the specific mental process results in the activation in the region of interest; however, the activations of brain region observed with fMRI are usually activated by a wide range of mental tasks. This means that reverse inference is a useful tool to drive subsequent behavioural or neuroimaging studies, rather than a direct means to interpret neuroimaging results (Poldrack, 2008).

Reverse inference is an informal approach to predicting mental states from neuroimaging data. In order to increase the accuracy of mental process prediction, pattern classification methods have been used and associated with standard statistical approaches. Pattern classification methods focus on quantification of information presenting in the neuroimaging signal across a large-scale network (Poldrack, 2008).

2.3 Neuromarketing and neuroeconomics

2.3.1 The introduction of neuromarketing

Neuromarketing describes the application of cognitive neuroscientific tools in marketing to measure consumers' responses, and it is now being integrated into mainstream market research, complementing insights derived from traditional explicit tools to reveal how consumers really feel (Calvert & Brammer, 2012). It has been defined as "the application of neuroscientific methods to analyse and understand human behaviour in relation to markets and marketing exchanges" (Lee, Roderick, & Chamberian, 2007).

BrightHouse, an Atlanta advertising firm, first used the term 'neuromarketing' in an article published in June 2002. The firm, which sponsored the interference of neurophysiologic research into marketing fields, established a business division that uses fMRI for marketing research purposes. However, their work was criticised by an anti-advertising civic group due to the promotion of junk food. Although BrightHouse sought help from Human Research Protections this was followed by investigation of their research by the United States senate, BrightHouse Neurostrategies's Website was masked off and this led to this young enterprise drawing less public attention since then (Fisher et al., 2010).

However in recent years, there has been a sharp rise in experimental studies applying neuroimaging methods to marketing, with the intention of uncovering hidden information about consumer experience and unconscious consumer behaviour that are never easily or even impossibly obtainable through conventional marketing methods. The incorporation of neuroimaging into decision making sciences in academic research has spread to the realm of marketing research (Ariely & Berns, 2010). The combination between cognitive neuroscience and marketing has resulted in creating a new interdisciplinary field and generated a well-known set of studies on neuromarketing and consumer neuroscience (Fugate, 2007). One experiment was carried out by using functional brain scanning to find correlations of people's preference for Coke and Pepsi (McClure et al., 2004). Participants were required to perform two tests. First test is anonymous taste test which is carried out outside the scanner. The test required subjects to make choice to indicate their preference for "soda" in one of two unmarked cups (one cup contained Coke and the other contained Pepsi). The other task was carried out in the scanner, and then following by the examinations of two conditions including: (1) anonymous delivery of Coke and Pepsi, and (2) brand-cued delivery of Coke and Pepsi. In the scanner, subjects were trained to expect Coke and Pepsi at fixed time following distinct cues. Following training, in anonymous groups, the predictive visual cues were flashes of yellow and red light, counterbalanced and paired with subsequent Coke and Pepsi delivery. In semi-anonymous groups, the two fluids were identical (both either Pepsi or Coke). One of the cues was anonymous (yellow or red light), and the other provided brand information (picture of a Coke can or a Pepsi can). For the anonymous task, the result reported a consistent neural response in the ventromedial prefrontal cortex that correlates with subjects' behavioural preferences for these beverages. In the brand-cued experiment, brand knowledge for one of the drinks had a dramatic influence on expressed behavioural preferences and on the measured brain responses. McClure et al. (2004) showed much stronger fMRI activation of brain areas associated with emotion and motivation when participants were cued with the "Coke" brand – even though both cups contained the same drink. Neuroimaging can help uncover hidden information regarding unconscious consumer behaviour, because it is an implicit measure.

Another illustrative example of a neuromarketing fMRI experiment was performed by Kühn, Strelow, and Gallinat, (2016) to forecast consumer behaviours to chocolate bars in a supermarket through the measurement of the corresponding data from explicit interviews, fMRI data and real product sales (Kühn, Strelow, & Gallinat, 2016). Six chocolate bar

communications displayed as pictures (i.e. group, couple, hands, hands with text, women and toothbrush) were shown to participants to collect the fMRI data and self-reported liking judgements. During the fMRI experiment, participants were presented with different pictures including product pictures as well as six different communications. After scanning, the authors obtained the data from ranking the ads of liking on the same products. Authors hypothesized that fMRI activation of nucleus accumbens, medial orbitofrontal cortex, amygdala, hippocampus, inferior frontal gyrus, and dorsomedial prefrontal cortex would correlate positively with sales and that activation in dorsolateral prefrontal cortex and insula would correlate negatively with sales. As a result, the explicit interview indicated the rank order of inclination was hands without text, toothbrush, couple or group, women, hands with text. Bold signal extracted from eight regions of interest and computed by means of their a priori proposed fMRI-derived sales prediction value showed the rank order as follow, group first, then women, toothbrush, couple, hands without text, and hands with text ranked last. BOLD signal changed from seeing the product after compared to before the communication rank order was the couple ranked first, followed by the group, the woman, hands with text, toothbrush and then the hands without text. However, the actual sales in supermarket were offered on a quarter palette with the corresponding communication in the back, rank order measured was: group, women, couple, toothbrush, hands with text, hands without text. In terms of forecast, both a rank order based on the signal during communication viewing and signal based on the changes during product viewing after as compared with before the communication were more accurate than the explicit self-report judgement.

2.3.2 The relationship between neuromarketing and neuroeconomics

Economics has begun to utilise neuroimaging techniques in its research – resulting in the creation of another interdisciplinary field, 'neuroeconomics'. Neuroeconomics defines itself as "the application of neuroscientific methods to analyse and understand economically relevant behaviour" (Kenning & Plassmann, 2005). Neuroeconomics is the study of the neurobiological and computational basis of value-based decision making (Rangel, Camerer, & Montague, 2008).

Neuroeconomics is a new transdisciplinary field focusing on analyses brain activity when people calculate risks and evaluate rewards, and utilizes brain-scanning technology to study the procedure of decision makings, and how people evaluate personal choices and even

decide which products to buy (Belden, 1990). Contrasted with neuroeconomics, traditional economics has paid more attention on how to maximize people's desire. According to the traditional view, when people make economic decision, for instance a purchase decision, they rely primarily on the personal preferences (Yokoyama et al., 2014). However, microeconomic theory proposed that purchases are driven by a combination of consumer preference and price. Knutson, Rick, Elliott Wimmer, Prelec, and Loewenstein, (2007) carried out a research study aiming to find out whether distinct neural circuits respond to product preference versus excessive prices, and to explore whether anticipatory activation extracted from these regions could independently predict subsequent decisions to purchase. The hypothesis was that purchase decisions involved a trade-off between the potential pleasure of acquisition and the pain of paying. The results, consistent with neuroimaging evidence, suggested that distinct circuits anticipated gain and loss: product preference activated the nucleus accumbens (NAcc), while excessive prices activated the insula and deactivated the mesial prefrontal cortex (MPFC) prior to the purchase decision. In addition, these findings also suggested that even commonplace purchasing decisions could be deconstructed with methods adopted from psychology, economics, and neuroscience (Knutson et al., 2007).

Currently, both neuroeconomics and neuromarketing are crucial fields to assist with understanding of the decision making process. Neuromarketing can be defined as a subset of the study of neuroeconomics which combines neuroscience, genetics, economics and psychology to understand how specific neuron activation may lead to large scale market behaviour. Conversely, based on many core methodological principles and classical models derived from economics to neuroscience, neuroeconomic research could lead to new interpretation for the mechanism of decision making studied by neuroscience (Levallois et al., 2012). While both neuromarketing and neuroeconomics involve the use of neuroimaging tools, neuromarketing focuses on the aspect of selling products to consumers and how to create superior products or profound advertisements to attract consumers' purchasing power and attention. The use of neuroimaging technology provides insights that may help scientists and marketers understand consumers' mind to find the motives behind their purchases.

These are two new lines in understanding the decision making process, namely neuroeconomics and neuromarketing; moreover, both neuroeconomics and neuromarketing are new emerging interdisciplinary fields that study how people make decision at the

interface between neuroscience, psychology, economics and marketing. One in an immersive context, the economic one and the other, customizing, focuses on how consumers make a decision to buy. Furthermore, both disciplines highlight the link between the decision-making process and the brain regions involved in its development. Using neuroscience specific methods, the above two disciplines offer a new vision of the decision-making process.

2.3.3 The strengths and weaknesses of neuroscience methods applied to consumer behaviour

Neuroscientists have long sought to study the dynamic activity of human brain, that is, when people are thinking, feeling and acting, what is happening in the brain. There are many interventional procedures that examine the relationship between brain and behaviour, such as EEG, fMRI, MEG, PET and so on. Moreover, these tools have now become both more precise and much more widely used. However, these tools also reveal some advantages and disadvantages when applied to consumer behaviour.

2.3.3.1 Strengths

The brain measurement techniques explained in previous sections are powerful and effective tools, well adopted by academics and industry to address big questions relevant to how marketing works and to improve marketing more accurately rather than using traditional tactics. Researchers from different knowledge backgrounds such as behavioural economics, finance, marketing and even politics, are now looking forward to employing neuroscience to provide insights into the peculiarities of choice that often plague their own domain (Seymour & Dolan, 2008).

Contrasting what customers buy with why they buy, the former is relatively easier for business to keep track of, however the latter is much too sophisticated to be figured out. That is the strength of neuromarketing, which uses the tools of neuroscience to determine why customers prefer some products over others, and researchers is endeavouring to use neuroimaging to unlock the mysteries of consumer choice and get a better deep understanding of how our brain influences the way we think, feel and act.

The potential functionalities of these tools are able to provide further investigations in order to add insight to the survey-based researches, marketing and consumer behaviours. The major advantage of neuroscience methods is that apply these brain-imaging techniques in the marketing by offering a better accuracy of prediction in terms of consumer acceptance of new brands, products and campaigns at a speed that makes them accessible as routine pretesting tools that will clearly demonstrate return on investment (Calvert & Brammer, 2012).

Although neuroscience methods are unlikely to be cheaper than other conventional tools in the near future, there is already growing evidence, on basis of ongoing research, that it may provide hidden information about consumer experience. The contribution of neuroscientific methods can make and boost understanding of marketing-relevant human behaviour is likely to be considerable.

2.3.3.2 Weaknesses

Although neuromarketing will provide insights into the consumer brain, however, when used incorrectly, neuromarketing might be invasive to consumers, and results might be easily manipulated by marketers and misunderstood by readers. Some disadvantages of neuroscientific method are listed as following:

The first limitation is that the design of experiments using most neuroscientific methods is not ecologically valid so far. Take fMRI method as an example, when performing an fMRI experiment, participants must be laid down inside the machine, which is not conductive to eliciting the same reaction as watching a TV advertisement at home or shopping in a store. Portable EEG, eye-tracking and near infrared spectroscopy (NIRS) may be less subject to these limitations.

The second limitation may occur when interpreting captured neuroimaging results using reverse inference from brain activations to brain functions. When researchers use fMRI as a measure of brain activity while a subject is performing a specific task, traditionally, these data then allow inferences of information about the role of a specific brain region in brain function (Poldrack, 2006). However, research increasingly uses fMRI data to infer in the opposite direction by concluding that a specific cognitive function is present, based on the activation of an identified brain area. Researchers should use caution in making reverse

inferences, especially when theory-based confidence in the engagement of function in a specific brain area is low (Reimann, Weber, & Neuhaus, 2011). In fact, the value of neuroscience is highly dependent on interpretation.

The last limitation is that neuroimaging tasks have a restricted level of complexity which may lead to seem simpler than other behavioural experiments or surveys. Since stimuli must be repeated to gain enough data per subject, the number of manipulations is limited, lowering task complexity and, therefore, focusing the research project on more essential questions (Reimann, Weber, & Neuhaus, 2011).

Chapter 3 The Influence of Magazine Context and Car Model on A "Desire to Purchase" Decision: Behavioural Study

3.1 Previous research on contextual effects in consumer behaviour: research aims and hypotheses

The interdependence of emotions and body state and their important impact on behaviour was realized already in the 19th century by the American philosopher and psychologist William James (James, 1884). A system-level neuroanatomical and cognitive framework for the influence of emotions on decision making has been proposed by Damasio in his somatic marker hypothesis (Damasio, 1994).

In the homogeneous product society environment, a homogeneous product is one which is indistinguishable from competitors other than by brand and price. However, a heterogeneous product is one where competing products differ from one another in their intrinsic properties such as design, material composition and performance. It might be argued that cars are heterogeneous, but within general car categories, such as "5-door family hatchback", competition between different manufacturers has led to increasing homogeneity, increasing the importance of subjective rather than intrinsic properties. Because brand positioning, advertising strategies and even pricing strategies are often based on constructing such as emotions, thus neuropsychological findings and methods should have important implications for practitioners in the field of brand management and advertising (Kenning, Plassmann, & Ahlert, 2007). Recently, merchants have paid more attention to the scientific pursuit of an objective and accurate approach to predicting consumer's tendency of decision making for purchase.

The prediction of product choice is considered not to be mainly due to global evaluations of attractiveness but might reflect automatic choice-related processing itself. Many cognitive factors as well as their interactions with automatic valuation processes might contribute to a complex choice. (Tusche, Bode, & Haynes, 2010). Figure 3.1 shows such a hypothesis on complex interaction involved in decision making.

Figure 3.1 - Diagram of the hypothesized interaction involved in buying decisions (based on suggestions of Bechara et al. 1997)

For products with equal quality, brand information plays an important role to distinguish one product from others, and it turns out that, social information has more influence on consumers' decision making. In particular, a consumer's tendency to purchase a product is influenced by the choices made by his associative reference group (Berns et al., 2009). The social information includes a variety of formats, such as recommendations from friends, comments suggested from experts, advertisements from TV commercial and poster, and the sales volume information in public.

In the previously mentioned research from Berns et al. (2009) they were interested in identifying the mechanism whereby social information effects consumption decision, and they chose adolescents as subjects to figure out the influence of popularity on adolescent ratings of music. Based on the above case study, I would like to find out whether advertisements displayed within magazines have any influence on consumers' preference in my current research.

The aim of this research is to find out how advertisements in the different formats will have any influence on consumers' decision making of cars preferences. More specifically, the tests will be carried out on how people respond to car information from car magazines, fashion magazine compared to plain images of cars, respectively.

Provisional hypotheses of this research are that car photos considered as stimuli chosen from advertisements, whether from "other interest" magazines or auto magazines, would have a higher level of influence on preferences compared to the photos of the same or similar cars in everyday use. The second hypothesis will be focusing on whether the car photos chosen from the car magazine has different influence on preference of car purchasing compared the ones from (for example) a fashion magazine. The above arguments will be clarified by analysing data obtained from a behavioural experiment.

3.2 Experimental methods

3.2.1 Participants

12 male participants, age in the range from 20 to 40, have taken part in the behavioural study. Ethical approval was obtained from the psychology ethics committee and the experiment was conducted in line with British psychological society ethical guidelines.

3.2.2 Stimuli and materials

In terms of the images used in the study, these were originally obtained from Google Images websites but with some sort of modifications in order to suit the purpose of this study. Figure 3.2 shows an example of modifications made on images (a) the original image and (b) the modified image. The 12 car models were selected to be roughly similar in price range (from £35,000 to £80,000) and body type (either 4-door saloon or 2-door saloon) and model years range (from 2013 to 2016). The decision making task was conducted using stimuli with 3 image attributes for each car-model: plain images, car magazine advertisements and fashion magazine advertisements, which are the pictures shown to participants (see Figure 3.2). Those images are uploaded and presented using e-prime software.

(a) (b)

Figure 3.2 - An example of (a) original image and (b) modified image

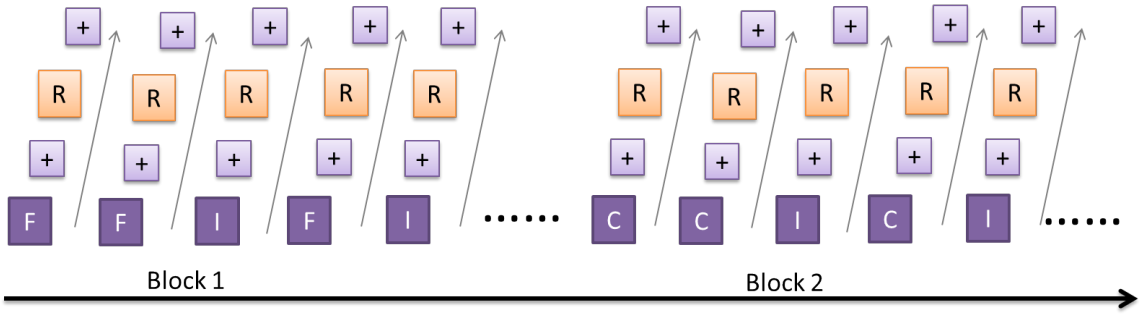
3.2.3 Experimental design and procedure

The purpose of this behavioural study is to test the factors that make a product shown as an image desirable to a prospective buyer. The independent variables were the context, which had 3 values, fashion magazine, car magazine and plain; and car model (12 models). Each car model appeared in all three contexts. Order of contexts was counterbalanced between participants. The dependent variables were desire to purchase (yes or no) and reaction time.

Before the tests, the participants read and signed the consent form and were given the instructions. The participants were also instructed to give an overall rating of how much they like the car. In addition, the instructions asked the participant to assume for the experiment that the participant had enough money to purchase the car.

Figure 3.3 shows the flow procedure of the task. The whole run has two blocks. Block 1 has 12 fashion magazine advertisements and 12 plain images and Block 2 has 12 car magazine advertisement and 12 plain images. Each attribute has 12 images and each image displays 4 seconds. The letter of 'F' represents fashion magazine advertisement, 'C' represents car magazine advertisement and 'I' represents plain image and 'R' represents for decision making rating. Between each image displayed to the participant, the decision making have 1 second fixation. Moreover, all types of image displayed in a random sequence. The

participant makes their rating after the image being displayed, by selecting either a key 1 (yes) or a key 0 (no) on a keyboard when the slide asks them to give rating.



1 Run = 2 Blocks = (12C +12I) + (12F+12I) = 48 Decisions

Figure 3.3 - Buying decision-making task. The letter "F" represents fashion magazine advertisement, "C" represents car magazine advertisement, "I" represents plain image and "R" represents for decision making rating. For detail, see text

3.3 Results

The pictures shown to participants have been categorized into three types – plain images, car magazine ads and fashion magazine ads. The mean "intention to purchase" scores are shown in the following Table 3.1. The numbers represent the intention as a probability of purchase (between 0 and 1).

Table 3.1 - The mean rating of three contexts

Subject	I (Plain images)	C (Car magazine ads)	F (Fashion magazine ads)
1	0.5	0.25	0.33
2	0.38	0.42	0.33
3	0.38	0.5	0.33
4	0.58	0.17	0.33
5	0.67	0.25	0.58
6	0.42	0.33	0.33
7	0.33	0.25	0.33
8	0.54	0.42	0
9	0.75	0.67	0.75
10	0.67	0.58	0.58
11	0.58	0.25	0.58
12	0.46	0.58	0.58

A one-way correlated analysis of variance on the mean probability of purchase across all car models shows the social information effect for three conditions, $F(2, 22) = 3.30$, $p = 0.056$, partial $\eta 2 = 0.23$. Since this value is bigger than 0.05, the conclusion can be drawn that there is no significant difference on the mean intention to purchase for the three conditions. However, since the p (obtained) is close to the critical value of p, we can say that there is a non-significant trend for the context to influence the rated likelihood of purchase. This could be supplemented by an analysis of variance summary Table 3.2.

Table 3.2 – The analysis of variance summary

Source of variation	Sum of squares	Degree of freedom	Mean square	F-ratio
Conditions	0.12	2	0.57	3.30*
Residual error	0.38	22	0.17	

Note: Marginally non-significant at 5% level

The mean scores in Table 3.3 indicate that the highest likelihood of purchase occurs in the I (no context) condition. Within-subjects' simple contrasts (Table 3.4) in ANOVA shows a significant difference between the I (no context) and the C (car magazine) condition, $F(1, 11) = 6.11$, $p < .05$. The difference between the I and F contexts does not reach significance.

Table 3.3 - Within subjects factors

(a) Measure: MEASURE_1

Factor 1	Dependent variable
1	I
2	C
3	F

(b) Descriptive statistics

	Mean	Standard deviation	n
I	0.5217	0.13306	12
C	0.3892	0.16373	12
F	0.4208	0.19916	12

Table 3.4 - Tests of within subjects contrasts

Measure: MEASURE_1						
Source	**Context**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Content	Level 2 vs Level 1	0.211	1	0.211	6.114	0.031
	Level 3 vs Level 1	0.122	1	0.122	4.405	0.060
Error (Content)	Level 2 vs Level 1	0.379	11	0.034		
	Level 3 vs Level 1	0.305	11	0.028		

As the decision to purchase variable is inherently binary, a more detailed analysis of results can be carried out using binomial logistic regression. This allows the variance due to different preferences for different car models, and the order of presentation of the blocks, to be taken into account.

Table 3.5 - Variables in the equation

		B	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**
Step 1[a]	Context			8.866	2	0.012	
	context (1)	-0.603	0.221	7.467	1	0.006	0.547
	context (2)	-0.442	0.219	4.075	1	0.044	0.643
	car_model			54.648	11	0.000	
	car_model (1)	0.087	0.416	0.043	1	0.835	1.091
	car_model (2)	0.344	0.416	0.686	1	0.408	1.411
	car_model (3)	1.069	0.432	6.119	1	0.013	2.912
	car_model (4)	-0.653	0.436	2.239	1	0.135	0.521
	car_model (5)	-0.088	0.419	0.044	1	0.834	0.916
	car_model (6)	0.259	0.416	0.387	1	0.534	1.295
	car_model (7)	-0.986	0.456	4.682	1	0.030	.373
	car_model (8)	0.259	0.416	0.387	1	0.534	1.295
	car_model (9)	1.069	0.432	6.119	1	0.013	2.912
	car_model (10)	0.876	0.425	4.249	1	0.039	2.402
	car_model (11)	-1.244	0.476	6.833	1	0.009	.288
	order	0.428	0.179	5.727	1	0.017	1.535
	Constant	-.640	0.408	2.458	1	0.117	0.527

Note: a. Variable(s) entered on step 1: context, car_model, order

The dependent variable in the regression model was likelihood of purchase (0, 1). The predictor variables were context (no context, fashion magazine, car magazine), car model (12 different models were presented) and order of presentation.

The Backward (Wald) method of model selection was used. Context and car model were coded as categorical variables. The final regression model indicated that the context and the order of presentation were significant predictors of the likelihood of purchase. The car model was also a significant predictor. The final regression model is shown in Table 3.5. The regression model was 68.9% correct in predicting "unlikely to purchase" (0) and 65.2% correct in predicting "likely to purchase" (1). The model explained 12.3% (Cox and Snell R-square) of the variance in the likelihood of preference and correctly classified 67.2% of cases.

3.4 Discussion and conclusions

The ANOVA showed a marginal overall effect of context on likelihood of purchase, which was significant only when comparing the car magazine with the no context condition. However, the binary logistic regression allowed a more complete analysis of possible sources of variance.

The binary logistic regression showed that the car model was a significant predictor at the $p < .0005$ level. Models 3, 9, and 10 were significant predictors of likelihood of purchase at $p<.05$ and models 7 and 11 were significant predictors of unlikelihood of purchase at $p < .05$ and $p<.001$ respectively. The context of the car image was also significant at $p < .05$, and the two magazine contexts were separately predictors of unlikelihood to purchase at $p<.05$ (negative B). There was separately a significant effect of presentation order at $p<.05$ which is a general order effect, orders of conditions being counterbalanced overall. Likelihood of purchase was rated higher on the second block.

The present findings of the behavioural study, show that there was a small but significant difference in the preference for a car depending on whether the image appears among advertisements in car magazine, fashion magazine and plain images of car. The mean value of likelihood of purchase of the plain images was higher than in the context of car magazine and fashion magazine. However, the car image in the fashion magazine did have slightly higher rating of likelihood of purchase compared to the same image in a car magazine.

There are five possible reasons to explain the unexpected results as follows:

(1) The image quality of the different experiment design contexts is different, and this might have influenced consumers' recognition and responses.

(2) The experiment design context is not ecologically valid as it would be if participants were reading a magazine. In other words, the aim of experiment design to manipulate the context is not as effective as it would be in the field.

(3) All Participants were males. The result can't represent all people's decision making performance, because females and males may have different emotional responses and choices to the cars and contexts in this experiment.

(4) The experiment subject are cars - a luxury article, meaning that people will have a special feeling or emotion for each type of car, which leads to some participants focusing on the car itself and ignoring the different contexts. The fact that car model was a significant predictor may reflect the heterogeneity of cars as a product.

(5) The negative effect of magazine contexts could well be a real effect. For example, the plain images could be more direct – cars are obviously designed to produce a pleasurable visual effect. People may read car magazines because they want more information on which to base their decision and this may be to eliminate cars that only look good but don't perform as well. So a car magazine may appeal to their critical faculties resulting in lower "likely to purchase" responses.

The first experiment showed a reliable effect of brand/model on likelihood to purchase, but also an effect of the context in which a product is presented. To explore these effects further, it was decided to look more closely at brand/model effects by quantifying the market popularity of different brands with reference to actual sales volumes. Also to look at what is intuitively the strongest "contextual" influence on preference for a product, namely the product's price. Finally, the impact of product images on the potential consumer would be studied with covert (fMRI) as well as behavioural (inclination to purchase, product ratings) methods.

Chapter 4 Effect of Sales Volume and Price Offer on Decision Making of Food Products: fMRI Study

4.1 Introduction

Despite a decade of research there are many unresolved issues about the brain process underlying purchase decisions, for example, which brain networks are involved, and how these networks relate to different sub-processes in decision-making. To address this question, functional magnetic resonance images (fMRI) were acquired while subjects (n = 20) made choices during a stimulated purchase decision experiment, which was designed to assess the effect of brand sales volume and pricing information. Behavioural data indicated that only pricing information of packaged and branded snack products influenced decisions. Increased fMRI activations in left and right insula; frontal pole; putamen; and visual cortex were related to brand sales volume. However, the neural correlates of pricing information did not reach significant levels of activation in factorial ANOVA of fMRI data. The data are interpreted as showing that the sales volume of products influences brain areas associated with emotional processing during a purchase decision task.

4.1.1 Previous fMRI experiments on simulated purchase

Research into purchase decisions has identified that people normally combine several factors linked together, some factors inherent in the features of product itself, such as price, quality, durability and so on; while others are attributes of consumer themselves, examples like goals, attitudes, discretionary income (Venkatraman et al., 2011). In order to understand and predict consumer choice, researchers in the fields of psychology, economics, and marketing have proposed various models that explain how trade-offs between the emotions associated with products and the price, and many other characteristics are evaluated in multi-attribute decision making (Khan, Zhu, & Kalra, 2011; McFadden, 1986; Tversky, 1972).

The multi-attribute approach is often subsumed into a dual-systems model. In dual-systems models, two semi-autonomous cognitive or neural systems contribute to a decision outcome, and the balance between these systems varies according to a variety of external and internal inputs. Chaiken et al. (1999) share the foundational view that human perception and behaviour are guided by two principal types of processing: emotional processes (often referred to as "affective" or "automatic" processes) and cognitive processes (often referred to as "rational" or "controlled" processes) (see also Loewenstein & O'Donoghue, 2004; Strack & Deutsch, 2004). There are various versions of the duality, but a typical formulation is the traditional two-system model, in which a "cold", rational, far-sighted cognitive system battles against a "hot", irrational, short-sighted emotional system (Seymour & Dolan, 2008).

Neuroscience studies are of interest because they seem to offer a direct method of accessing and visualising the internal states that underlie decision making, and assessing the factors that influence those states. For example, they may help to deeply understand how choice processes are modulated whether externally e.g., in the framing of problem or internally e.g., through mood, or memory (Venkatraman et al., 2011) or by various contextual changes. An example of a neutrally-inspired theory of decision making is the Somatic Marker hypothesis formulated by Damasio (1994) which emphasises the importance of feelings in decision making, and explains the decision making process based on a system-level neuroanatomical and cognitive framework. The key point of this hypothesis is that the decision making is a process influenced by marker signals which arise from bioregulatory processes, including processes that express themselves in emotions and feeling. The influence can be operated at conscious and non-conscious levels.

While the emotional processes are often described as fast, associative, and intuitive, they often take place unconsciously. Oppositely, the cognitive processes are slower, rule governed, and effortful, and usually require concentration (Kahneman, 2003; Weber & Johnson, 2009). The two systems associated with these processes are connected and interact with each other (Strack & Deutsch, 2004). Some scholars constantly argue that the effect that emotions impose on cognition is stronger than the effect that cognition imposes on emotions, which is consistent with the view that emotionality, as a driver of decisions, preceded the development of cognition in human evolution (Loewenstein & O' Donoghue, 2004).

A number of previous fMRI studies have examined neural correlates of the different factors influencing consumer decisions. Knutson et al. (2007) looked at the influence of consumer

preference and price on purchase decisions. In the first interval of each trial they presented an image of the product, in the second interval they added price information, and in the third interval the participant made a decision to purchase or not. Activation during the first interval included anterior cingulate, medial frontal and insular cortex as well as N. Accumbens. Areas influenced by pricing included frontopolar, orbitofrontal and insular cortex. The separation of processing of product image and price was reinforced by the delayed presentation of pricing information. This result would give some support to a neural dual-systems model (Knutson et al., 2007).

Other studies have looked at contextual factors in purchase decisions. Yokoyama et al. (2014) conducted a purchased decision task, to test the effect of social risk (i.e. the anticipated disapproval of others) on making purchases. fMRI data were obtained while subjects rated the purchase intention and social risk. Activation in the left anterior insular cortex was positively correlated with subjective rating of social risk during purchase intention task (Yokoyama et al., 2014). Cherry et al. (2015) also applied a purchase decision making task, which aim to find out the influence of "price condition" and "production method condition" (consumers' ethical concern about the wellbeing of hens in egg production) on the food-related decision making. A series of fMRI scans were conducted while participants undertook food-related decision task which manipulated price and production method conditions. Contrary to the researchers' hypothesis, the result showed that the more consumers take ethical concern into consideration, the less they may rely on neurofunctional activity in the left dorsolateral prefrontal cortex. Cherry et al. (2015) had originally argued that activity in this area correlates with ethical decision making, and to explain their paradoxical result they proposed that making ethical purchase decisions is more routine for those with high ethical concerns, it therefore becomes a more perfunctory process requiring fewer cognitive resources (Cherry et al., 2015).

An important point for the present study is the distinction between an individual's liking for a product and its sales volume in the population or peer group to which that individual belongs. A study by Berns et al. (2010) found that brain activations in anterior insula and anterior cingulate, recorded while listening to a song recording, could be influenced by providing information on the song's sales volume. Berns and Moore (2012) followed up by using fMRI to predict sales volume, that is, the extent to which a product is popular in the wider population rather than an individual purchase decision. They found that activity in ventral

striatum recorded three years earlier was correlated with subsequent sales of recordings (Berns & Moore, 2012).

The purpose of the present study was to expand on a purchase decision task, examining the neurofunctional correlates of preference and pricing information in a simulated purchase task. In addition to analysing data according to purchase decision and whether prices were discounted, products were rated as higher or lower in sale volume on the basis of published sales volume figures. The aim of this study is to evaluate the effect of sale volume and price offer on neural activation in decision making.

In addition to an exploratory, whole-brain, random-effects factorial analysis of task variables, a specific hypothesis was that brand sales volume, would activate affective systems in the brain. Thus, fMRI data was extracted from a priori selected brain regions: amygdala and insular cortex, which have both been associated with emotional feelings. Activity in the amygdala has been implicated in emotional learning and emotional processing (Morris et al., 1998). Activation in insula cortex is often associated with self-awareness and introspective perception, and it has also been linked with emotional sensory experiences, specifically with negative emotions like disgust and with norm violations (Craig, 2009; Jabbi et al., 2008).

4.1.2 Research aims and hypotheses

This research aims are: firstly, to examine whether choice behaviour of participants in a stimulated purchase experiment reflects the actual sales of products in the wider population. Secondly, it will determine whether the UK sales volumes of snack foods differentially affects brain activity, and whether this effect is related to, or independent from, the individual's purchase decision. Thirdly, it will assess the influence of pricing information, including discounts, on choice behaviour and brain activations.

In addition, Snack food was chosen as stimulus to carry out the experiment in this research. To choose a suitable as well as accurate stimulus can be considered as extremely important as the design of experiment itself. The reasons for using snacks as stimuli are three fold, as follows:

(1) Based on the evolutionary perspective, the ability to identify, select and evaluate food-related stimuli is of fundamental survival value, and it is likely therefore that brain power will be allotted to it;

(2) It would be fairly straightforward to design a study that varied cognitive aspects as the primary manipulation to achieve in this research;

(3) Food marketing is important commercially and everyone is quite often interested in food. Therefore, the participants without specialist knowledge are also applicable to this research.

4.2 Methods

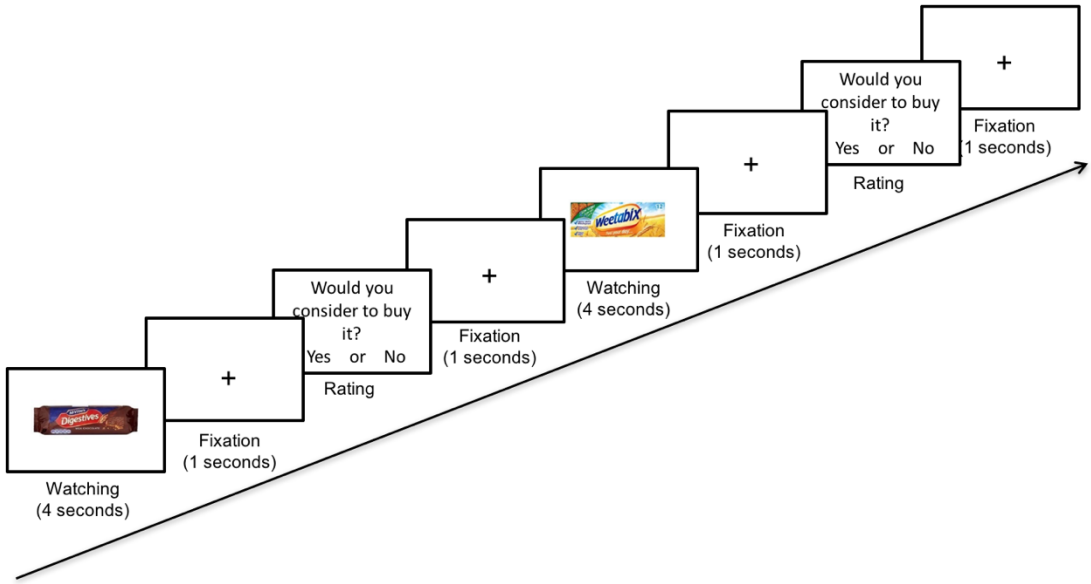
4.2.1 Participants

20 participants aged from 18 to 34 years old (13 females) were recruited through posting advertising on University notice-board and websites. Each participant was provided £20 for their time and effort. All participants were in good health without any previous history psychiatric or neurological diseases. All participants provided their written informed consent as part of a protocol approved by the Brunel University Department of Psychology Ethics Committee and were informed of their right to withdraw. fMRI Procedures were conducted according to the rules of operation of the Combined Universities Brain Imaging Centre.

4.2.2 Stimuli

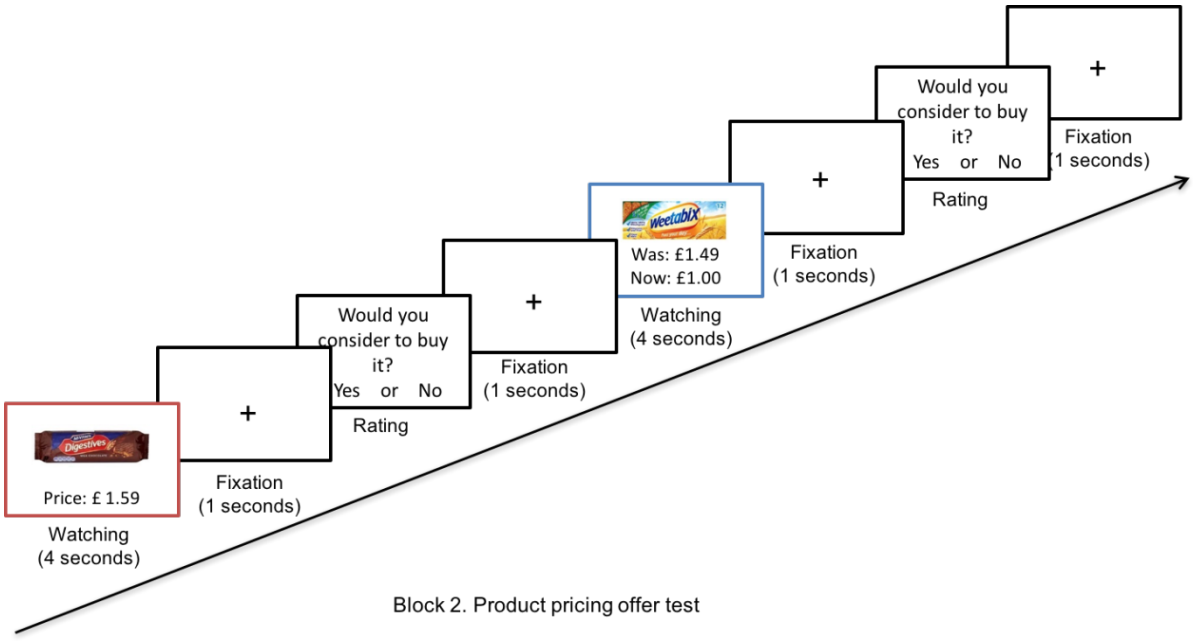
A total of 80 images of packaged food products were used as stimuli. These consisted of 40 higher sales volume products (shortened as H), and 40 lower sales volume products (shortened as L). The first block was the image-alone condition, in which the 80 images alone were presented in random order, and participants indicated whether or not they were inclined to purchase the item. And the second block is an image + pricing condition, in which exactly the same 80 products were presented in a different random order and with pricing information included on the slide: higher sales volume products were presented with their original price displayed (shortened as HP), whereas with lower sales volume products a price discount was shown (shortened as LP) see Figure 4.1(a) and (b). Again, participants indicated their inclination to purchase. Sales volumes were assessed from statistics posted on the Internet, such as Statista (2013), The Richest (2013), Food Manufacture (2014), Confectionery News (2014), Dairy Reporter (2013) as well as Market Research Resources (2015). These sources generally show ranked sales volumes for products within a category (e.g. soft drinks or

biscuits) so that it was possible to select higher and lower ranked products per category. The order in which product images were presented was randomized across participants.



Block 1. Product popularity test

(a)



Block 2. Product pricing offer test

(b)

Figure 4.1 - Buying decision making task: (a) in Block 1 of the experiment images with no pricing information were shown; (b) in Block 2, the higher sales volume products were displayed with original price (red frame) and the lower sales volume products displayed with discounted price (blue frame) n.b. frame colour is for indicative purposes and did not occur in the experiment

4.2.3 Procedure and design

Prior to entering the scanner, participants were verbally advised to avoid head movements during scanning procedure. Inside of scanner, head fixation was maintained using foam pads. Earplugs were provided to protect against scanner noise but allowed communication between scans. Subsequently, the participants underwent two functional scans lasting about 30 minutes in total. The first functional run was the image-only session and the second run was the image + pricing session. In both phases of the study, each photo of a product was presented for 4 seconds. Timing for each trial period was intentionally limited to minimize distractions and maximize affective engagement in the task (Knutson et al., 2007). Participants performed a food-related decision making task in the scanner. Participants were asked to make a choice of 'yes' or 'no' for each question to indicate whether they would consider to buy the products or not. Their responses in the scanner were recorded by pressing right and left button. Accordingly, the following eight conditions are modelled in the GLM according to the participants' responses: yes for higher sales volume stimuli (Yes_H); yes for lower sales volume (Yes_L); yes for higher sales volume with showing price (Yes_HP); yes for lower sales volume with showing price (Yes_LP); no for higher sales volume (No-H); no for lower sales volume (No_L); no for higher sales volume showing price (No_HP); no for lower sales volume showing price (No_LP). All participants completed a questionnaire after scanning to give brief demographic details (e.g. age, gender) to provide confirmatory information on rating their preference for all food products presented in the experiment, and to rank the factors affecting their choice.

4.2.4 Functional imaging data acquisition

The study was conducted on a MAGNETOM Trio 3T scanner (Siemens Medical Solutions; Bracknell, UK) using Siemens' integrated parallel acquisition technology (iPAT), which was deployed with a generalized auto calibrating partially parallel acquisitions (GRAPPA) acceleration factor of two, via a Siemens eight-channel array head coil. For each functional run, an ultra-fast echo planar gradient-echo imaging sequence sensitive to blood-oxygen-level dependent (BOLD) contrast was used to acquire 41 transverse slices (3 mm slice thickness) per TR (3000 ms, TE 31 ms, flip angle = 90^{o}). For each version of the experiment, approximate 200 volumes were acquired in a 192 × 192 mm field of view with a matrix size of 64 × 64 mm, giving an in-plane spatial resolution of 3 mm (generating 3 mm^3 voxels).

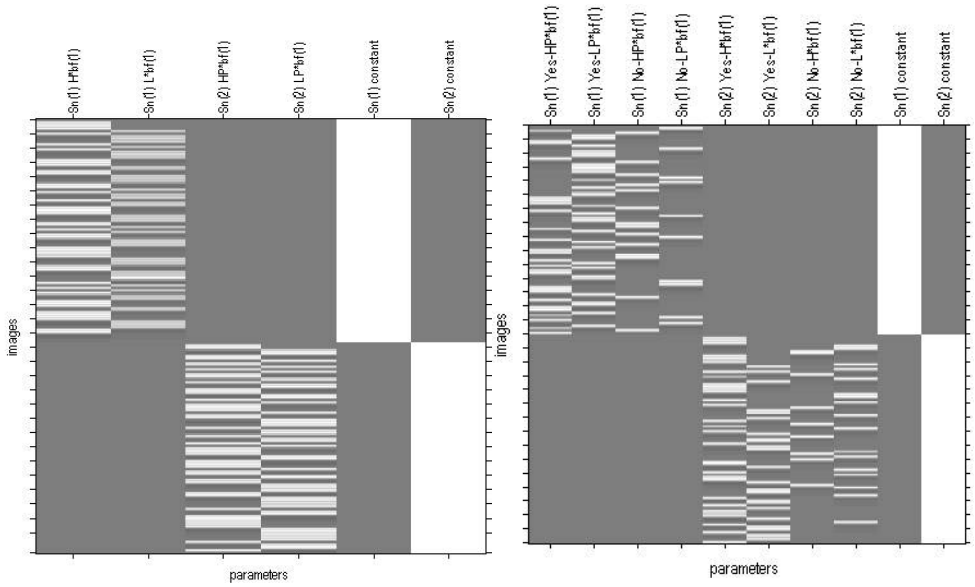
Anatomical data were collected in the same orientation and plane as the functional images data to enable localization, using an MP-RAGE T1-weighted sequence, in which 176 one-mm slices alternated with a 0.5 mm gap. The structural sequence incorporated 1830 ms TR, 4.43 ms TE, FoV 256 mm and a GRAPPA acceleration factor of two. Stimuli were presented with E-prime software (psychology software tools, Pittsburgh, PA, USA) on a personal computer, the task was presented on a screen positioned at the rear of the scanner's bore, and participants viewed the projector through a mirror mounted on the MRI head coil.

4.2.5 fMRI data processing

Statistical parametric mapping (SPM12) (welcome Department of Imaging Neuroscience, University College London, London, UK. http://www.fil.ion.ucl.ac.uk/spm/) was employed to analyse the fMRI data. Functional images for both sessions were spatially realigned by initially aligning the first images of each session, and then aligning the images within each session to the first image, to moderate the effects of participants' head motion. Images were normalized using the SPM12 EPI template to account for anatomical variability, and to facilitate reporting of activation sites in the Montreal Neurological Institute (MNI) standard space. Finally, data were smoothed using a Gaussian kernel of 6 mm full-width half-maximum (FWHM) to increase the signal-to-noise ratio according to the matched filter theorem. The selected design matrix convolved the experimental design with a hemodynamic response function (HRF) to model the hemodynamic lag behind the neuronal response. This model was estimated using proportional scaling over the session to remove low-frequency noise, and with a high pass filter with a cutoff period of 128 s.

Two sets of individual level whole-brain event-related fMRI one sample t contrasts were computed separately and independently from the first level analysis. Firstly, according to the experiment design, there were four basic conditions, namely, H, L, HP and LP. Figure 4.2(a) shows the design matrix corresponding to the experimental design used in this study. The design matrix included six regressors and the last two columns model the average activity in the two fMRI sessions. The second design matrix shown in Figure 4.2(b) was based on how participants made their choice (whether they were considering buying it or not) on the same set of characterised products, thus there were 8 conditions as variables in this analysis, namely: Yes_H, Yes_L, Yes_HP, Yes_LP, No_H, No_L, No_HP, No_LP (see Figure 4.2(b) of design matrix). For both of these two situations, first level one sample t-test were

calculated in the first level analysis for each participant individually. In addition, in order to test the main effect of each variable previously mentioned (H, L, HP, LP), second-level models were constructed for group analysis in SPM12 using contrast images from the first-level model above. Second-level, random effect analysis of between group differences were performed using full factorial (2 × 2) mixed ANOVA procedure in three separate independent group analyses. Figure 4.3 shows the design matrix corresponding to the experimental design used in ANOVA analysis. The two factors were sales volume level, that is, high sales volume products and low sales volume products; and two price levels, for example, original price and discounted price. In the first group- "yes" and "no" responses were combined, thus the input data to the ANOVA model were first-level t-contrasts for H, L, HP, LP. In the second group, "yes response", the input data to the ANOVA model were the first-level t-contrasts for Yes_H, Yes_L, Yes_HP, and Yes_LP; in the third group- "no response", the input data to the ANOVA model were the first-level t-contrasts for No_H, No_L, No_HP, No_LP. Each analysis was performed independently. A post-hoc analysis focused in more detail on how different brain areas respond in the preference and price conditions, paired t-test contrasts in BOLD activation in a region in one condition(e.g. H) versus another (e.g. HP) were used. Identification of the location of peaks and clusters and assignment of Brodmann area (BA) labels was carried out in MNI co-ordinates using the xjView toolbox (http://www.alivelearn.net/xjview).



(a) (b)

Figure 4.2 - First-level design matrices: (a) 4 conditions (H, L, HP, LP); (b) 8 conditions (Yes_H, Yes_L, Yes_HP, Yes_LP, No_H, No_L, No_HP, No_LP)

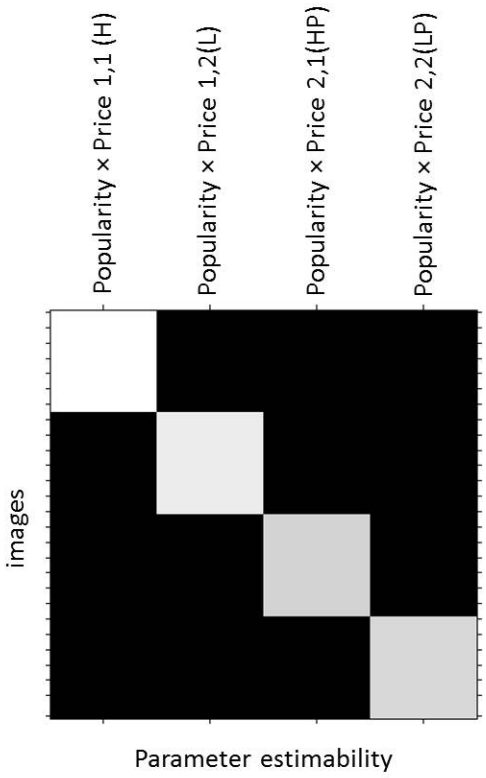


Figure 4.3 - ANOVA analysis design matrix

4.3 Results

It was hypothesised that both sales volume and pricing information would have an effect on inclination to purchase and on fMRI brain activations. And it was also hypothesised particularly that areas of insula, amygdala and basal ganglia which are associated with emotional feeling would be activated by the influence of sales volume of products.

4.3.1 Behavioural results

The behavioural data generated during the fMRI acquisition were analysed with SPSS statistics 20 (SPSS 20, SPSS Inc., Chicago, IL, USA). The effect of product sales volume and price manipulation on inclination to purchase (yes versus no) was assessed in a 2 x 2 ANOVA. There was a significant main effect of block (presence or absence of pricing information) on purchase decision, $F(1, 19) = 8.36$, $p < 0.01$, $\eta 2p = 0.31$. An analysis of variance table for this analysis is presented in Table 4.2. The addition of pricing information made products less likely to be considered for purchase: M (SD) percent in Block 1 (H, L) = 49.0 (3.65) and M (SD) = 44.6 (3.72) in Block 2 (HP, LP). The main effect of sales volume

was not significant, but there was a significant interaction between sales volume and the presence or absence of pricing information, $F(1, 19) = 7.78$, $p < 0.05$, $\eta 2p = 0.29$. In this experiment, "1" representing "yes" response indicates likely to purchase; and "0" representing "no" response indicates dislike to purchase. As a result, through comparison on the mean values between H sets and L sets in Table 4.1 and the line graph see in Figure 4.4, The highest prospective purchasing score was obtained for H products in the absence of pricing information (H = 51.75%) but this fell by nearly 10% (HP = 41.87%) with the introduction of pricing information. The effect of sales volume on likelihood of purchase was significant in the predicted direction in Block 1: H = 51.75%, L = 46.25%, $p < 0.05$ one-tailed. The mean purchasing likelihood for low sales volume products (L = 46.25%) rose by only 1.12% with discounting (LP = 47.37%). It can be concluded that the price does have influence on decision making of food such that awareness of price decreases preference for popular products, and that discounting of lower sales volume products stabilises preference.

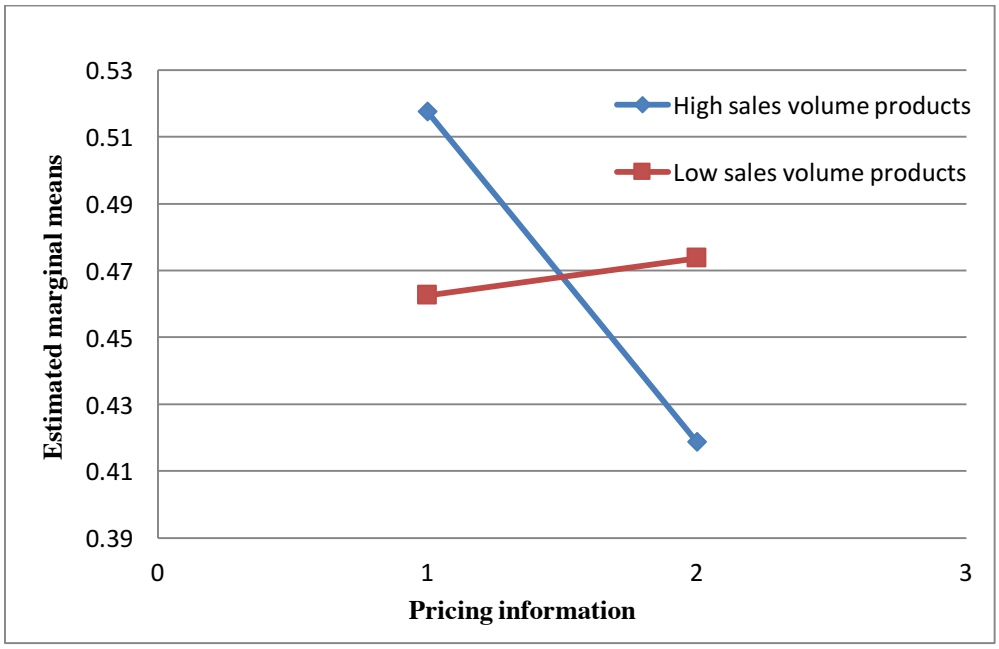


Figure 4.4 - Interaction graph of mean scores (y axis) against price (x axis) with high sales volume products and low sales volume products (lines)

Table 4.1 - Descriptive statistics result

Price	Sales volume	Dependent variable	Mean probability of purchase	Standard deviation	n
1	1	High sales volume products (H)	0.5175	0.19519	20
	2	Low sales volume products (L)	0.4625	0.15229	20
2	1	High sales volume showing price (HP)	0.4187	0.20064	20
	2	Low sales volume showing price (LP)	0.4737	0.19030	20

Table 4.2 - ANOVA summary table

Source of variance	Sums of squares	Degrees of freedom	Mean square	F-ratio	Sig.	Effect size
Within subjects factor- sales volume	0.00	1	0.00	0.00	1.00	0.00
Within subjects factor- price	0.38	1	0.38	8.36	0.01	0.31
Within subjects error- sales volume	0.41	19	0.21			
Within subjects error- price	0.09	19	0.01			
Interaction	0.06	1	0.06	7.78	0.01	0.29

4.3.2 Post-hoc questionnaire results

The post-fMRI, self-report questionnaire of food choices measures the most important factors identified by participants influencing a purchase decision on snack food or drinks. This questionnaire asked participants to rank the following options from 1 to 7, where 1 is the most important and 7 is the least important- and to ensure that each rating value is used only once. The mean rankings across all participants are shown on Figure 4.5, participants rank the taste of food (2.7) and the price of the food (2.8) as the most important factors that influence their purchase behaviour in real life. Next, participants pay attention to the familiarity of the food (3.9), health related issues (4.0) and the weight control considerations (4.2). Compared these reasons, they considered that they pay less attention to the brand name (4.75). The least important reason given for making a choice of food was the packaging (5.45).

Figure 4.5 - The self-ranked level of importance of influences on decisions to purchase food products (1 = most important, 7 = least important)

4.3.3 fMRI results

4.3.3.1 Whole-brain ANOVA analysis

In order to examine the effects on brain activity of the relationship between the sales volume of food and the presence or absence of pricing information, statistical analyses of group data were performed using full factorial designs. The statistical analyses were divided into three separate analyses consisting of (1) fMRI activations to stimuli on combined "yes" and "no" trials (regardless of participants' responses) according to the products' primary categories. (2) fMRI activation to stimuli where the participant responded "yes"; (3) fMRI activation to stimuli on which the participant responded "no". In the first of these analyses, there are two levels of factors in two variables (2 x 2 factorial design). Thus, in Block 1 there are higher sales volume (H) and lower sales volume (L) products considered as two levels. Moreover, with the price variable, there are two levels in the second block: H plus original price and L plus discounted price may be considered as the other two factors. Cluster peaks were located in MNI coordinates in SPM12 and mapped to Brodmann areas and labels using the xjView toolbox. Reference was also made to Palomero-Gallagher et al. (2015) to locate a cluster in

subgenual anterior cingulate cortex (sACC). Detailed analysis of the 2nd-level effects in the full factorial design and coordinates of significant clusters are listed in Table 4.3. No significant effects were found for main effects or interactions involving the price variable.

Table 4.3 - Regions with activity changes based on whole brain ANOVA analysis

Cluster size (Voxels)	Region of activation	BA	t or F value	MNI coordinates		
				x	y	z
(1) "Yes & No" regardless of behavioural response						
Main effect of sales volume (H vs L) F test						
16	R Frontal lobe	8	32.21	22	4	42
9	R Anterior cingulate cortex	25	23.82	8	12	-18
12	L Frontal lobe	44	23.08	-44	-8	22
25	R Frontal_Mid	10	22.17	42	48	0
Positive effect of sales volume (H > L) t-test						
15	R sACC	27	4.88	8	12	-18
26	L Frontal lobe	44	4.80	-44	-8	22
46	R Frontal_Mid	10	4.71	42	48	0
5	R Sub-lobar	13	4.16	32	-8	16
Positive effect of sales volume (L > H) t-test						
77	R Frontal lobe	8	5.68	22	4	42
15	R Frontal lobe	6	4.58	18	16	68
10	R Frontal lobe	3	4.09	26	-36	38
10	L Vermis_10		3.64	-2	-50	-26
6	R Cerebellum		3.47	12	-46	-32
(2) "Yes" responses						
Main effect of sales volume (H versus L) F test						
34	L Insula	13	25.92	-42	-14	4
25	R Occipital_Inf	18	25.19	32	-92	-8
5	L Temporal_Inf	37	20.33	-44	-30	-16
13	L Frontal_Mid	10	18.93	-22	46	8
Positive effect of sales volume (H > L) t-test						
52	L Insula	13	5.09	-42	-14	4
9	L Temporal_Inf	37	4.51	-44	-30	-16
16	R Insula	13	4.48	38	10	-12
8	R Putamen		4.41	34	-8	2
13	L Frontal lobe	6	4.37	-42	-6	28

40	L Frontal_Mid	10	4.35	-22	46	8
5	L Sub-lobar	13	4.02	-30	-18	10
Positive effect of sales volume (L > H) t-test						
106	R Occipital_inf	18	5.02	32	-92	-8
11	L Frontal lobe	6	3.86	-14	18	68
5	R Frontal_Sup	6	3.80	18	8	72
11	L Occipital lobe	18	3.73	-38	-86	-14
6	L Occipital_Mid	18	3.63	-30	-96	-4

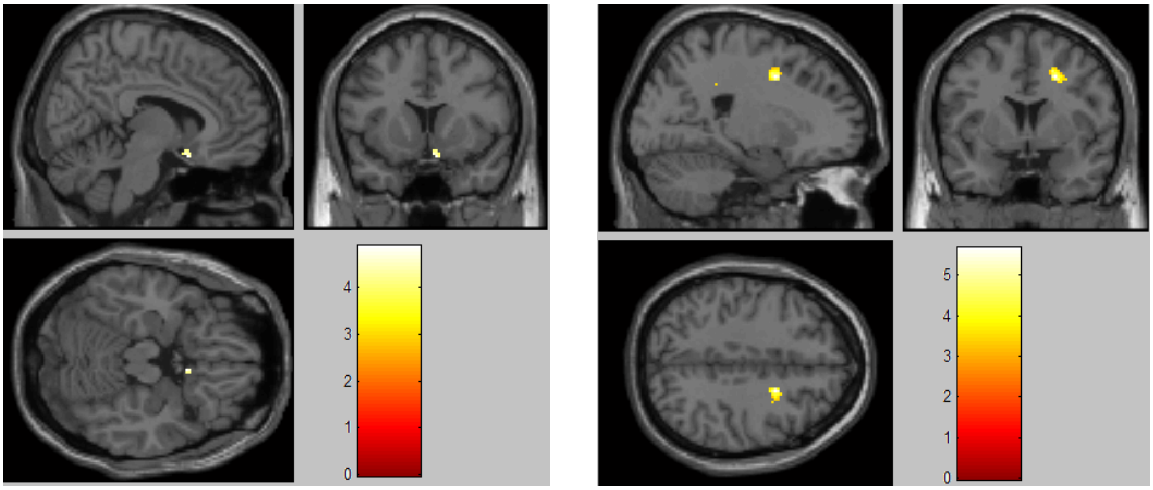
(3) "No" responses

Main effect of sales volume (H versus L) F test						
7	L Insula	13	32.86	-40	-14	4
6	L Precentral	6	30.62	-48	-4	24
Positive effect of sales volume (H > L) t-test						
15	L Insula	13	5.73	-40	-14	4
10	L Precentral	6	4.60	-46	-4	24
Positive effect of sales volume (L > H) t-test						
80	R Occipital_Inf	18	4.11	32	-92	-8
5	L Midbrain		3.95	0	-18	-12
5	L sACC	27	3.54	-2	26	-2

Note: Only peak activations of clusters are listed; L, left hemisphere; R, right hemisphere; BA, Brodmann area

4.3.3.2 Main effect of sales volume on all responses trials

In the analysis of "Yes & No" responses, the results of main effect of sales volume are reported at $p < 0.0001$, uncorrected, $k \geq 5$ (Table 4.3 and Figure 4.6). Activity regions found in right frontal lobe, anterior cingulate cortex and middle frontal gyrus, and left frontal lobe. The results of positive effect of sales volume (H > L) are reported at $p < 0.0001$, uncorrected, $k \geq 5$, which revealed significant differences in right sACC (subgenual anterior cingulate cortex: Palomero-Gallagher, et al. 2015), middle frontal gyrus, and left frontal lobe. The results of positive effect of sales volume (L > H) are reported at a more liberal threshold $p < 0.001$, uncorrected, $k \geq 5$, activation were found in right frontal lobe and cerebellum and left vermis_10. Figure 4.6 shows significant voxels following a t-test evoked by the sales volume.



(a) (b)

Figure 4.6 - (a) Brain regions with significant activations evoked by sales volume (H > L) based on "Yes & No" free responses condition which are reported at $p < 0.0001$, uncorrected, $k \geq 5$; (b) brain regions with significant activations evoked by sales volume (L > H) are reported at $p < 0.001$, uncorrected, $k \geq 5$. The result is visualized using xjView toolbox (http://www.alivelearn.net/xiview)

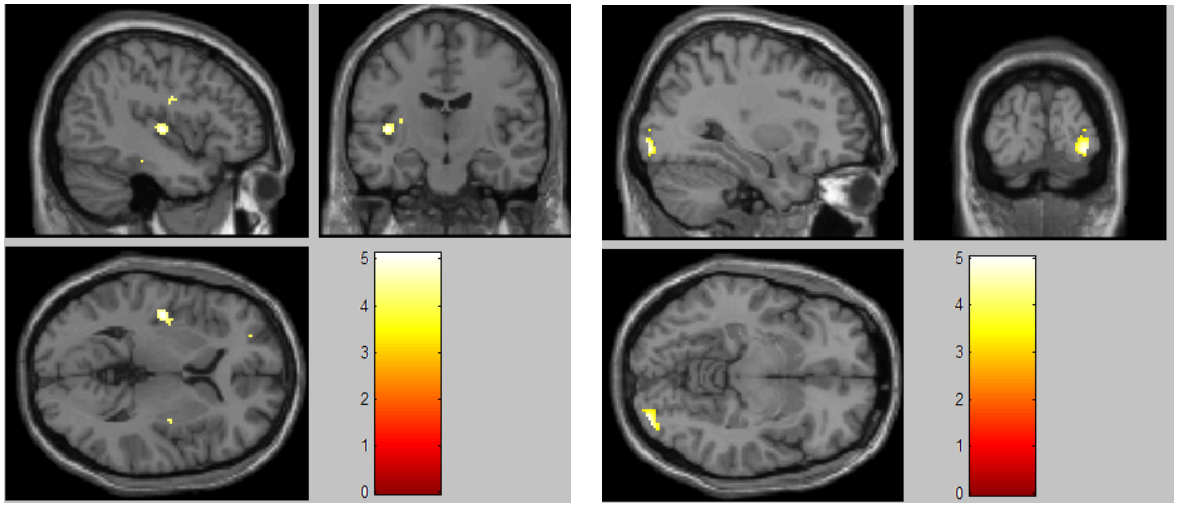
4.3.3.3 Main effect of sales volume (H > L): regions of interest analysis

In the t-tests of the positive effect of sales volume (H > L), ROIs result with small volume correction showed significant effect for left insula with peaks at -36 -10 12 ($p < 0.05$, FWE correction), -32 8 -18 ($p < 0.05$, FWE correction). And right insula, 32 -8 -16 ($p < 0.05$, FWE correction), 36 8 -10 ($p < 0.05$, FWE correction).

4.3.3.4 Main effect of sales volume on "yes to purchase" trials

For "yes" responses (Table 4.3 and Figure 4.7), the results of main effect of sales volume are reported at $p < 0.0001$, uncorrected, $k \geq 5$. Activation patterns in left insula, inferior temporal gyrus and middle frontal, and right inferior occipital lobe were found. The results of positive effect of sales volume (H > L) are also reported at $p < 0.0001$, uncorrected, $k \geq 5$, which revealed significant differences in left insula, inferior temporal gyrus, frontal lobe, middle frontal gyrus, and right insula and putamen. Some areas were found that were more active for low sales volume products. The positive effect of sales volume (L > H) is reported a more liberal threshold at $p < 0.001$, uncorrected, $k \geq 5$, activations were found in right inferior occipital lobe and superior frontal gyrus and left frontal gyrus (BA6) and occipital lobe (BA

18). Figure 4.7 shows significant voxels following a t-test comparing H and L stimuli for both positive and negative contrasts.



(a) (b)

Figure 4.7 - (a) Brain regions with significant activations evoked by the contrast (H > L) based on "Yes" responses which are reported at $p < 0.0001$, uncorrected, $k \geq 5$; (b) brain regions with significant activations evoked by L > H on "Yes" trials are reported at $p < 0.001$, uncorrected, $k \geq 5$

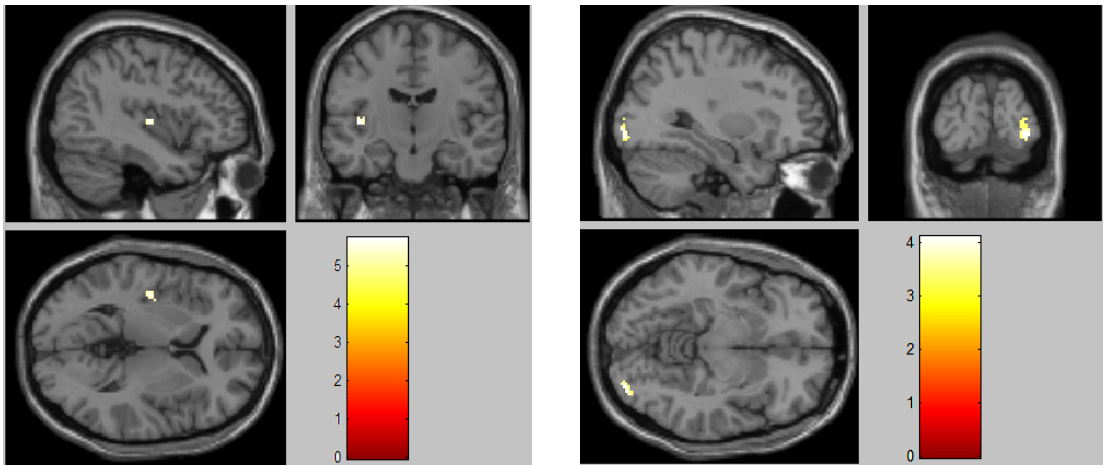
4.3.3.5 Main effect of sales volume on "yes to purchase" trials: regions of interest analysis

Tests of specific hypotheses were carried out using a-priori ROIs in left insula, right insula, left amygdala and right amygdala, with small volume correction. In the t-test of the positive effect of sales volume (H > L), ROIs result with small volume correction showed significant effect for left insula with peaks at -42 -14 4 ($p < 0.001$, FWE correction) and -28 8 -14 ($p < 0.05$, FWE). Also, right insula with peaks at 38 10 -12, ($p < 0.05$, FWE correction) and 32 -12 18 ($p < 0.05$, FWE correction). Moreover, left amygdala -24 4 -20 ($p < 0.05$, FWE correction).

4.3.3.6 Main effect of sales volume on "no to purchase" trials

For "no" responses, the results of main effect of sales volume is reported at $p < 0.05$, FWE corrected, $k \geq 5$. Activation showed significant differences found in left insula and precentral

gyrus. The contrast result of the "positive effect of sales volume" (H > L) are also reported at $p < 0.05$, FWE corrected, $k \geq 5$. The activated regions were found respectively in left middle occipital lobe, right precentral gyrus, and left insula and precentral gyrus. The results of the positive effect of sales volume contrast (L > H) are only visible at a liberal threshold $p < 0.001$, uncorrected, $k \geq 5$, activations were found in right inferior occipital lobe and left midbrain and sACC. Figure 4.8 shows significant voxels following a t-test of the sales volume contrast.



(a) (b)

Figure 4.8 - (a) Brain regions with significant activations evoked by sales volume (H > L) based on "No" responses condition by using a threshold of $p = 0.05$, FWE corrected, $k \geq 5$; (b) brain regions with significant activations evoked by sales volume (L > H) are reported at $p < 0.001$, uncorrected, $k \geq 5$

4.3.3.7 Main effect of sales volume, regions of interest analysis with small volume correction

For the "No" responses, in terms of positive effect of sales volume (H > L), ROIs result with small volume correction showed significant effect for left insula with peaks at -40 -14 4, ($p < 0.001$, FWE correction), -32 8 -16 ($p < 0.05$, FWE correction), -30 -32 20 ($p< 0.05$ FWE correction). And right insula with peaks at 36 8 -14 ($p < 0.05$, FWE correction). 34 -10 4 ($p < 0.05$, FWE correction), 32 -28 22 ($p < 0.05$, FWE correction). And Left amygdala with peaks at -32 6 -16 ($p < 0.05$, FWE correction).

In a conclusion, for the contrast H > L activations were found in limbic, visual and frontal lobe regions, both for "yes" and for "no" responses, and also for the first block alone and for

Block 1 plus Block 2. No significant activations were observed corresponding to the main effect of price or the interaction between sales volume and price.

For the "yes" condition, results were significant at $p < 0.0001$ for brain regions of interest, (predicted on the basis of past literature, reviewed in the Introduction), which gives some confidence. Therefore, the hypothesis that the sales volume of products, as an index of product sales volume, has a significant effect on brain activity was confirmed, both for products for which participants register a decision to purchase, and for products overall. The brain regions showing a difference in brain activation related to differences in sales volume of products were predominantly in areas such as Insula which are known to be involved in emotional responses to stimuli.

The result of ANOVA and ROIs analysis support the hypotheses, that was sales volume have an effect on inclination to purchase and on fMRI brain activations was found in the regions of insula, amygdala which associated with emotional feeling. However, pricing manipulation did not produce detectable differences in the BOLD responses.

4.3.4 Paired t-test analysis

Post-hoc second level paired t-tests (based on first level one sample t-test) used, for a more fine-grained analysis of differences in brain activation between experimental conditions. Planned comparisons were employed selectively based on the hypotheses of the experiment. Results are reported at a statistical level of $p < 0.001$ uncorrected and cluster size ≥ 5.

Firstly, to test the significantly different activation on brain between the higher sales volume products and lower sales volume products, the contrast has been made between H and L. In this contrast there was a significant greater activation in the H condition than the L condition (i.e. H > L) observed in the lingual gyrus. Secondly, the contrast H versus HP and L versus LP were considered as two individual tests, revealing more information regarding the activation of brains in terms of the effect of price - based conditions. Both the positive contrast and the negative contrast was obtained through comparing H versus HP, the former gave activations in right orbital middle frontal gyrus and the latter in frontal gyrus. The results obtained though the contrast of L versus LP only shows significant effects for the negative comparison, which elicited activation in middle frontal gyrus and the right of frontal gyrus and superior frontal gyrus (see Table 4.4).

Table 4.4 - Brain regions encoding contrast result of paired t-test

Cluster size (Voxels)	Region of activation	Side	t value	MNI coordinates x	y	z	Correlation direction
H versus L							
6	Lingual (BA18)	R	3.85	8	-78	-4	Positive
H versus HP							
8	Frontal Lobe	R	4.25	18	50	-10	Positive
24	Frontal_Mid_Orb	R	4.21	28	-35	53	Positive
13	Frontal lobe	R	4.56	20	4	46	Negative
L versus LP							
33	Frontal_Sup	R	6.22	22	12	68	Negative
6	Frontal_Mid	R	4.21	30	2	56	Negative

Note: Results are reported on a statistical level of $p < 0.001$ *uncorrected and cluster size* $k \geq 5$*; only peak activations of clusters are listed. L, left hemisphere; R, right hemisphere; BA, Brodmann area*

Planned comparisons may help to explain the experiment result. For example, the planned paired test result of the contrast Yes_L versus No_L (see Table 4.5) demonstrated that responses in the left postcentral and right cerebellum, parietal lobe and caudate area evoked by contrast Yes_L and No_L positive correlations, which also include significant negative correlations in the right of postcentral, rolandic operculum, pallidum and in the left of cerebellum.

Comparison of Yes_H and Yes_HP, revealed significant activation including significant positive differences in right parietal lobe and thalamus and left postcentral and inferior temporal cotex. And significant negative differences in both left and right occipital lobe.

In the contrast of Yes_L versus Yes_LP, this elicited positive activation in right supramarginal gyrus, superior tempmporal lobe and left rolandic operculum, frontal lobe, inferior temporal lobe and insula. Yes_LP evoked more activation than Yes_L in the regions of both left and right occipital lobe and frontal lobe.

Table 4.5 - The comparisons to examine products sales volume and price offer effect on brain

Cluster size (Voxels)	Region of activation	Side	t value	MNI coordinates			Direction of t-contrast
				x	y	z	
	(1) Yes_L versus No_L						
264	Postcentral (BA3)	L	4.65	-36	-24	42	Positive
97	Postcentral (BA2)	L	4.43	-50	-30	58	Positive
42	Cerebelum_4_5	R	4.26	20	-54	-18	Positive
12	Parietal lobe	R	3.95	20	-58	42	Positive
5	Caudate	R	3.71	10	10	0	Positive
1508	Postcentral	R	6.70	44	-24	54	Negative
122	Rolandic_Oper	R	4.77	44	-24	20	Negative
5	Rolandic_Oper	R	4.19	44	0	14	Negative
12	Pallidum	R	4.10	26	-4	-6	Negative
5	Cerebellum_6	L	4.04	-20	-54	-28	Negative
9	Cerebellum_4_5	L	3.94	-14	-56	-18	Negative
5	Postcentral (BA7)	R	3.91	14	-42	78	Negative
	(2) Yes_H versus Yes_HP						
27	Parietal lobe	R	5.07	42	-30	26	Positive
10	Postcentral	L	4.40	-62	0	16	Positive
10	Sub-lobar	R	4.37	34	-12	24	Positive
5	Thalamus	R	4.13	18	-12	4	Positive
5	Temporal_Inf	L	3.74	-46	-30	-16	Positive
71	Occipital_Mid	R	5.13	28	-96	0	Negative
6	Occipital lobe (BA18)	L	4.02	-38	-86	-14	Negative
	(3) Yes_L versus Yes_LP						
72	SupraMarginal	R	5.22	46	-32	24	Positive
29	Rolandic_Oper	L	4.58	-52	-12	12	Positive
16	Sub-lobar	R	4.52	32	-16	16	Positive
19	Temporal_Sup	R	4.31	66	-18	8	Positive
19	Frontal_Sup	L	4.07	-18	50	14	Positive
6	Frontal_Mid	L	4.04	-22	46	8	Positive
5	Temporal_Inf	L	3.99	-44	-28	-16	Positive

5	Insula (BA13)	L	3.92	-42	-12	4	Positive
9	SupraMarginal (BA40)	R	3.74	56	-30	26	Positive
110	Occipital_Inf	R	5.11	28	-96	-2	Negative
55	Occipital_Mid	L	4.90	-30	-94	-4	Negative
7	Frontal_Sup_Medial	R	4.44	6	32	62	Negative
20	Frontal_Sup	R	4.23	26	8	68	Negative

Note: All contrast results are reported on a statistical level of $p < 0.001$ *uncorrected and cluster size* $k \geq 5$*; only peak activations of clusters are listed, L, left hemisphere; R, right hemisphere; BA, Brodmann area*

4.3.5 3 ways ANOVA result

3 ways ANOVA analysis include the factor of purchase intention (yes/no), factor of sales volume (H/L), and factor of pricing information (HP/LP) were employed. The main effect of Yes versus No (Table 4.6) and the main effect of H versus L (Table 4.7) were obtained, pricing information did not produce detectable differences in the BOLD responses.

Table 4.6 and Figure 4.9 show the result of main effect of purchase decision, activity regions found in the right precentral gyrus and cerebellum_4_5 and left precentral gyrus. The result of positive effect of purchase intention (Yes > No) revealed significant differences in the left precentral gyrus, postcentral gyrus and left cerebellum_4_5. The result of positive effect of purchase intention (No > Yes), activations were found in the right precentral gyrus and postcentral gyrus. All result were reported at uncorrected, $p < 0.001$, $k \geq 5$.

Table 4.6 - Regions with activity changes evoked by the purchase intention based on whole brain 3 ways ANOVA analysis

Cluster size (Voxels)	**Region of activation**	**BA**	**t or F value**	**MNI coordinates**		
				x	**y**	**z**
Main effect of purchase intention (Yes vs No, F test)						
529	R Precentral	4	27.23	36	-22	52
235	L Precentral	4	20.19	-36	-22	52
6	R Cerebellum_4_5	19	12.34	20	-52	-20
Positive effect of purchase intention (Yes > No, t test)						
351	L Precentral	4	4.49	-36	-22	62
28	R Cerebelum_4_5	19	3.51	20	-52	-20
11	L Postcentral	2	3.33	-44	-34	60
5	L Precentral	6	3.30	-30	-12	70
Positive effect of purchase intention (No > Yes, t test)						

654	R Precentral	4	5.22	36	-22	52
12	R Postcentral	3	3.41	56	-14	50

Note: Uncorrected, $p < 0.001$, $k \geq 5$

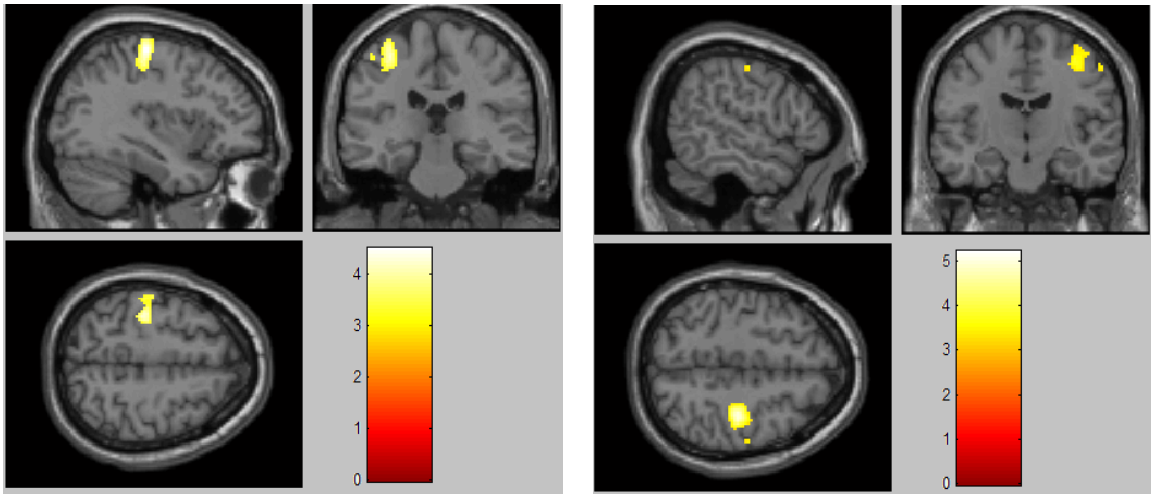
Table 4.7 and Figure 4.10 show the activity changes evoked by the sales volume and the result were reported at FWE corrected, $p < 0.05$, $k \geq 5$. The result of main effect sales volume revealed the significant differences found in left insula, inferior temporal gyrus, precentral gyrus, rolandic operculum, superior frontal gyrus, postcentral gyrus and right occipital lobe, putamen, temporal gyrus, superior frontal gyrus, middle temporal gyrus, post cingulum, rolandic operculum, superior temporal gyrus. Activation was found in the right inferior occipital lobe in the positive effect of sales volume (H > L). In terms of the positive effect of sales volume (L > H), the activated regions were found in left insula, inferior temporal gyrus, precentral gyrus, superior frontal gyrus, hippocampus, postcentral gyrus, and right putamen, temporal gyrus, superior frontal gyrus, middle temporal gyrus, posterior cingulate, rolandic operculum, superior temporal gyrus, parietal lobe, olfactory gyrus and postcentral gyrus.

Table 4.7 - Regions with activity changes evoked by the sales volume based on whole brain 3 ways ANOVA analysis

Cluster size (Voxels)	**Region of activation**	**BA**	**t or F value**	**MNI coordinates**		
				x	**y**	**z**
Main effect of sales volume (H vs L, F test)						
189	L Insula	13	56.54	-42	-14	4
31	L Temporal_Inf	20	50.75	-46	-30	-18
77	R Occipital	18	46.49	32	-92	-8
86	L Precentral	6	45.19	-48	-4	24
60	R Putamen	13	44.65	34	-8	2
17	L Temporal	19	38.84	-36	-60	2
49	R Temporal	13	38.66	36	10	-12
12	L Temporal_Inf	20	35.62	-44	-18	-26
28	R Frontal_Sup	10	33.68	22	58	4
10	R Temporal_Mid	37	32.56	52	-58	2
12	L Insula	13	32.14	-30	8	-16
6	R Cingulum_Post	23	31.28	12	-40	28
16	R Rolandic_Oper	13	30.79	56	-20	18
27	L Rolandic_Oper	6	30.52	-52	-8	10
24	L Frontal_Sup	10	30.25	-20	52	14
22	R Temporal_Sup	42	30.25	66	-20	6

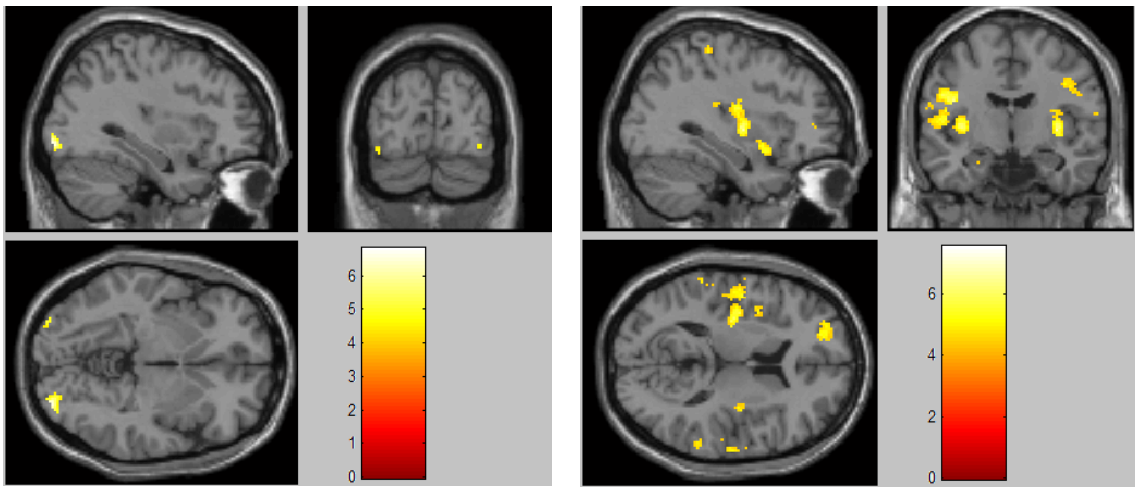
5	L Precentral	6	30.19	-36	-12	38
5	L Insula	13	30.14	-34	6	2
8	L Postcentral	43	29.24	-62	0	16
5	L Frontal_Sup	10	28.49	-22	54	4
9	R Rolandic_Oper	13	27.83	50	-26	20
	Positive effect of sales volume (H > L, t test)					
99	R Occipital_Inf	18	6.82	32	-92	-8
	Positive effect of sales volume (L >H, t test)					
269	L Insula	13	7.52	-42	-14	4
38	L Temporal_Inf	37	7.12	-46	-30	-18
105	L Precentral	6	6.72	-48	-4	24
84	R Putamen	13	6.68	34	-8	2
62	R Temporal	13	6.22	36	10	-12
15	L Temporal_Inf	20	5.97	-44	-18	-26
47	R Frontal_Sup	10	5.80	22	58	4
20	R Temporal_Mid	37	5.71	52	-58	2
21	L Insula	13	5.67	-30	8	-16
11	R Cingulum_Post	31	5.59	12	-40	28
57	R Rolandic_Oper	13	5.55	56	-20	18
65	L Frontal_Sup	10	5.50	-20	52	14
34	R Temporal_Sup	42	5.50	66	-20	6
9	L Precentral	6	5.49	-36	-12	38
26	L Insula	13	5.49	-34	6	2
9	R Parietal	31	5.46	16	-52	30
9	L Hippocampus	29	5.41	-22	-40	4
8	L Postcentral	4	5.41	-62	0	16
10	R Parietal	3	5.33	22	-36	54
8	R Olfactory	25	5.23	6	12	-16
8	R Postcentral	4	5.16	48	-6	30
7	R Postcentral	3	5.08	28	-34	62

Note: FWE corrected, $p < 0.05$, $k \geq 5$



(a) (b)

Figure 4.9 - (a) Brain regions with significant activations evoked by purchase decision (Yes > No) which are reported at $p < 0.001$, uncorrected, $k \geq 5$; (b) brain regions with significant activations evoked by purchase decision (No > Yes) are reported at $p < 0.001$, uncorrected, $k \geq 5$. The result is visualized using xjView toolbox (http://www.alivelearn.net/xiview)



(a) (b)

Figure 4.10 - (a) Brain regions with significant activations evoked by sales volume (H > L) which are reported at FWE corrected, $p < 0.05$, $k \geq 5$; (b) brain regions with significant activations evoked by sales volume (L > H) are reported at FWE corrected, $p < 0.05$, $k \geq 5$. The result is visualized using xjView toolbox (http://www.alivelearn.net/xiview)

4.4 Discussion

The objectives of this research were to investigate the effect of sales volume of food products and price offer on brain areas responsible for processing a decision making task. An event-related design fMRI paradigm was employed to study cerebral activities associated with

variables having different types of effects on decision making. In overall, behavioural results showed a strong influence of pricing information on inclination to purchase, indicating both a significant main effect and a significant interaction with sales volume. However, in the fMRI data only product sales volume, as indexed by sales volume, produced significant effects in ANOVA. Thus there was a partial disconnection between fMRI results, simulated purchase decision and post-hoc self-ratings of factors controlling choice.

In terms of ANOVA analysis result, a consistent pattern emerged in the brain regions activated during both positive and negative decisions related to the sales volume of the products shown as stimuli. Prominent among areas sensitive to the contrast between products high and low in sales volume is Insula (BA13). This structure integrates sensory information from the body and the external world and is known to be responsive to emotional stimuli. More specifically, insula region has not only previously been associated most prominently with aversive and negative stimuli (Knutson et al., 2007; Straube & Miltner, 2011), but also been linked with positive emotions such as pleasant tastes (O'Doherty, Rolls, Francis, Bowtell, & McGlone, 2001). Clusters were also identified in sACC, another structure associated with emotional processing as well as the senses of smell and taste (Palomero-Gallagher et al., 2015; Rolls, 2000). The reverse contrast L > H also produced significant activation, but generally not in insula or amygdala.

The stimulus modality in this experiment was vision, and the activations in occipital and temporal cortex may reflect differences in visual attention to H and L products, and frontal lobe activations may reflect control processes. Differences in the brain activations produced by more popular versus less popular products were found in the "Yes & No" combined responses. These differences may depend on greater familiarity with popular products (Horn et al., 2016) or differences in strength of sensory and affective imagery evoked by the packaging and presentation. These would be interesting questions to explore in further research.

In addition, regions of interests (ROIs) analysis was employed and both left and right insula were activated on the main effect of sales volume and the positive effect of sales volume (only on the contrast of H > L) in the condition of "Yes", "No" responses, and "Yes & No" combined responses. ROIs also found the activation in the left amygdala on the main effect of sales volume and the positive effect of sales volume of sales volume (only on the contrast of H > L) in the conditions of "Yes", "No" responses. Anatomically, the amygdala is connected

with the medial orbitofrontal cortex, which puts it into an ideal position to influence the computation of values according to Price (2003).

Further involvement of reward pathways is suggested by post-hoc contrasts. In terms of the paired contrast of Yes_L versus No_L, comparing the difference between preference and non-preference, the worth mentioning is that a positive contrast (Yes_L > No_L) shows significant activation in right caudate. Caudate is a key structure implicated in impulsive behaviour and is part of what is referred to as a "reward system" of brain (Deppe et al., 2005; Knutson et al., 2000; Komura et al., 2001). The caudate nucleus is often associated with emotion, motivated behaviour (Delgado et al., 2003; Haruno & Kawato, 2006), and has even been linked to customer loyalty (Plassmann et al., 2007).

In the planned contrast of Yes_H > Yes_HP, there was significant activation in right thalamus. Some nuclei of the thalamus have been associated with reward processing and the prediction of future reward values (Knutson et al., 2000; Komura et al., 2001). Behavioural data showed that price particularly reduced inclination to purchase in the high sales volume products. Price reduces reward, therefore the higher sales volume product is more rewarding than the higher sales volume product when showing with price and the difference shows as activation in the reward pathways. Reward is important for shaping goal-directed behaviour and associative learning, an organism can assess the motivational value of the incoming stimuli on the basis of past experience (retrospective processing), and predict forthcoming rewarding events (prospective processing) (Dickinson & Balleine,1994; Schultz, 2000; Schultz et al., 2000; Rainer et al., 1999).

The planned contrast of Yes_L versus Yes_LP explored the difference in the brain activation to people's chosen lower sales volume products with and without showing the discounted price information. This contrast activated brain regions in supramarginal gyrus, superior temporal, superior frontal, medial frontal, occipital lobe, and insula. Medial prefrontal cortex, which contains reward-related pathways, had earlier been identified by Plassmann et al. (2008) as sensitive to pricing. In addition, they also found that high prices caused increased activation in brain areas associated with loss anticipation such as insula (Plassmann et al., 2008). When making value-based purchasing decisions, rejecting an attractive item for purchase has been found to be associated with increased activity in bilateral insula, whereas accepting such an item for purchase resulted in decreased activity in the same region (Knutson et al., 2007). It's worth noting that in the present study some brain areas associated

with emotion were activated through this economical manipulation. Also Deppe et al. (2005) have shown that right supramarginal gyrus (BA40) is one of brain regions involved in processing of emotions and self-reflections during decision making (Deppe et al., 2005).

In the result of 3 ways ANOVA analysis, the activation of precentral gyrus and postcentral were found in the effect of purchase intention, which obviously shows the motor cortex sending out the command to the left and right hand. And the cerebellum_4_5 also found in this contrast, that is also a region of the brain that plays an important role in motor control and mainly contributes to coordination.

In the effect of sales volume of 3 ways ANOVA analysis, most interestingly, more activity brain areas such as, the insula, inferior temporal gyrus, putamen, posterior cingulate cortex, parietal gyrus, hippocampus, subgenual cingulate (BA25) and superior frontal gyrus (BA10), where were found increased activity during the presentation of low sales volume products compared high sales volume products. BA 24 and BA 25 have anatomical connectivity profiles that highlight their membership of distinct anatomical systems. These areas are interconnected with each other (Barbas, Ghashghaei, Dombrowski, & Rempel-Clower, 1999; Pandya, Vanhoesen, & Mesulam, 1981; Vogt & Pandya, 1987), the inferior temporal cortex (Vogt & Pandya, 1987), the amygdala (Amaral & Price, 1984), and the hippocampal formation (Vogt & Pandya, 1987). These areas are commonly considered as parts of a system that allow decisions to be biased by outcomes such as rewards (Doya, 2008).

The region of putamen is key structure of the impulsive system and what is referred to as a "reward system" of the brain (Hubert & Hubert, 2006). The ventral area of the caudate and the putamen form the ventral striatum, where the nucleus accumbens is located. The nucleus accumbens plays a central role in the dopamine and reward system of the brain (Hubert & Hubert, 2006) and has repeatedly been shown to be involved in the perception of favourable products (Knutson, Rick, Wimmer, Prelec, & Loewenstein, 2007), or in the anticipation of monetary rewards (Knutson et al., 2001). Activity changes in the ventral striatum even seem to be a strong predictor of purchase behaviour (Grosenick, Greer, & Knutson, 2008).

The parietal cortex has been implicated in decision making of the processes related to the resolution of uncertainty (Huettel et al., 2005). Parietal activation may play a role in mapping evaluative information to spatial action plans (Knutson, Rick, Wimmer, Prelec, &

Loewenstein, 2007). Deppe et al. (2005) suggested the favourite brand associated with an increased activation in posterior cingulate cortex.

Behavioural results showed a strong influence of pricing information on inclination to purchase. This result is in line with a previous study (Plassmann et al., 2008), Marketing actions attempt the manipulation of nonintrinsic attributes of goods such as prices to affect consumers' experienced pleasantness. However, activation in the brain regions associated with emotion predominated in the fMRI results, which is in line with the somatic marker hypothesis (Damasio, 1994) which suggests that unconscious hunches instead of rational decision making may be essential for preference judgments (Damasio, 1994; Bechara, Damasio, Tranel, & Damasio, 1997): somatic markers influence decision making before thinking about advantages or disadvantages related to response alternatives. Hence, somatic markers are working instead or ahead of subject's behaviour by biasing the decision making and may then guide the subject's behaviour by biasing the decision process. Although pricing information is known to modulate affective systems in the brain (Plassmann et al., 2008), this effect did not reach significance in the present study's ANOVA. Overall, the research shows the effect of product sales volume, as indexed by sales volume, is more evident in a covert measure (fMRI activations) than the effect of pricing, which is more evident in behavioural responses. Thus, images of the popular brands are more effective than the unpopular brands at engaging the affective systems of the brain, regardless that the post-hoc self-report ratings indicated that participants considered branding and packaging as the least important factors in product choice. Moreover, fMRI indicated significant effects of brand sales volume (sales volume) in affective systems of the brain both for chosen products (Yes responses) and non-chosen products (No responses). This may thus be an example, demonstrated here across a wide range of food brands, of the brand knowledge effect for culturally familiar products (McClure et al., 2004).

The behavioural results show clearly that the price manipulation was effective in changing choices, and that there was an interaction between pricing and sales volume. Thus prices would change consumers' mind as well as their final decision making, depending on how strong is the emotional level towards products. From the fMRI results it is suggested that the sales volumes could affect an individual's brain activity through the "cultural familiarity" effect of brands (McClure, et al. 2004). This could be tested directly by measuring

recognition memory for products. The further work in this thesis will therefore focus on ERP studies to investigate the effect of sales volume and economic factors on recognition memory.

While several other brain regions related to the decision making did not play central role in the present study, perhaps due to specific aspects of the experiment design that could be improved in future work as follows:

(1) When the prices were manipulated, the price difference is slightly different between higher sales volumes products and lower sales volumes products.

(2) The price conditions manipulated in H and L are different. One is the original price in higher sales volumes products and the other is reduced price in lower sales volumes products. It would be better if the method of controlling the price were to be identical in each condition, namely HP1, LP1, HP2, and LP2. Moreover, P1 and P2 are the original and reduced prices respectively.

(3) 80 items in total were utilized in this study; however, not all participants have tried everything before. Through the questionnaires taken after scanning, the average percentage of products recognised by participants as previously tasted or consumed, from the food listed on the experiment is 50%.

(4) The level of sales volume of food was defined by the sale volumes rankings on the internet. However, if we tested the emotional effect on the products, this might provide a different categorisation. Sales volume cannot be represented by all participants' feeling on these foods.

Chapter 5 An Emotional-Economic Investigation of Event-Related Potentials (ERPs) to Food Product Recognition: EEG Study

5.1 Introduction

Recognition memory has been extensively investigated by psychologists and cognitive neuroscientists, it is a fundamental cognitive ability and a popular paradigm for assessing human as well as nonhuman beings' memory (Tsivilis, Otten, & Rugg, 2001). Recognition memory has often been assessed using the judgement about whether or not a stimulus event has been previously experienced (Rugg & Curran, 2007). Moreover, results of cognitive and neuroimaging studies of human memory have increasingly indicated that recognition memory performance reflects two distinct memory processes that are well known as recollection and familiarity.

For two decades, the applications of neuroimaging methods have been increasingly used to figure out how different elements influence recognition memory. The most frequently used technique is EEG event related potential (ERP) technique (Luck, 2012), and combined with the recognition memory paradigm, this entails comparison of ERPs to "old" (previously presented) and "new" stimuli. For the most part, functional interpretations of the ERP old/new effect have been made within the framework of dual-process theories of recognition memory (Rugg & Curran, 2007). Thus ERPs have been carried out in several studies relevant to the dual-process framework.

Underlying performance on tests of recognition memory, the independent processes of recollection and familiarity were first proposed by Wilding and Rugg (1997). Recollection is defined as the successful retrieval of a prior episodic memory including remembering specific contextual details, thereby allowing an item to be defined as "old"; by contrast, familiarity

involves simply knowing that an item was previously presented, without having available any additional information about the learning episode (Squire, Wixted, & Clark, 2007). This presents a problem for neuroscientists because dual process theories posit that correctly recognized items in the tests of recognition memory elicit neural activity that will be a mixture of neural correlates of familiarity and recollection (Vilberg & Rugg, 2008). These authors argue that experimenters should assess whether or not recognition is accompanied by recollection of specific details of the context surrounding the first presentation, such as the location or colour in which an item was presented. A second popular method for segregating recollection- and familiarity-driven recognition, the 'Remember- Know' procedure (Tulving, 1985), requires the subject to make an introspective judgment as to whether recognition is accompanied by retrieval of details of the study episode.

The distinction is well explained by the common experience of recognizing a person as familiar but not being able to recollect what the person's name is, or, where they were previously encountered. Such introspections suggest that memory judgements can be based either on recollection of information about previous study events or on assessments of stimulus familiarity.

5.1.1 Signal detection theory in recognition memory.

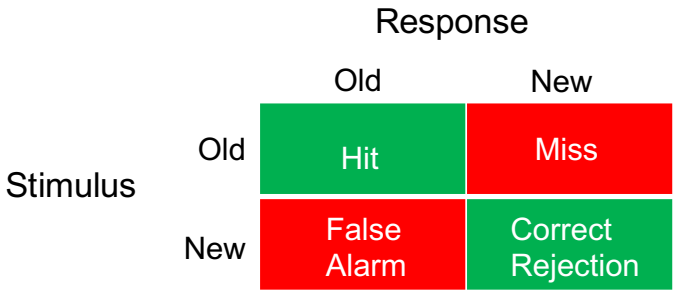


Figure 5.1 – Introduction to signal detection theory

It well known that signal detection theory can be applied in the use of a number of different recognition memory paradigms, but a common use is in old/new recognition (Hill & Windman, 2014). The procedures used in yes-no forced choice recognition tasks make it natural to apply a signal detection analysis to data (Macmillan & Creelman, 1991). More specifically, in a recognition task, the participant is required to recognise the item as studied (old) or unstudied (new), when the participant is saying "old" to a studied item, we call it a

hit; saying "new" to studied stimulus, we call it a miss; saying "old" to unstudied stimulus, we call it a false alarm; and saying "new" to unstudied stimulus, we call it a correct rejection (see Figure 5.1).

Signal detection theory (SDT) accounts of recognition memory, (Hill & Windmann, 2014) indicate that items in a recognition memory test elicit a feeling of familiarity that corresponds with the item's position on a continuous memory strength dimension. The mean familiarity signal is higher for studied (old) items than for unstudied (new) items while being normally distributed for both item types due to random variation. A difference in the mean familiarity between studied and unstudied items reflects the accuracy of old/new recognition (or d' for discrimination). However, to the extent that the two item distributions overlap, an accurate old/new discrimination is not possible, so that participants depend on a decision threshold. This threshold (c for criterion), is defined as the point on the memory strength dimension above which participants respond "old" and below which they respond "new" (Hill & Windmann, 2014). β is response bias, a measure of the tradeoff made by subject between positives and false positives. β is similar to c except it also takes into account d prime, which the is position of the signal and in the signal + noise distribution. So β is a ratio of signal/noise represented by the height of distribution.

5.1.2 The overview of ERP studies of memory recognition for branded products

Brands create product personalities that could be considered to affect consumer decisions. A ERPs study of branded and name free products was performed by Thomas et al. (2013) to test whether brands were associated with implicit positive attitudes. In this experiment, participants were required to respond to one category of goods (e.g. cosmetics) and one kind of words (e.g. positive) when they viewed series of photos of cosmetics and food items (half of them brands) intermixed with positive and negative words. The ERPs results show the differences associated with the existence of implicit attitudes towards brand and name free stimuli. Especially, the late positive component was found to be enhanced for brand as opposed to name free stimuli, and this might ultimately contribute to consumer decisions (Thomas et al., 2013).

In many recognition context researches, familiarity is correlated with an old/new ERP difference occurring 300-500 millisecond after a stimulus has been presented in which old ERPs are more positive than new at mid-frontal electrodes, and this has been named as the "FN400".

Bruett and Leynes (2015) performed an experiment to collect data which encoded name-brand and off-brand products in an incidental task to further test this hypothesis. Participants were asked to make response to old or new during the test with products from the category of only name-brand (e.g., Dr Pepper) and the test with products from the category of only off-brand (e.g., Dr Skipper); and a mixed test where both name-brand and off-brand products were displayed. Recognition was supported by fluency when viewing off-brand products on test with products from the category of only name-brand and only off-brand. Meanwhile, the ERP results elicit that familiarity experience was produced by off-brand products due to the fact that FN400 effect has been found in the mixed test (Bruett & Leynes, 2015).

A replicate and extend study was performed by Leynes et al. (2017), which examined three experiments by presenting pre-experimentally familiar (i.e. name-brand) products and novel, off-brand products to test the hypothesis of that the FN400 reflects familiarity or activation of conceptual implicit memory triggered by the stimulus. In these experiments, some of the off-brand products were conceptually primed by the name-brand product to determine how FN400 amplitude would be affected by conceptually primed, but novel, products. The results provided evidence arguing both for and against theoretical views accounting for FN400. Experiment 1 and 2 shows that off-brand primed FN400 amplitude was between name-brand and off-brand FN400 amplitudes. Experiment 2 used meaningless images as a baseline, and revealed that name-brand FN400 was more positive and off-brand FN400 was more negative. Experiment 3 revealed that general testing context modulates FN400 amplitude because the name-brand FN400 was equivalent to the baseline in this study (Leynes, Bruett, Krizan, & Veloso, 2017).

Another brand-related study carried out by Bosshard et al. (2016) was to investigate brand attitude in implicit measurements which were driven by non-conscious processes. The experiment was constructed by individualized stimulus lists of liked and disliked brand types based on participants' subjective pre-assessment, followed by a session when participants re-rated them when ERPs were being recorded. The result revealed that liked brands are implicitly associated with increased motivational aspects compared to disliked brands and

this was associated with ERP differences over right parietal cortical areas. The finding has been interpreted that liked brands are associated with positive affect and disliked ones with negative affect-related motivational aspects (Bosshard, Bourke, Kunaharan, Koller, & Walla, 2016).

Several other ERP studies about memory recognition for branded products have been carried out. Ma et al. (2008) conducted an ERP experiment on brand extension, which is the behaviour of applying an established brand to enter new product categories. This works on the perception of attribute similarity successfully between the original brand and the extension product. They speculated that the participants' decision process was a categorization process, the brand name as a prime evoked the memory of specific products and the neurons in corresponding cortex areas were activated simultaneously (Ma et al., 2008). The P300 wave, known as positive deflection in the event-related voltage potential at 300 ms poststimulus, can be elicited by categorization processing for brand extension. That is, the higher perceived similarity and coherence of their attributes is, the larger the amplitude of P300. Otherwise, when there was no overlap between the brand attributes and its extension this resulted in smaller P300. Moreover, Ma et al. (2010) also recorded the N2 when they tried to find the impact of induced negative emotion on brand extension. The finding indicates that the induced negative emotion has a specific negative impact in moderate brand extension and the amplitude of N2 can be viewed as a reference measure reflecting such effect (Ma et al., 2010).

5.1.3 Review of ERPs studies of visual recognition memory (old/new tasks)

Numerous studies have been published on the ERP correlates of memory in old/new tasks, beginning in the late 1980s (Neville, et al., 1986; Rugg & Nagy, 1989), and these studies generally report more positive ERP waveforms for "old" relative to "new" items (Vilberg & Rugg, 2008). A number of visual memory recognition experiments relevant to ERPs studies have been employed to address the question of whether the neural correlates of recollection and familiarity differ qualitatively. For example, Curran and Cleary (2003) used a recognition memory test in which some of the new items were similar to the studied items (e.g. SWAMPS VS SWAMP) to dissociate the function of frontal and parietal ERP memory effects (Curran & Cleary, 2003). These items attracted a high proportion of false alarms, which were held to give rise to a strong feeling of familiarity in the absence of recollection.

The ERPs elicited by the recognized old items were found on both frontal and parietal areas. By contrast, the ERPs associated with these false alarms showed an early, frontal positivity relative to items correctly judged new, but did not exhibit the later parietal effect (Rugg & Yonelinas, 2003).

ERPs were used to examine changes in recognition memory responses to familiar and newly learned (novel) words over time by Palmer et al. (2013). Native English speakers as the participants were taught novel words and subsequently performed a recognition memory task in which they made old/new decisions in response to both words (trained words versus untrained words), and novel words (trained novel words versus untrained novel words). The recognition task was performed approximately 45 minutes after training (day 1) and then repeated the following day (day 2). The results show that late parietal old/new effect distinguished old from new items for familiar words and novel words on both day 1 and day 2. However, the effect became significantly weaker on day 2 for familiar words, in contrary, the effect became significantly larger on day 2 for novel words. These findings could suggest that while recognition memory for familiar items might fade over time, recognition of novel items, conscious recollection in particular, might benefit from a period of consolidation.

Tsivilis et al. (2001) employed ERPs in an experiment on recognition memory for previously studied visual objects. Three conditions of objects were presented. First, some studied objects were paired with the same context (landscape scenes) as at study. Second, some were superimposed on a different studied context. And third, some were paired with new contexts. Unstudied objects were paired with either a studied or a new context. ERPs results indicated that the test stimuli engaged distinct kinds of memory-related neural activity which differed in their specificity for task-relevant features.

Curran and Cleary (2003) employed ERPs to dissociate recollection from familiarity in picture recognition. During the tests, participants were asked to discriminate between the studied pictures and their mirror-reversed images (highly similar lures). The results indicate that FN400 differences were observed between ERPs elicited by new items and studied pictures and similar lures conditions. Furthermore, subjects with good behavioural discrimination between the studied item and similar lures elicited significant recollection-related differences in parietal old/new effect (Curran & Cleary, 2003).

Although there have been a great number of studies of recognition memory, little is known about the role of sales volume of products and price factors of food-related products works on the recognition memory. The aim of this research is to find out the effect of sales volume (sales volume), pricing information, and number of variants (flavours) on recognition memory for branded food snacks. Moreover, it also investigates the effect of participants' responses to the likelihood of purchase on recognition memory. In order to achieve this aim, the electroencephalogram (EEG) is used to capture event-related potentials (ERPs) signals induced from correctly identified stimulus (i.e. branded food products).

The ERP-related experiment at Brunel is participated by two independent groups and each individual group will perform two tasks, named as Block 1 and Block 2. The Group 1 with a manipulated product sales volume condition is performed by the first group of participants and the Group 2 with a manipulated pricing information condition is performed by the other group; moreover, both groups perform a simulated purchase task in Block 1 and an old/new task on Block 2. Based on a review of the existing scholarly literature, both FN400 and P300 components would expect to be observed to have a correlation with recognition memory using packaged food products defined as stimuli and with various condition effects, such as sales volume, pricing information and number of flavour variants.

5.2 Methods

5.2.1 Participants

The experiment was conducted with two independent groups comprising 41 healthy Brunel University London students. Participants were recruited through posting the advertising on notice board of Brunel University London; each participant was provided £12 for taking part in this experiment. Group 1 consisted of 10 females and 11 males with the average age of 24 years old and Group 2 of 8 females and 12 males with the average age of 25 years old. Before the EEG experiment, all participants confirmed that they have no neurological disorder, no skin allergies, no feeling unwell, and not suffer from migraine or tension headaches, have no any cuts, soreness or inflammation on the face or scalp. Each participant then signed informed consent documentation and was paid for participation and was informed of their right to withdraw. The study was approved by the Ethics Committee of the College of Engineering, Design and Physical Sciences Research.

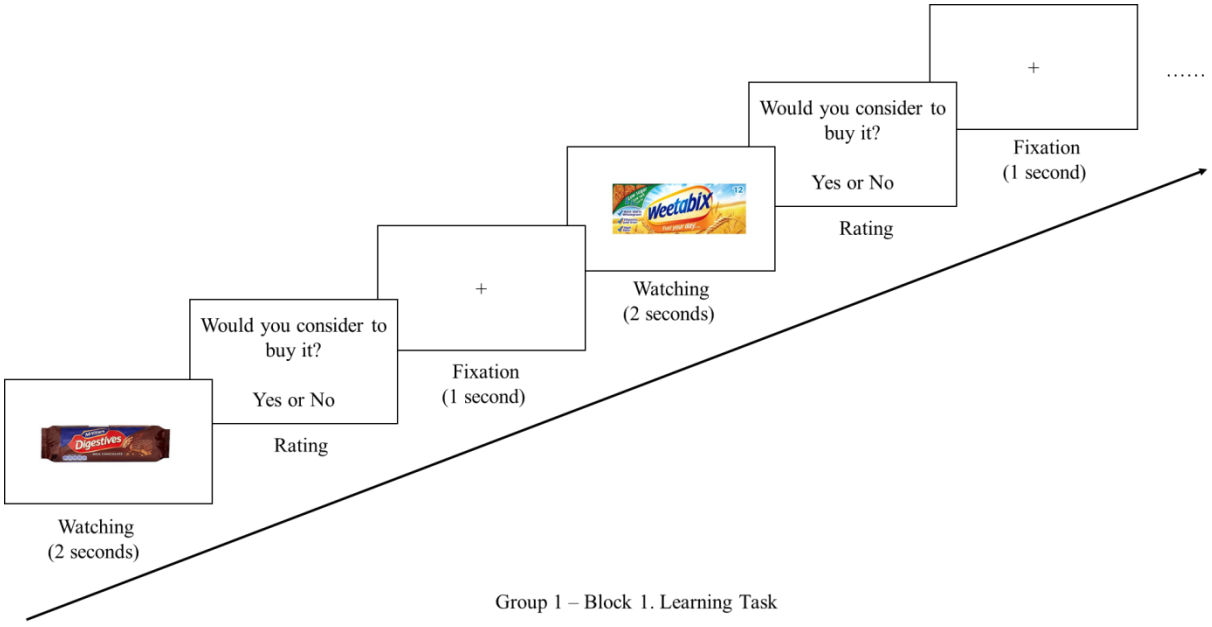
5.2.2 Materials

There were two independent groups for this experiment, they were manipulated in the conditions of product sales volume and price offered separately and each group's session consisted of two blocks. The stimuli and task for Group 2 Block 1 was similar to Group 1 Block 1 except displaying the price information on the products. In this block, for Group 2 higher sales volume products displayed with original prices and the lower sales volume products displayed with discounted prices. Images of branded snack products as stimuli were presented in the experiment. Flavour variants were another variable in this experiment, where, in the same branded product, different flavours were displayed in slightly different packaging. A given product therefore appeared either in one, two or three flavour versions, and number of variants was analysed as a stimulus variable. In the first block–learning task, 160 images were presented, and participants indicated whether they would consider buying the items ("yes" or "no" button offered for making decision). A half of the images represented products with higher sales volume (shortened as H) and the other half with lower sales volume (shortened as L). In the second block – memory task, a further 160 images were presented, of which (40H, 40L) had appeared in the first block and (40H, 40L) had not, that means a total of 80 images as new stimuli and another total of 80 images as old stimuli were presented in this block. Participants (n = 21) undertook this task with no pricing information provided on the images, and (n = 20) participants with pricing information on the images. For each of the images in the second block, participants needed to judge it as new (unstudied) or old (previously studied). Sale volumes were assessed from statistics posted on the Internet, such as Statista (2013), The Richest (2013), Food Manufacture (2014), Confectionery News (2014), Dairy Reporter (2013) as well as Market Research Resources (2015). These sources generally showed ranked sales volumes for products within a category (e.g. soft drinks or biscuits), so that it was possible to differentiate between higher and lower ranked products per category. The images alone were presented in a random order, and the order in which they were presented was randomized and counterbalanced across participants.

5.2.3 Procedures

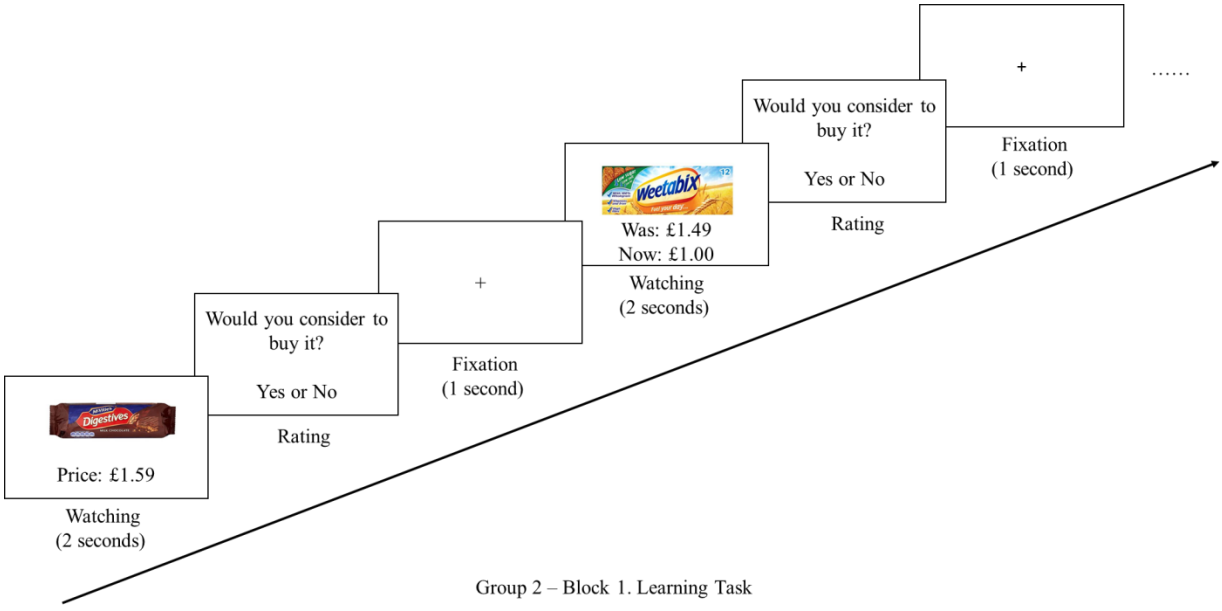
The experiment was designed using E-prime (psychology software tools). Figure 5.2 illustrates the procedures of the study and test phases. Figure 5.2(a) and (b) show the procedure of learning task for the Group 1 and Group 2 in which were manipulated in sale

volume condition with and without price information, respectively. In the learning task procedure, participants performed a food-related decision making task, each image of a product was presented for 2 seconds. Participants were asked to make a choice of "yes" or "no" for each question to indicate whether they would consider buying the products or not. Moreover, Figure 5.2(c) illustrates Block 2 memory task of Group 1 and Group 2. A total of 80 images as new stimuli and another total of 80 images as old stimuli were presented in this block and participants were asked to distinguish the new (not presented in a prior study phase) and the old (presented in a prior study phase).



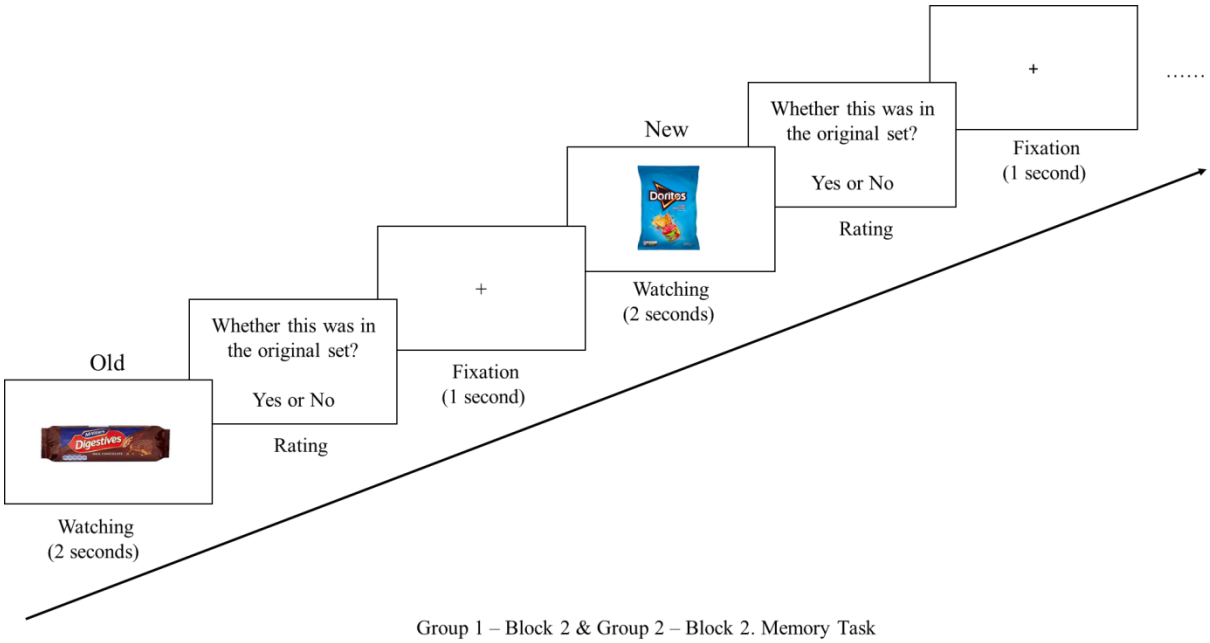
Group 1 – Block 1. Learning Task

(a)



Group 2 – Block 1. Learning Task

(b)



Group 1 – Block 2 & Group 2 – Block 2. Memory Task

(c)

Figure 5.2 - Stimuli and experiment design: (a) shows the learning task of Group 1 which manipulated in no pricing information condition; (b) shows the learning task procedure of Group 2 which manipulated in pricing information condition; and (c) shows the processes of memory task of Group 1 and Group 2

5.2.4 ERP recording and analysis

ERPs were recorded from 64 channels with sintered ceramic Ag/AgCI electrodes embedded in an elasticated quik-cap. Participants required wearing this cap filled with Quik Gel (compumedics neuromedical supplies). Electrodes were located at the following 10-20 system: O1, OZ, O2, PO7, PO3, POZ, PO4 PO8, P7, P5, P3, P1, PZ, P2, P4, P6, P8, TP7, CP5, CP3, CP1, CPZ, CP2, CP4, CP6, CP8, T7, C5, C3, C1, CZ, C2, C4, C6, T8, FT7, FC5, FC3, FC1, FCZ, FC2, FC4, FC6, FT8, F7, F5, F3, F1, FZ, F2, F4, F6, F8, AF7, AF3, AFZ, AF4, AF6, FP1, FPZ, FP2. All channels were recorded with a vertex reference and vertical and horizontal EOG were also recorded. Impedances were < 10 kΩ. EEG was amplified at a gain of 1000 and bandpass DC-200 Hz and digitized at 1000 Hz using SynAmps 2/RT and scan 4.4 acquisitions and analysis software (Compumedics Neuroscan). The offline EEG time series from all subjects' data was bandpass filtered at 0.1-70 Hz, 24 dB/octave, no phase shift, and Spatial Filter Procedure (scan 4.4) were applied to remove the blink artifacts. The cleaned EEG time series was epoched from -100 to 2000 ms (0 ms = stimulus onset). Sweeps

were baseline corrected (entire sweep), and those containing EEG amplitudes greater than ± 75 μV were rejected. Epoched ERPs for each experimental condition were then averaged for each participant and re-referenced to a common average reference. Peak amplitudes and latencies were measured with the peak detect procedure (scan 4.4) and transferred to Excel then SPSS for regions of interest analysis using ANOVA. Details of regions of interest and peak detection windows are provided alongside results in the next section. A second convergent method of analysis was used for complete electrode data which involved grand averaging of ERP data per experimental condition for all participants in each participant group. *T*-maps were then created to show the scalp topography of differences between experimental conditions (scan 4.4 t-test utility). The critical value of *t* was adjusted for multiple comparisons by a Bonferroni correction.

5.3 Results

In the following sections, products correctly judged as old items, will be referred to as belonging to hits (h); items correctly recognized as new will be referred to as correct rejections (CR); new items incorrectly recognized as old will be referred to as false alarms (FP) and old items incorrectly recognized as new will be referred to as misses (MISS).

5.3.1 Behavioural results

The behavioral data were analyzed using SPSS statistics 20 (SPSS 20, SPSS Inc., Chicago, IL, USA). The effect of sales volume (high, low), pricing information (Group 1 and Group 2) and the number of flavours (f1, f2, f3) on recognition memory for branded food snacks was assessed in a 2 × 2 × 3 repeated-measures ANOVA. There was a significant main effect of number of flavours (packaging variations) on sensitivity (d') and a significant 3-way interaction (sales volumes x pricing x flavours). On criterion measures (β, c) there was a significant main effect of sales volume, a significant main effect of flavours and a significant pricing × flavours interaction, and a significant 3-way interaction (sales volume × pricing × flavours).

5.3.1.1 ANOVA on d'

The effect of sales volume, pricing information and the number of flavours was assessed in a 2 × 2 × 3 ANOVA. An analysis of variance table for this analysis is presented in Table 5.1. There was a significant main effect of number of flavours (packaging variations) on sensitivity (d'), $F(2, 78) = 13.16$, $p < 0.0001$, $p\eta 2 = 0.25$. Moreover, there was a significant interaction between the sales volume and the presence or absence of pricing information on memory sensitivity, $F(2, 78) = 11.07$, $p < 0.0001$, $p\eta 2 = 0.22$. Furthermore, a significant interaction among the sale volume, with and without pricing information and the number of flavours was found, $F(2, 78) = 4.58$, $p < 0.05$, $p\eta 2 = 0.11$.

Table 5.1 - Descriptive statistics

(a) Within subjects factors

High/low	Flavours	Dependent variable
	1	highf1_d'
1	2	highf2_d'
	3	highf3_d'
	1	lowf1_d'
2	2	lowf2_d'
	3	lowf3_d'

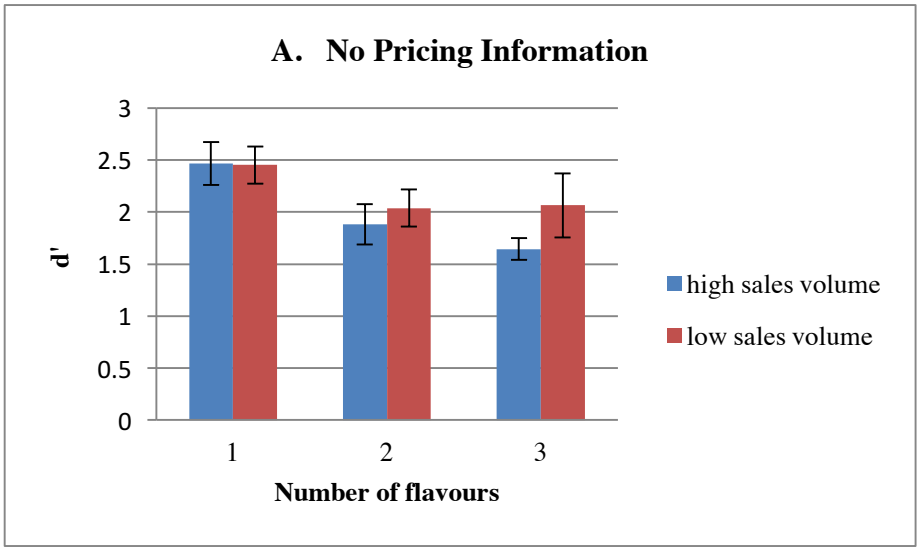
(b) Between subjects factors

		n
Group	1.00	21
	2.00	20

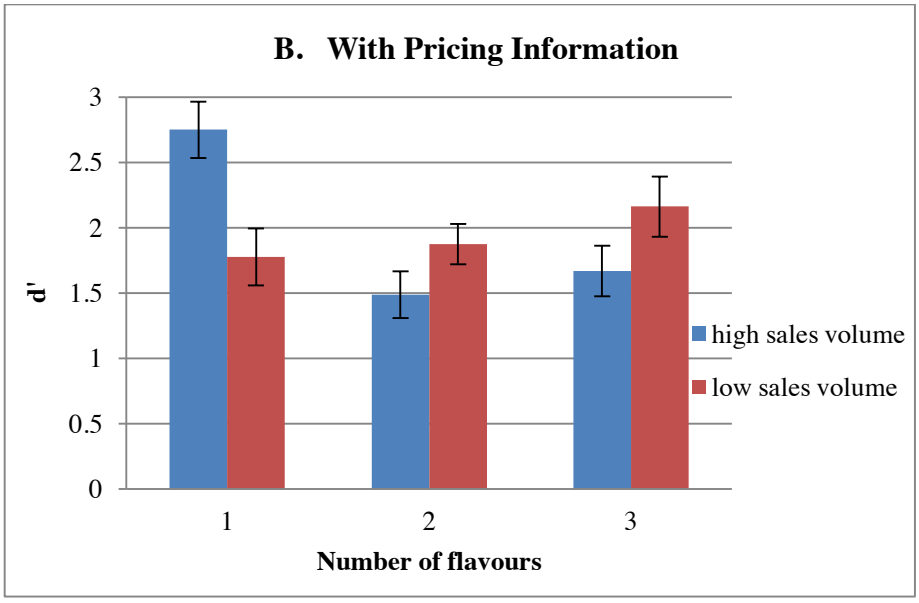
(c) Descriptive statistics

	Group	Mean	Standard deviation	n
highf1_dprime	1.00	2.4646	0.94708	21
	2.00	2.7509	0.96172	20
	Total	**2.6043**	**0.95331**	**41**
highf2_dprime	1.00	1.8833	0.89472	21
	2.00	1.4890	0.79872	20
	Total	1.6910	0.86203	41

highf3_dprime	1.00	1.6429	0.48551	21
	2.00	1.6687	0.86432	20
	Total	**1.6555**	**0.68766**	**41**
lowf1_dprime	1.00	2.4524	0.80747	21
	2.00	1.7769	0.96738	20
	Total	**2.1229**	**0.94200**	**41**
lowf2_dprime	1.00	2.0379	0.82119	21
	2.00	1.8772	0.68964	20
	Total	**1.9595**	**0.75479**	**41**
lowf3_dprime	1.00	2.0660	1.40669	21
	2.00	2.1634	1.02892	20
	Total	**2.1135**	**1.22258**	**41**



(a)



(b)

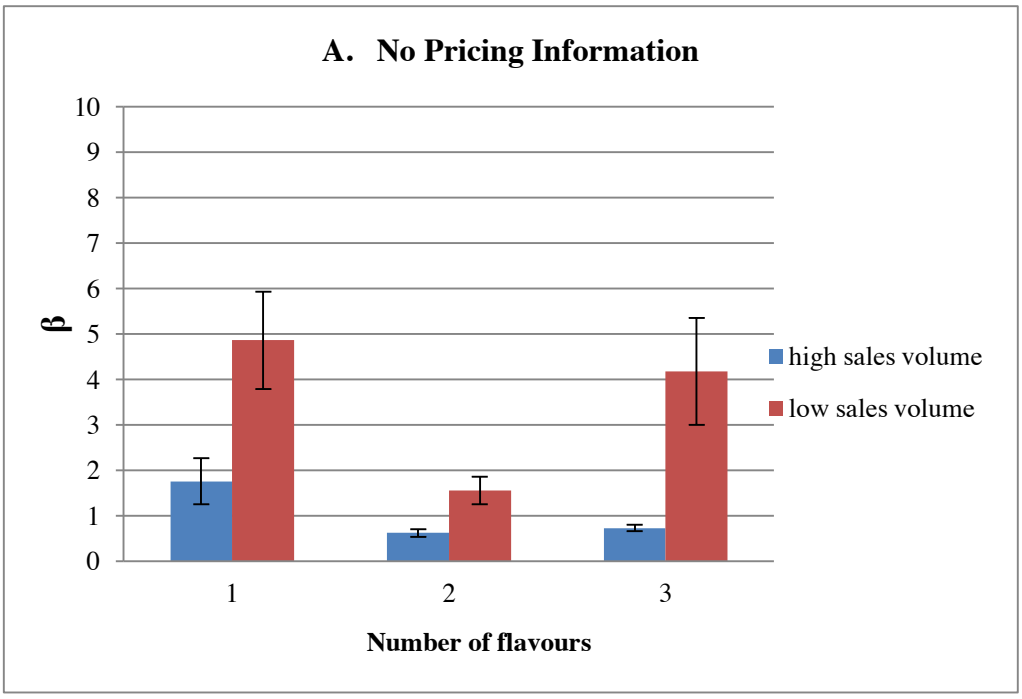
Figure 5.3 - The mean of d' for conditions of (a) no pricing information and (b) with pricing information

d-Prime (also known as d') is the measure of memory sensitivity in signal detection theory. The mean of d' for high sales volume and low sales volume products of 3 flavours is presented in Figure 5.3 in two conditions. Figure 5.3(a) shows the relationship between the number of flavours and d' in the condition of no pricing information obtained from Group 1's results and Figure 5.3(b) shows the one with pricing information obtained from Group 2's results. In Figure 5.3, it is observed that the mean of low sales volume products was always higher than the high sales volume products except the in the condition of flavour 1 in the presence of pricing information.

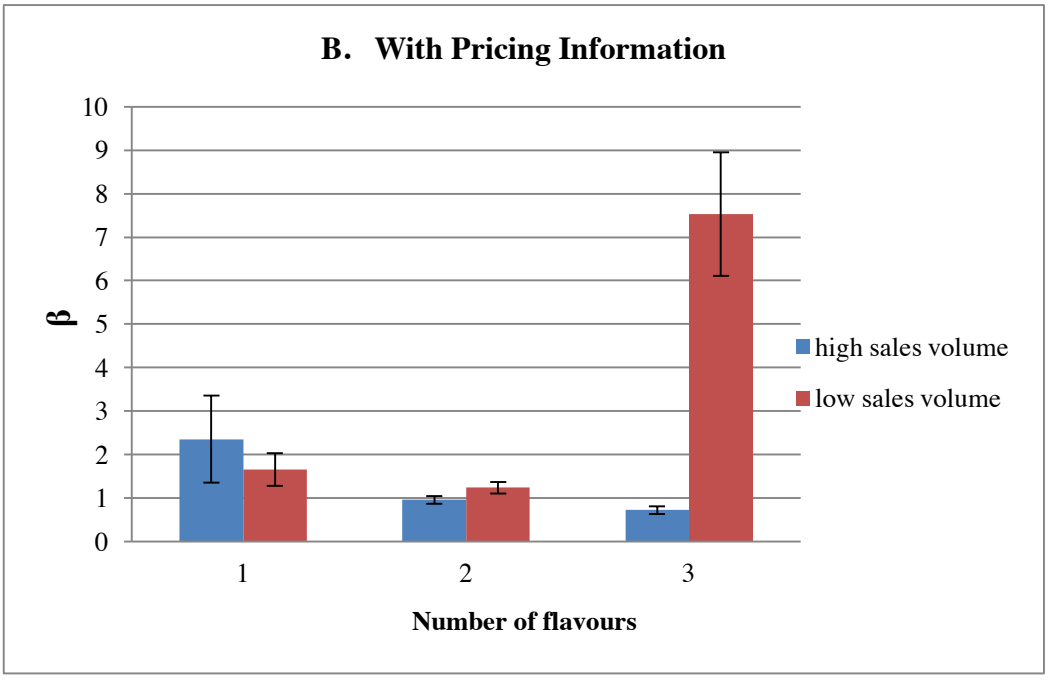
5.3.1.2 ANOVA on β

There was a significant main effect of sales volume, $F(1, 39) = 53.52$, $p < 0.00001$, $p\eta 2 = 0.58$, with a nearly neutral criterion for high and a conservative criterion for low sales volume products ($\beta_{high} = 1.20$, $\beta_{low} = 3.51$). Moreover, the main effect of flavours was significant ($\beta_{flavour1} = 2.67$, $\beta_{flavour2} = 1.10$, $\beta_{flavour3} = 3.29$) $F(2, 78) = 9.30$, $p < 0.00001$, $p\eta 2 = 0.19$. There was a significant interaction between the sales volume and number of flavours $F(2, 78) = 11.89$, $p < 0.00001$, $p\eta 2 = 0.23$, and a significant interaction between the flavours and presence or absence of pricing information, $F(2, 78) = 4.04$, $p < 0.05$, $p\eta 2 = 0.09$. Finally, a significant three-way interaction among sales volume, absence or presence of pricing

information and the number of flavours was found, $F(2, 78) = 6.32$, $p < 0.05$, $p\eta 2 = 0.14$. Figure 5.4 depicted the beta mean of high and low sales volume products in three flavours conditions in the absence (Figure 5.4(a)) or presence (Figure 5.4(b)) of pricing information.



(a)

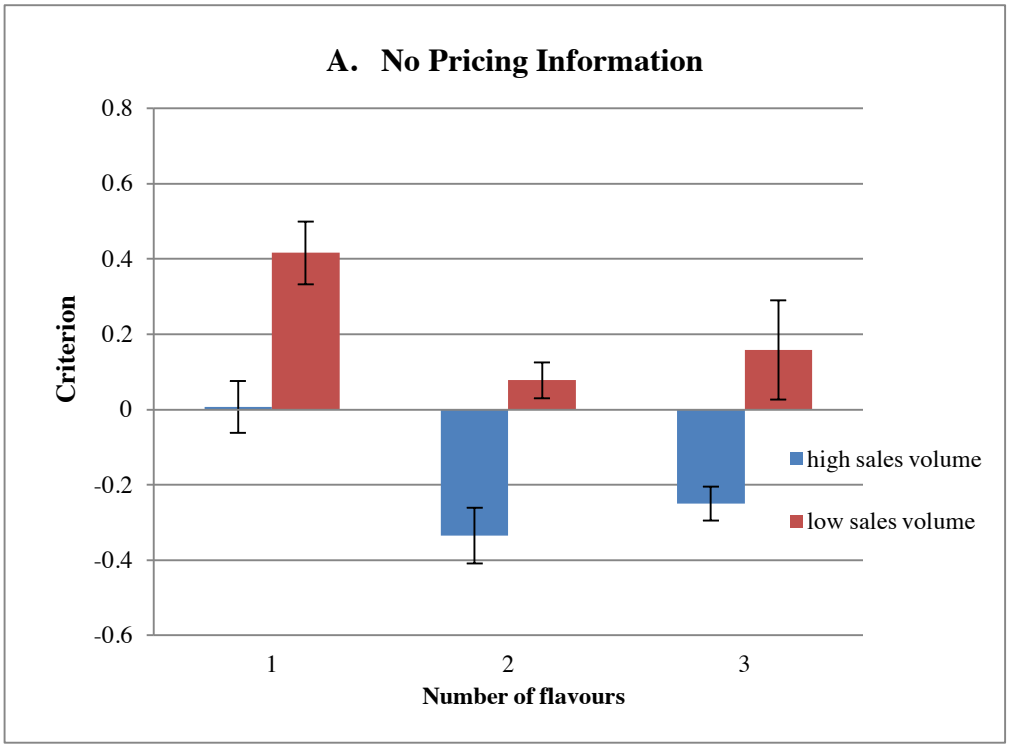


(b)

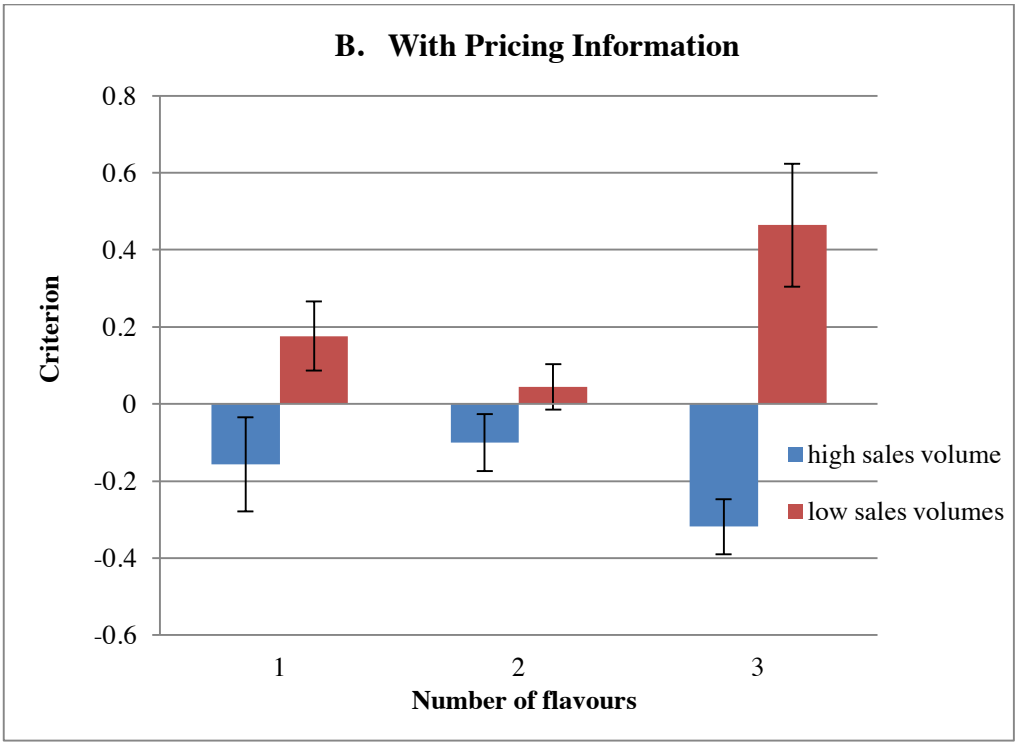
Figure 5.4 - The mean of beta for conditions of (a) no pricing information and (b) with pricing information

5.3.1.3 ANOVA on c

The criterion value c gives an intuitive representation of response bias, but unlike β it is not adjusted for differences in d'. There was a significant main effect of sales volume, with a more liberal criterion for high sales volume products and a more conservative criterion for low sales volume products (c_{high} = - 0.19 and c_{low} = 0.22), F (1, 39) = 77.01, p < 0.00001, pη2 = 0.66. The main effect of flavours was significant: the criterion was more conservative for 1 or 3 flavours and more liberal for 2 flavours ($c_{flavour1}$ = 0.11, $c_{flavour2}$ = - 0.08, and $c_{flavour3}$ = 0.01), F (2, 78) = 4.29, p < 0.05, pη2 = 0.10. There was a significant interaction between the sales volume and number of flavours, F (2, 78) = 4.25, p < 0.05, pη2 = 0.10. Moreover, there was a significant two-way interaction between the number of flavours and the presence or absence of pricing information, F (2, 78) = 3.88, p < 0.05, pη2 = 0.09.Finally, a significant 3-way interaction among sales volume, the number of flavours and the absence or presence of pricing information was found, F (2, 78) = 4.33, p < 0.05, pη2 = 0.10.



(a)



(b)

Figure 5.5 - The mean value of criterion across conditions: (a) the criterion mean of high and low sales volume products in three flavours conditions in the absence of pricing information; (b) the criterion mean of high and low sales volume products in three flavours conditions in the presence of pricing information. Zero is the neutral point of criterion

Figure 5.5 depicted the criterion mean of high and low sales volume products in three flavours conditions in the absence or presence of pricing information. All others indicated that criterion mean of low sales volume products were greater than 1, it indicated that the participants have a consevative response bias (says new frequently) and the high sales volume products were less than 1 in addtion to under the condition of no pricing information flavour 1, that indicated that the participants have a liberal responses bias (says old frequently).

5.3.2 ERP results

The ERP results are firstly reported for a repeated measures ANOVA analysis in terms of signal detection theory (SDT) measures. Two main hypotheses were tested by ANOVA on ERP amplitudes and latencies in pre-defined regions of interest (ROIs). The first is that there are significant differences in the ERPs to pictures of snack products when the subsequent decision is a hit (h) or a correct rejection (CR). The second hypothesis is that there will be

significant differences in ERPs to stimuli followed by responses which are hits (h) or false alarms (FP).

For the sake of clarity and brevity, only statistically significant results relevant to hypotheses are reported. Main effects of electrode position are not reported as they are not pertinent to experimental hypotheses. In a regions of interest (ROI) analysis, two repeated measures factors: response types and electrodes sites were analysed. ERP were analysed at a parietal region of interest (P7, P5, P3, P1, PZ, P2, P4, P6, P8) with sampling windows between 125 ms and 200 ms post-stimulus to measure component N1. For the components P1 (between 75 ms and 125 ms), P2 (between 200 ms and 300 ms), N2 or FN400 (between 300 ms and 420 ms) and P3 (between 375 ms and 500 ms), the ERPs were tested at a frontal central region of interest (FT7, FC5, FC3, FC1, FCZ, FC2, FC4, FC6, FT8). Greenhouse-Geisser corrected p-values were applied for all main effects and interactions involving the electrode position variable.

5.3.2.1 Group 1 – no pricing information

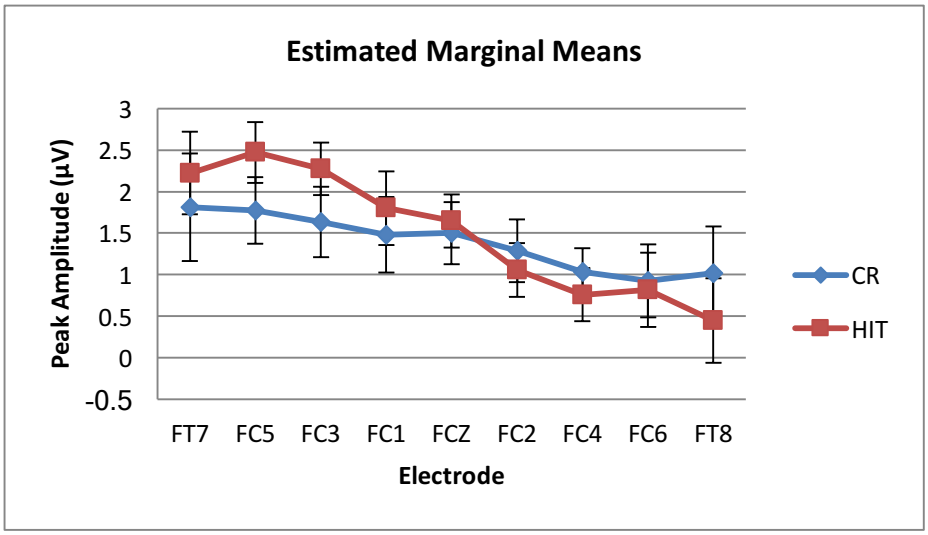
5.3.2.1.1 Comparisons of ERPs to stimuli in the recognition block as a function of signal detection variables (no pricing information)

Table 5.2 - Significant ANOVA result on component amplitudes and latencies in frontal ROI between factor of correct rejections versus hits and factor of electrodes positions

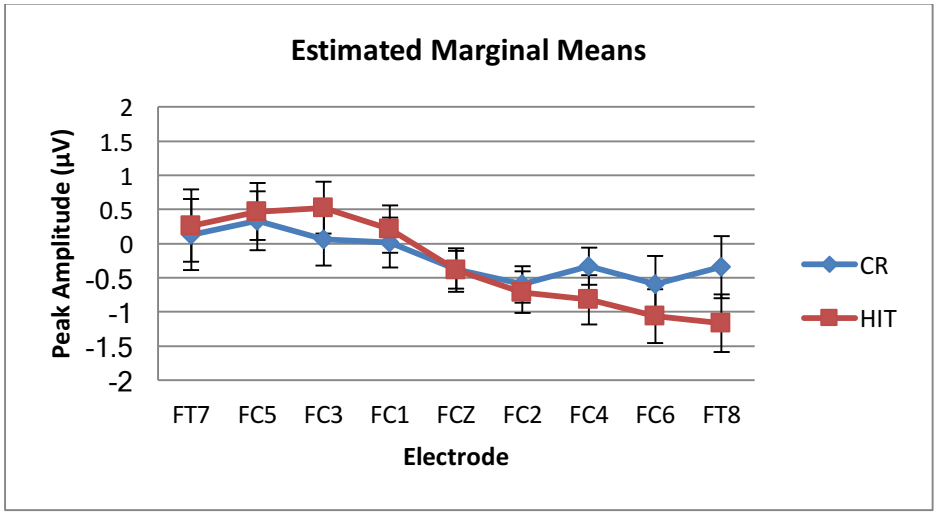
Hypothesis: CR vs h						**Mean**	
Component	Factor	F	df (adj.)	p	η^2_p	CR	h
P2 frontal amplitude	Condition * Electrode	2.84	3.86, 73.26	< 0.05	0.13		
P3 frontal amplitude	Condition * Electrode	3.40	3.89, 73.84	< 0.05	0.15		
P3 frontal latency	Condition	4.88	1,19	< 0.05	0.20	422 ms	410 ms

Table 5.2, Table 5.3 and Table 5.4 illustrate ANOVA results of common average reference data. Table 5.2 revealed that ANOVA analysis of correct rejection and hit responses show that there was a significant interaction between the response types and electrodes in

amplitude of component P2 and P3 (see Figure 5.6(a) and (b)). For P2, F (3.86, 73.26) = 2.84, $p < 0.05$, $_p\eta^2 = 0.13$. For P3, F (3.89,73.84) = 3.40, $p < 0.05$, $_p\eta^2 = 0.15$. in addition, there was an main effect of response categories in latency of component P3. F (1,19) = 4.89, $p < 0.05$, $_p\eta^2 = 0.20$, and the mean latency were 422 ms and 410 ms seperately for correct rejections (CR) and hits (h).



(a) P2 amplitude



(b) P3 amplitude

Figure 5.6 - The significant main effect and interaction between response types (correct reject and hit) and frontal electrodes site in component (a) P2 amplitude and (b) P3 amplitude

To conclude this section, there were significant interactions between hits and correct rejections for the P2 and P3 component within the region of interest. This may reflect

familiarity strength (old stronger than new) or it may reflect response preparation since the side of response for h and CR were different. There was also a significant main effect on P3 latency, with an earlier peak for hits (410 ms) than correct rejections (422 ms). This finding could be consistent with a familiarity strength account of recognition memory, since old items would have higher familiarity strength than new (Johnson, 1995; Rugg, 1995).

Table 5.3 - Significant ANOVA result in ERP components comparing false alarms versus hits as a function of electrodes position within the parietal and frontal ROIs

Hypothesis: FP vs h						**Mean**	
Component	Factor	F	df (adj.)	p	η^2_p	FP	h
N1 parietal amplitude	Condition	8.42	1,19	< 0.005	0.31	-3.6 μV	-2.3 μV
FN400 frontal amplitude	Condition	20.60	1,19	< 0.001	0.52	-3.5 μV	-2.0 μV
	Condition * Electrode	3.32	4.4,83.49	< 0.05	0.15		
P3 frontal amplitude	Condition	20.20	1,19	< 0.001	0.52	0.5 μV	-3.0 μV
P2 frontal latency	Condition	10.10	1,19	< 0.01	0.35	254 ms	237 ms
P3 frontal latency	Condition	4.38	1,19	< 0.05	0.19	422 ms	410 ms

In comparing false alarms and hits (see Table 5.3), there was a main effect of response type on component N1 amplitude, $F(1,19) = 8.42$, $p < 0.005$, $_p\eta^2 = 0.31$; the mean amplitudes were -3.6 μV and -2.3 μV respectively for false alarms and hits. There was a main effect of response categories and a significant interaction with ROI electrode position on the amplitude of component FN400. For the main effect of responses, $F(1,19) = 20.60$, $p < 0.001$, $_p\eta^2 = 0.52$, and the mean amplitudes were -3.5 μV and -2.0 μV respectively. For the significant interaction result, $F(4.4, 83.49) = 3.32$, $p < 0.05$, $_p\eta^2 = 0.15$ (see Figure 5.7). There was a main effect response categories in amplitude of component P3, $F(1,19) = 20.20$, $p < 0.001$, $_p\eta^2 = 0.52$, and the mean amplitude of false alarm was 0.51 μV, the mean amplitude of hit was -3.0 μV. On top of that, the ANOVA result revealed the main effect of response types in latency of component P2 and P3. For component P2, $F(1,19) = 10.10$, $p < 0.01$, $_p\eta^2 = 0.35$, the mean latency of false alarms was 254 ms and the mean latency of hits was 237 ms. For

component P3, F (1,19) = 4.38, $p < 0.05$, $_p\eta^2 = 0.19$, the mean latencies of false alarms and hits were 422 ms and 410 ms respectively.

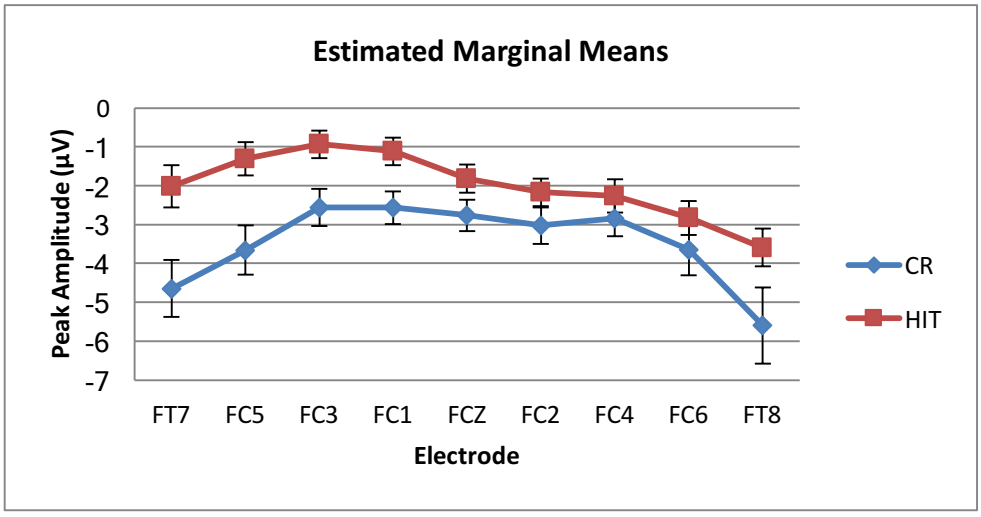


Figure 5.7 - The significant main effect and interaction between response types (false alarms and hits) and frontal electrodes site in component FN400

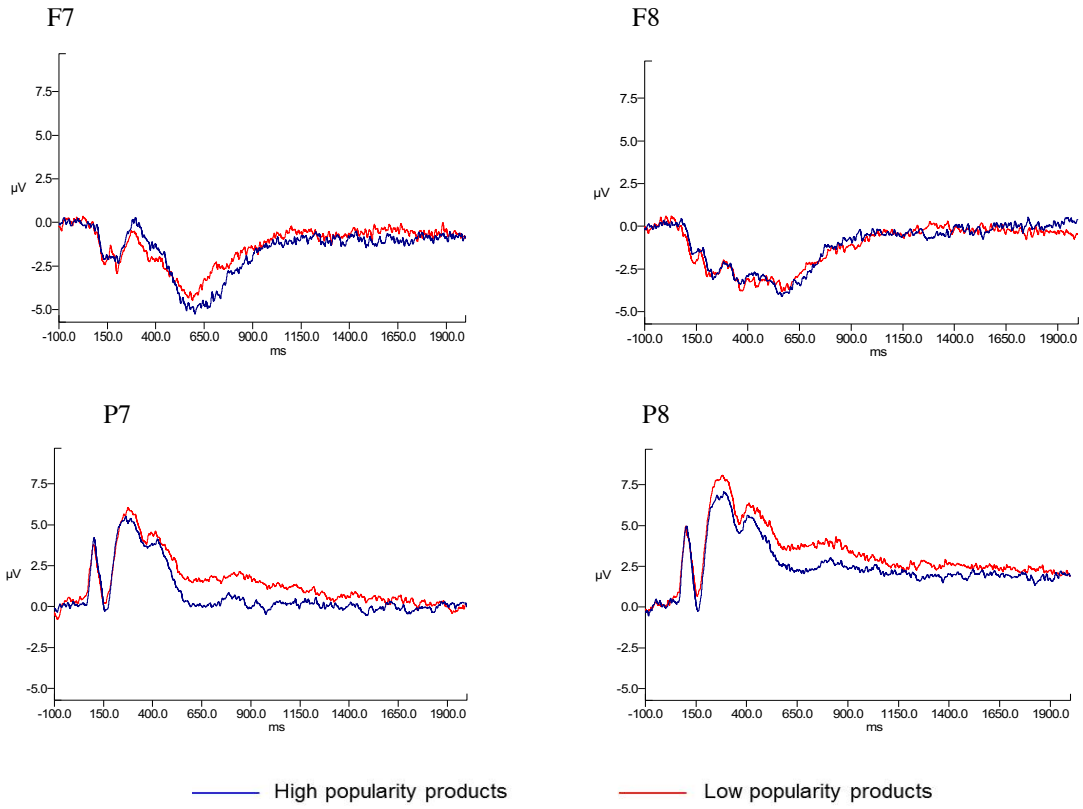
Table 5.4 - Significant ANOVA results for different component amplitudes, comparing correct rejections versus misses (condition) and electrode positions within parietal or frontal ROI (electrode)

Hypothesis: CR vs MISS						Mean	
Component	Factor	F	df (adj.)	p	η^2_p	CR	MISS
N1 parietal amplitude	Condition	13.67	1,19	< 0.005	0.42	-2.7 μV	-4.2 μV
FN400 frontal amplitude	Condition	18.54	1,19	< 0.001	0.49	-2.0 μV	-3.7 μV

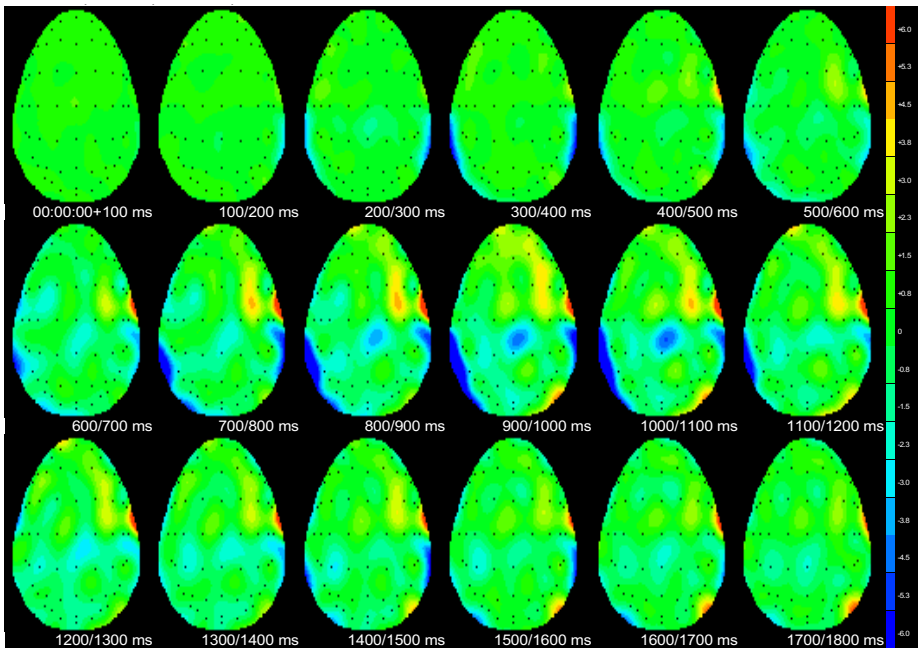
In comparing ERPs preceding the response categories of correct rejections and misses, ANOVA results (Table 5.4) revealed main effects of response types on amplitudes of component N1 and FN400. For the N1, F (1,19) = 13.67, $p < 0.005$, $_p\eta^2 = 0.42$, and the mean amplitudes were -2.7 μV and -4.2 μV respctively. For FN400, F (1,19) = 18.54, $p < 0.001$, $_p\eta^2 = 0.49$, the mean amplitude of correct reject was -2.0 μV and of the miss was -3.7 μV.

5.3.2.1.2 ERPs to high versus low sales volume products in the first (decision to purchase) block without pricing information

Figure 5.8(a) depicts grand mean ERPs to the visual stimuli which were elicited during the phase of decision to purchase (Block 1). The grand-average ERPs for high sales volume products versus low sales volume products is shown at electrode location of left and right frontal F7, F8, and left and right parietal P7 and P8; and in Figure 5.8(b) the scalp topographies of the same contrast represent t-values for the differences between high and low sales volume products for both categories of response (inclined to purchase, not inclined to purchase). From 250 ms post-stimulus the ERPs to the low sales volume products were more positive than high sales volume products at parietal electrode locations. This gave rise to negative t-values (blue) in the scalp maps.



(a)

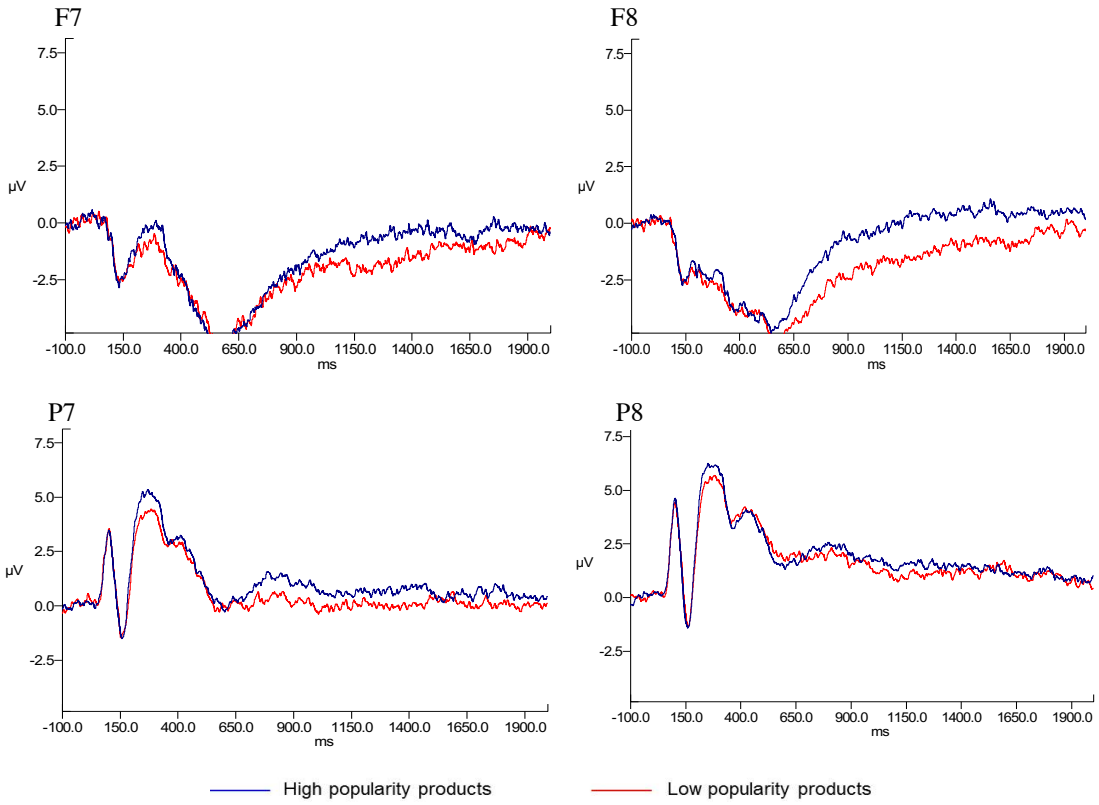


(b)

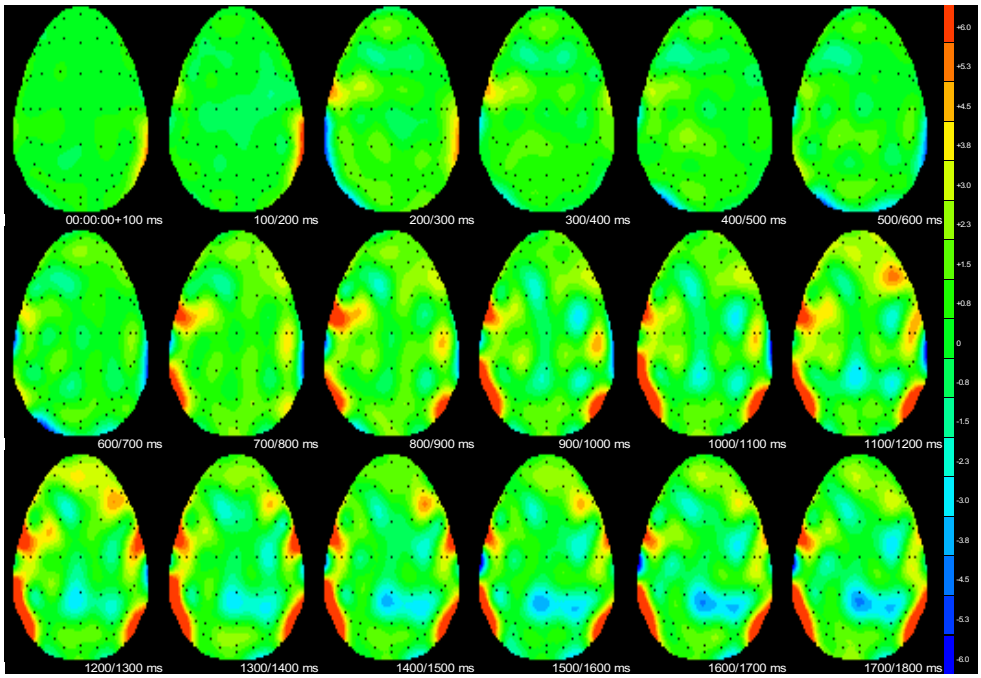
Figure 5.8 – Group 1 Block 1: (a) grand-average ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes; (b) scalp t-value topographies for ERPs associated with the contrast between high sales volume products versus low sales volume products in Block 1 (direction of subtraction: high minus low). Green represents non-significant differences (Bonferroni corrected across electrodes). Scale: Maximal positive t (6.0) is indicated by red and maximal negative t (-6.0) by blue

5.3.2.1.3 ERPs to high versus low sales volume products in the second (recognition) block without pricing information

In Block 2, the recognition memory phase, comparing high sales volume and low sales volume product, both an early and a prolonged positivity was observed in the ERPs elicited by high sales volume products (Figure 5.9(a)). At frontal electrode locations, the magnitude of the difference between high and low sales volume product was larger over the left than over the right hemisphere from 600 ms onwards. Scalp maps (Figure 5.9(b)) showing the t-values for the comparison of ERPs to high and low sales volume products in the second interval show significant differences over lateral parietal electrodes from 700 ms, and more marginal early differences in lateral parietal and frontal locations.



(a)

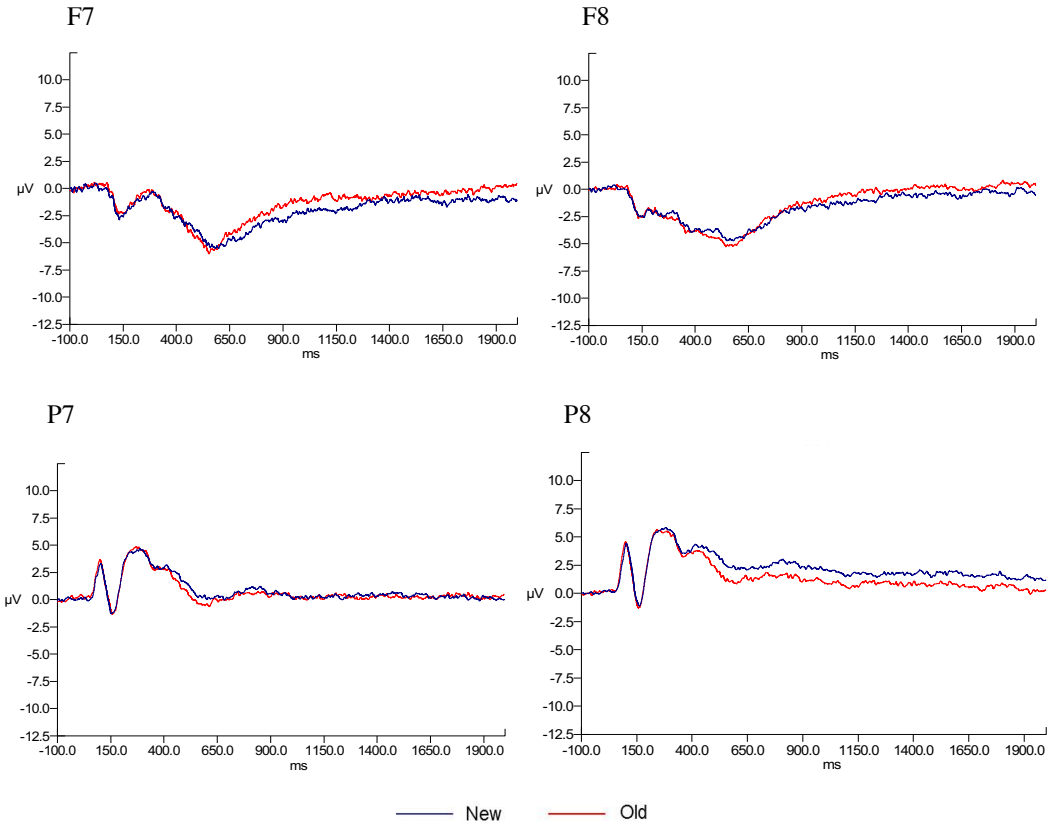


(b)

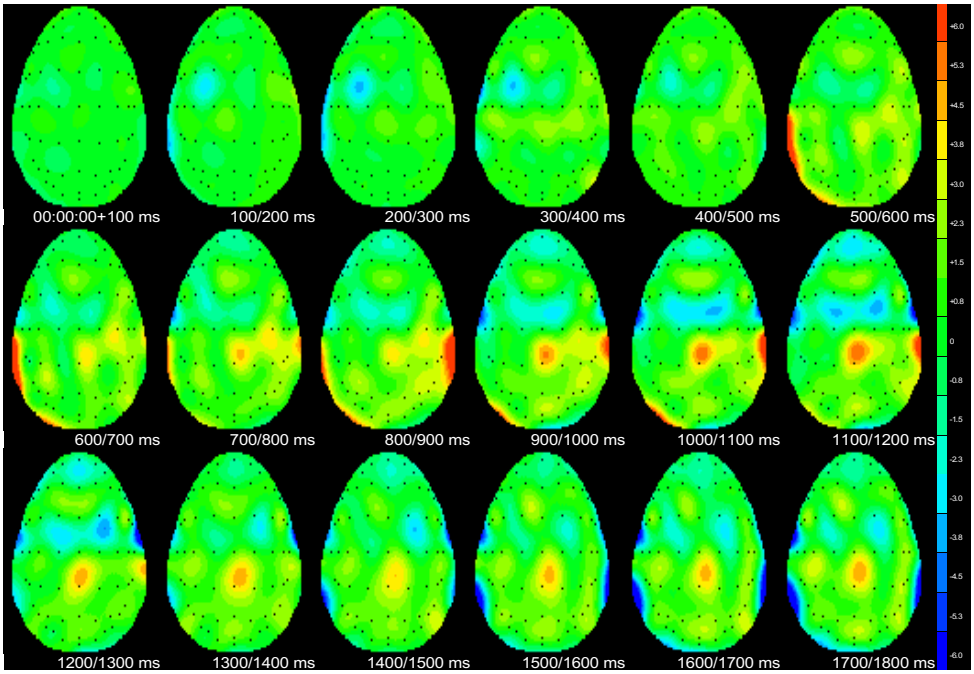
Figure 5.9 – Group 1 Block 2: ERPs result associated with the contrast between high sales volume products versus low sales volume products without pricing information in the recognition block (Block 2): (a) grand-average ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes; (b) scalp t-value topographies for the difference in ERPs for high versus low sales volume products (direction of subtraction: high minus low). Green represents non-significant differences (Bonferroni corrected across electrodes). Maximal positive t (6.0) is indicated by red and maximal negative t by blue (-6.0)

5.3.2.1.4 ERPs to old versus new stimuli in the second (recognition) block without pricing information

Comparisons of grand mean ERPs to new and old stimuli in Block 2 are shown in Figure 5.10(a). At lateral frontal location sites, ERPs to old stimuli were more positive than ERPs to new stimuli after 650 ms. In the t-maps this shows as a band of light blue between fronto-central and central electrodes. However, in the right parietal location, the ERPs elicited by new items were more positive, the difference occurring from 500 ms.



(a)

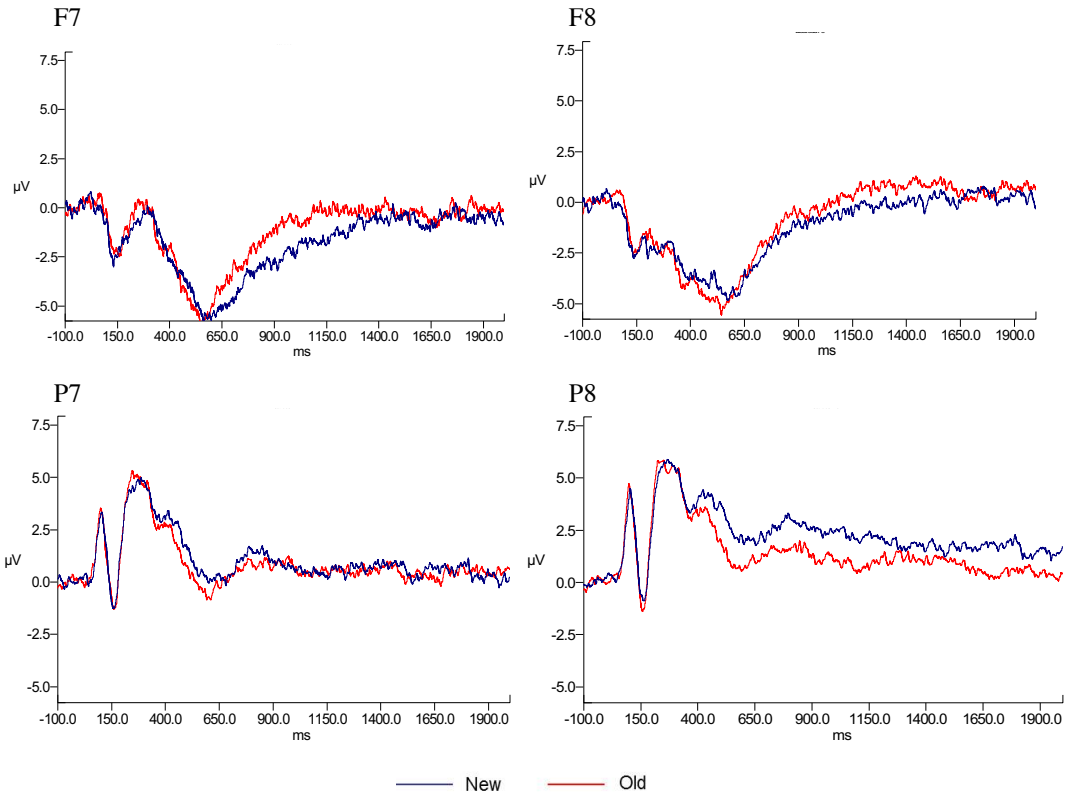


(b)

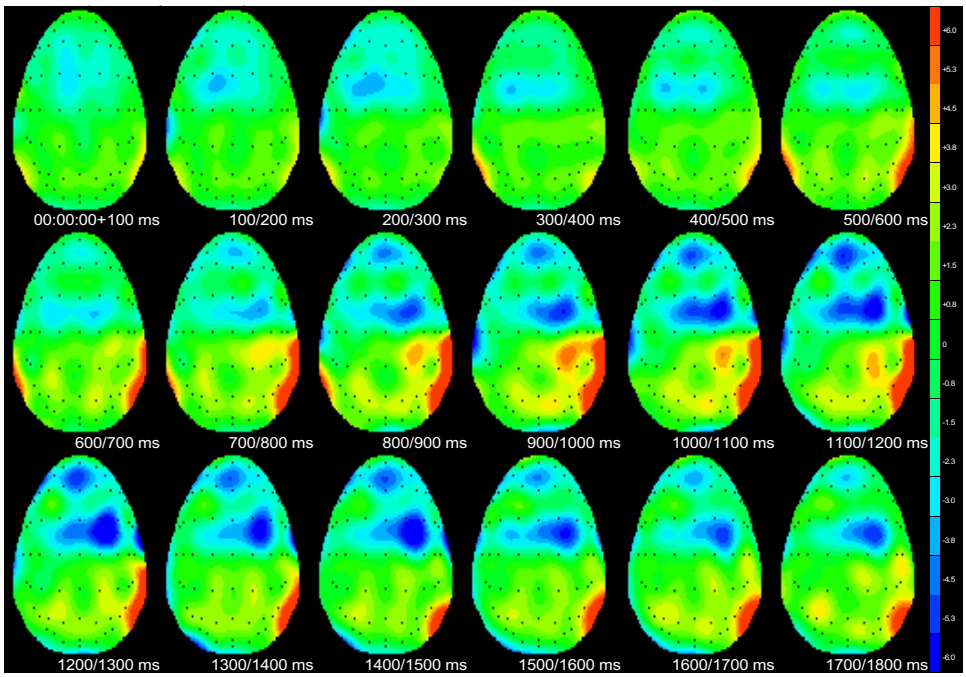
Figure 5.10 – Group 1 Block 2 new/old: (a) grand-average (n = 20) ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes evoked by new and old items in the recognition block (Block 2); (b) scalp t-value topographies for the difference in ERPs for old versus new items in the recognition block (direction of subtraction: new minus old). Green represents non-significant differences (Bonferroni corrected across electrodes). Maximal positive t (6.0) is indicated by red and maximal negative t by blue (-6.0). Without pricing information

5.3.2.1.5 ERPs to old versus new stimuli in the second (recognition) block: high sales volume stimuli, no pricing information

The ERPs depicted in Figure 5.11(a) are the comparison of responses to new and old stimuli in the second (recognition) block for high sales volume products alone. The waveforms elicited by old items were predominantly more positive than new items at frontal locations after 600 ms. The effect is seen strongly as a blue band in the t-maps with peak values around FC4. By contrast, the waveforms of new items appear predominantly more positive than old items at right parietal locations.



(a)

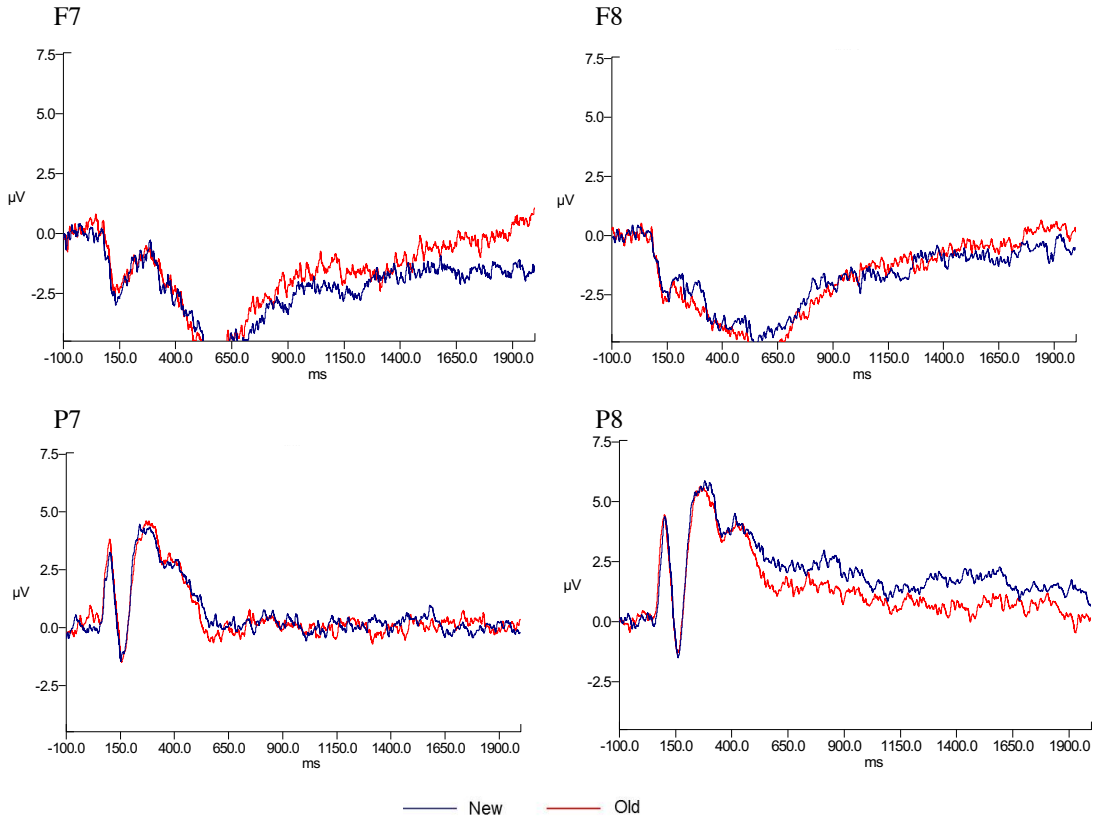


(b)

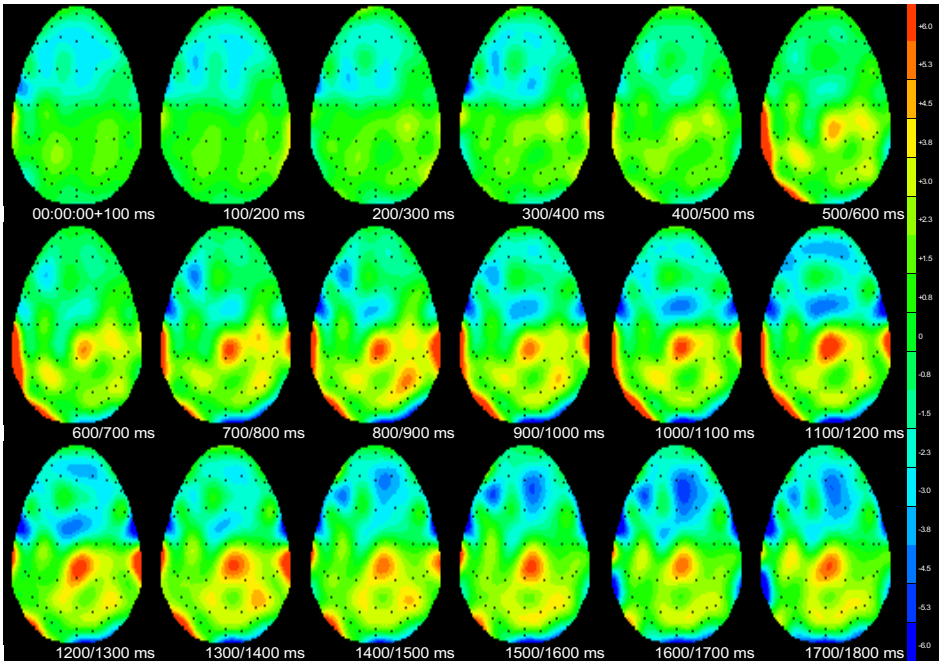
Figure 5.11 – Group 1 Block 2 new/old high sales volume: (a) grand-average (n = 20) ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes evoked by new versus old items in the condition of high sales volume products in Block 2; (b) scalp t-value topographies for the difference in ERPs for old versus new items in the recognition block for high sales volume products alone (direction of subtraction: new minus old). Green represents non-significant differences (Bonferroni corrected across electrodes). Maximal positive t (6.0) is indicated by red and maximal negative t by blue (-6.0)

5.3.2.1.6 ERPs to old versus new stimuli in the second (recognition) block: low sales volume stimuli, no pricing information

The analysis ERPs displays in Figure 5.12(a) show the contrast between ERPs to new versus old items for low sales volume products. The waveforms elicited by old items were more positive than new items at left frontal sites. Opposite to this, the waveforms elicited by new items appeared predominantly more positive in amplitude than old items at right parietal electrode, and the positive peaking at approximate over 300 ms epoch.



(a)



(b)

Figure 5.12 – Group 1 Block 2 new/old low sales volume: (a) grand-average (n = 20) ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes evoked by new and old items for low sales volume products alone in Block 2; (b) scalp t-value topographies for the difference in ERPs for old versus new items in the recognition block for low sales volume products alone (direction of subtraction: new minus old). Green represents non-significant differences (Bonferroni corrected across electrodes). Maximal positive t (6.0) is indicated by red and maximal negative t by blue (-6.0)

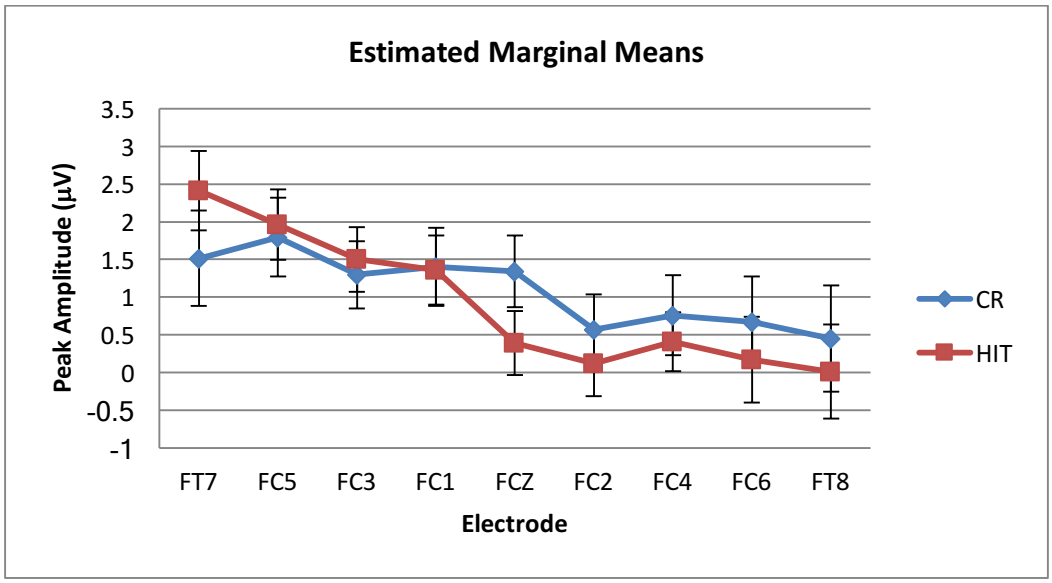
5.3.2.2 Group 2 – with pricing information

5.3.2.2.1 Comparisons of ERPs to stimuli in the recognition block as a function of signal detection variables (with pricing information)

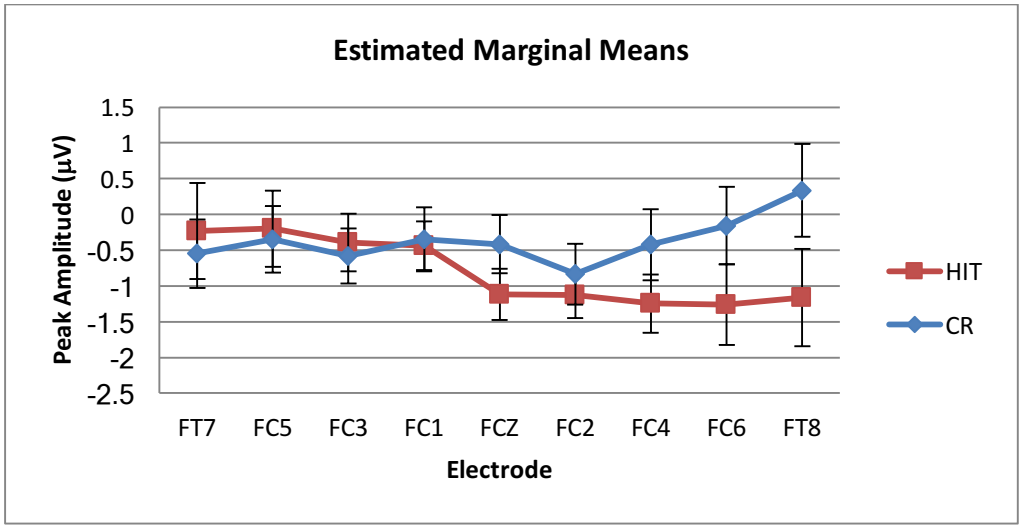
Table 5.5 displays a significant main effect of response types (CR vs h) on component N1 amplitude, $F(1,19) = 4.96$, $p < 0.05$, ${}_p\eta^2 = 0.21$. The mean amplitude of correct rejections and hits were -2.8 μV and -3.5 μV respectively. There was also a main effect of response types (CR vs h) on component P3 latency, $F(1,19) = 4.66$, $p < 0.05$, ${}_p\eta^2 = 0.20$. The mean latency of correct rejections and hits were 429 ms and 416 ms, respectively. Figure 5.13 displays the significant interaction between response types and electrode sites on the amplitude of components P2 and P3. For P2 amplitude, $F(3.27, 62.17) = 2.90$, $p < 0.05$, ${}_p\eta^2 = 0.13$. for P3 amplitude, $F(3.67, 69.55) = 5.23$, $p < 0.05$, ${}_p\eta^2 = 0.22$.

Table 5.5 - Significant ANOVA result for different components amplitudes and latencies comparing correct rejections versus hits and electrode positions within parietal or frontal ROI

Hypothesis: CR vs h						Mean	
Component	Factor	F	df (adj.)	p	η^2_p	CR	h
N1 parietal amplitude	Condition	4.96	1,19	< 0.05	0.21	-2.8 µV	-3.5 µV
P2 frontal amplitude	Condition * Electrode	2.90	3.27, 62.17	< 0.05	0.13		
P3 frontal amplitude	Condition * Electrode	5.23	3.67, 69.55	< 0.005	0.22		
P3 frontal latency	Condition	4.66	1,19	< 0.05	0.20	429 ms	416 ms



(a) P2 amplitude



(b) P3 amplitude

Figure 5.13 - The significant interaction between response types (correct rejections and hits) and frontal electrodes positions for component (a) P2 amplitude and (b) P3 amplitude

In the comparison of false alarms and hits, ANOVA results also revealed a main effect of response categories (FP vs h) at frontal sites on component FN400, $F(1,19) = 4.59$, $p < 0.05$, ${}_p\eta^2 = 0.20$. The mean amplitude of ERPs to false alarms and hits were -4.3 µV and -3.6 µV respectively (see Table 5.6).

Table 5.6 - Significant ANOVA result in components between factor of responses types (false positive and hit) and factor of electrode position within the frontal ROI

Hypothesis: FP vs h						**Mean**	
Component	Factor	F	df (adj.)	p	η^2_p	FP	h
FN400 frontal amplitude	Condition	4.59	1,19	< 0.05	0.20	-4.3 µV	-3.6 µV

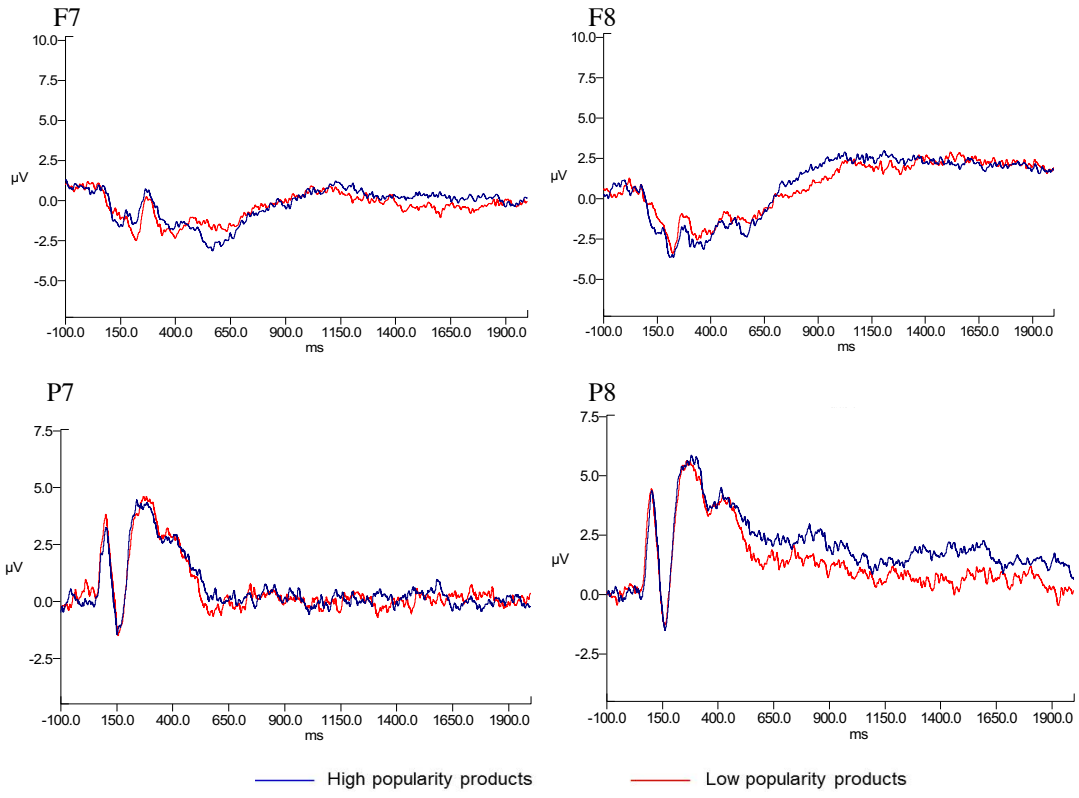
Table 5.7 displays the significant main effect of response type (correct rejections versus misses) in ANOVA) at frontal sites. $F(1,19) = 10.06$, $p < 0.05$, ${}_p\eta^2 = 0.35$. The mean amplitude of false alarms and hits were -3.3 µV and -4.6 µV, respectively.

Table 5.7 - Significant ANOVA result on component amplitudes in frontal ROI in comparison of correct rejections versus misses

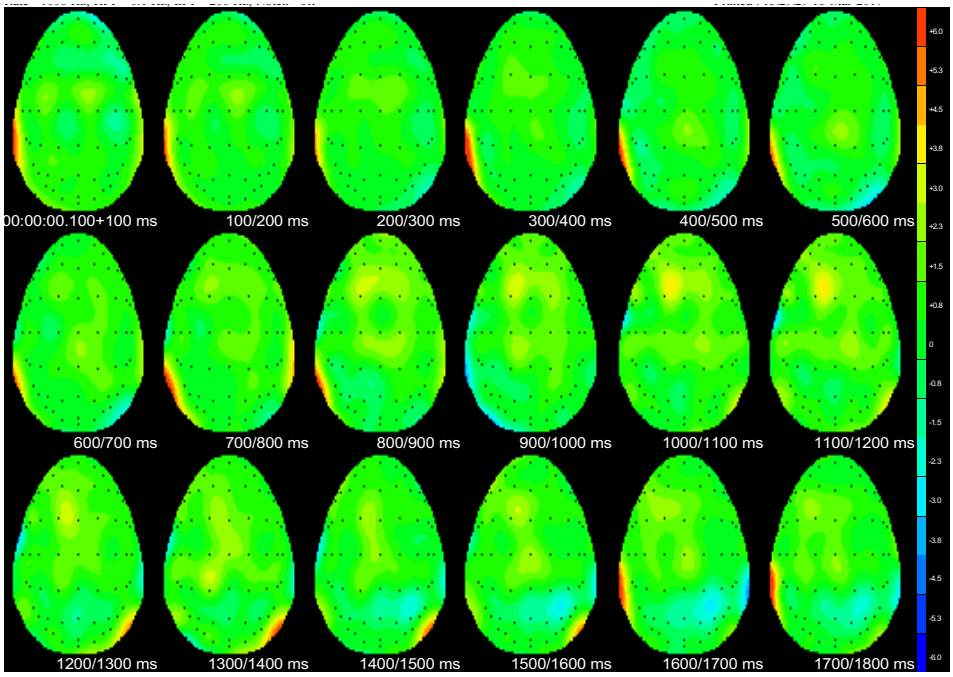
Hypothesis: CR vs MISS						Mean	
Component	Factor	F	df (adj.)	p	η^2_p	CR	MISS
FN400 frontal amplitude	Condition	10.06	1,19	< 0.05	0.35	-3.3 μV	-4.6 μV

5.3.2.2.2 ERPs to high versus low sales volume products in the first (decision to purchase) block, with pricing information

In Group 2, Block 1 of the experiment, grand averaged ERPs were obtained for high and low sales volume items displayed with pricing information (see Figure 5.14) across electrode sites F7, F8, P7 and P8. The ERPs evoked by high sales volume items were more positive-going than low sales volume items at P8 sites after 300 ms, and the positive peaking at approximate over 300 ms epoch.



(a)

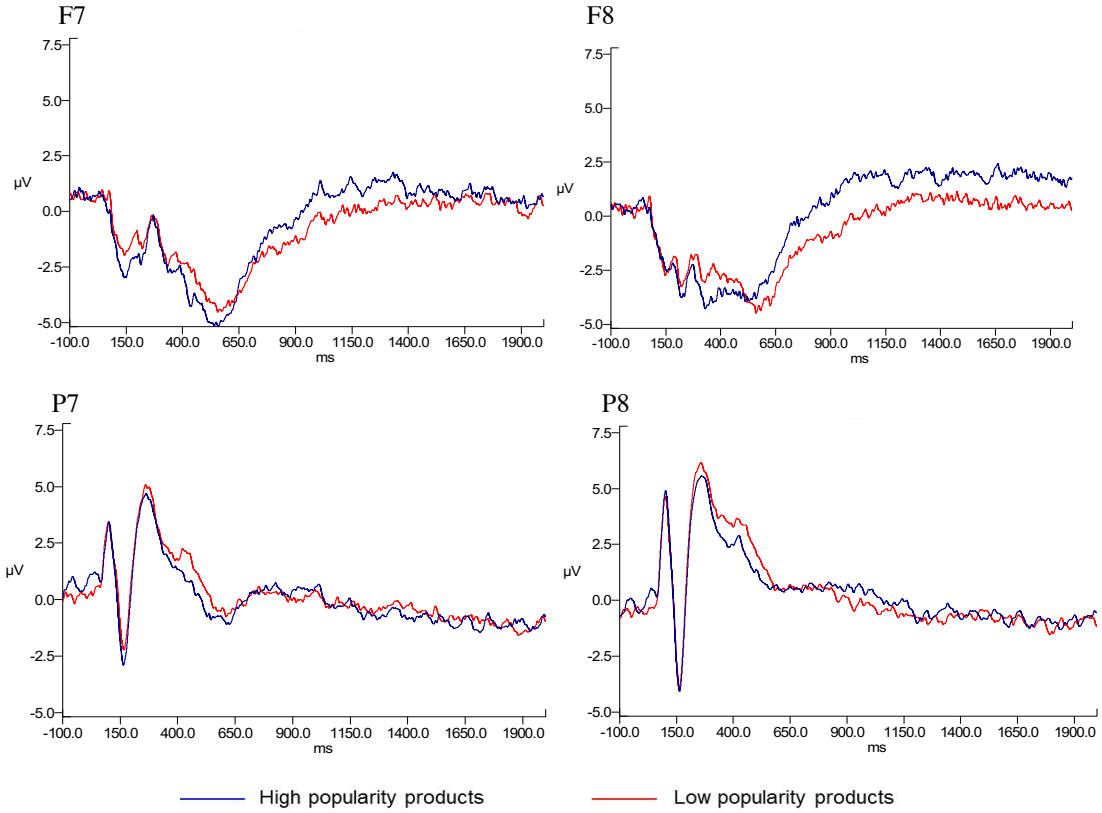


(b)

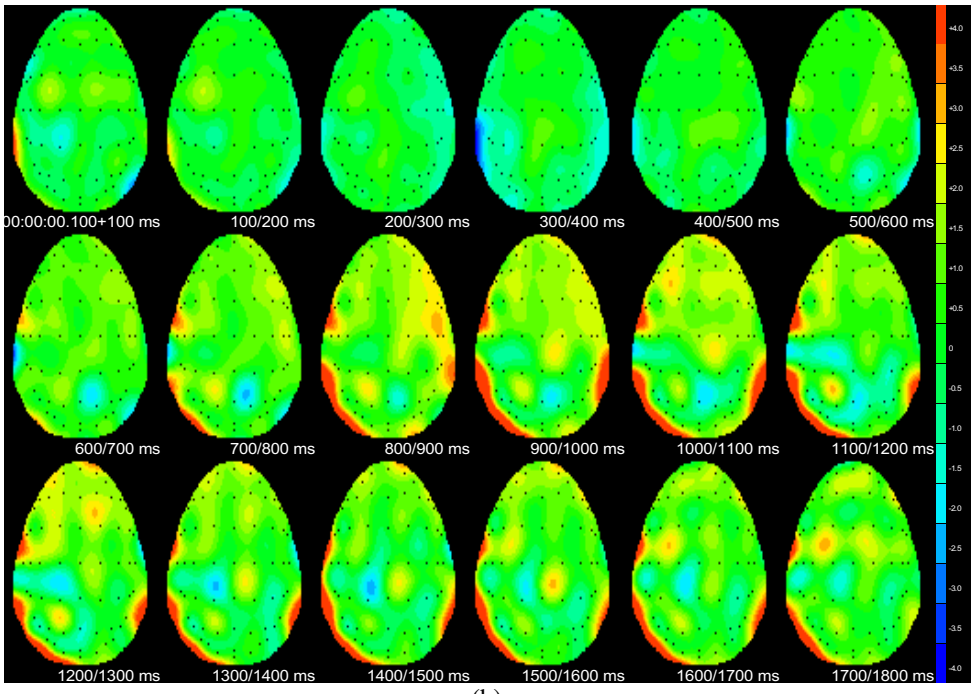
Figure 5.14 – Group 2 Block 1 high/low sales volume: (a) grand-average (n = 20) ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes evoked by high and low sales volume items in Block 1; (b) scalp t-value topographies for the difference in ERPs for high versus low sales volume products in the decision to purchase block with pricing information (direction of subtraction: high minus low). Green represents non-significant differences (Bonferroni corrected across electrodes). Scale: Maximal positive t (6.0) is indicated by red and maximal negative t by blue (-6.0)

5.3.2.2.3 ERPs to high versus low sales volume products in the second (recognition) block, with pricing information

In terms of the contrast between high and low sales volume items displayed with the pricing information in Block 2; at frontal sites, the waveforms evoked by high sales volume items were more negative-going between approximate 250-550 ms. However, after 650 ms, the ERPs elicited by high sales volume items become more positive-going than those for low sales volume items (Figure 5.15). At parietal sites, the waveforms evoked by the high sales volume items were more negative than low sales volume items between approximate 250-600 ms.



(a)



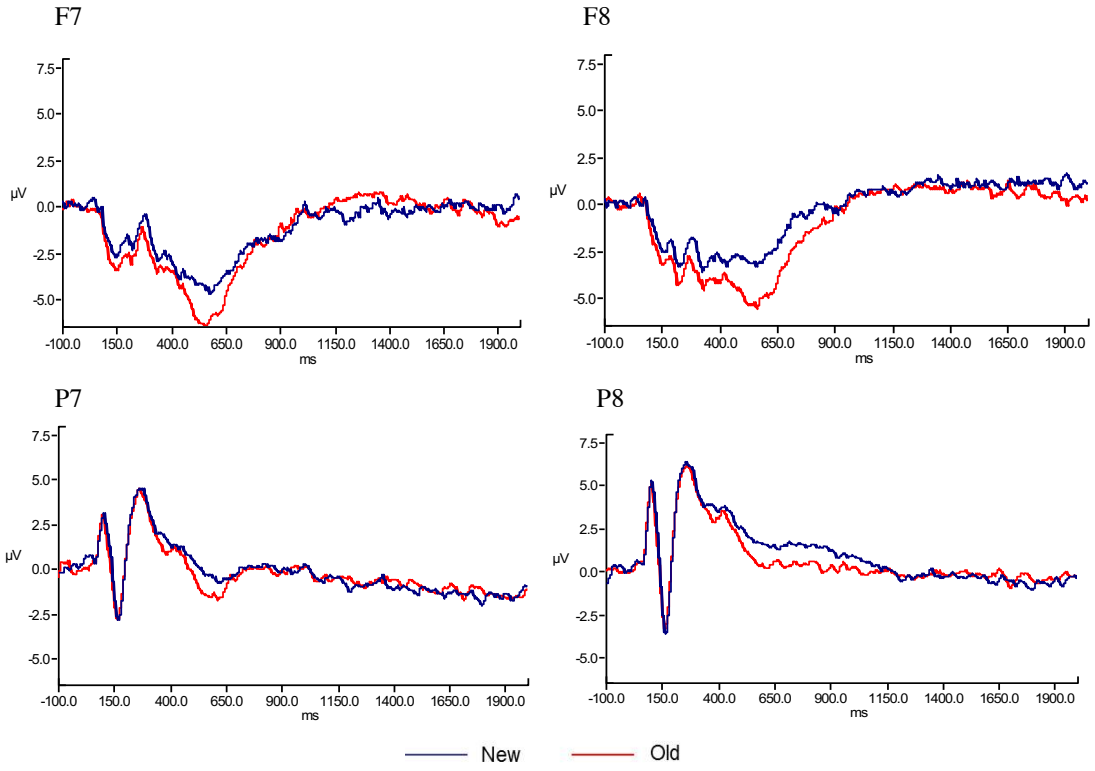
(b)

Figure 5.15 – Group 2 Block 2 high/low sales volume: (a) grand-average (n = 20) ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes evoked by high and low sales volume items in Block 2; (b) scalp t-value topographies for the difference in ERPs for high versus low sales volume products in the recognition block with pricing information (direction of subtraction: high minus low).

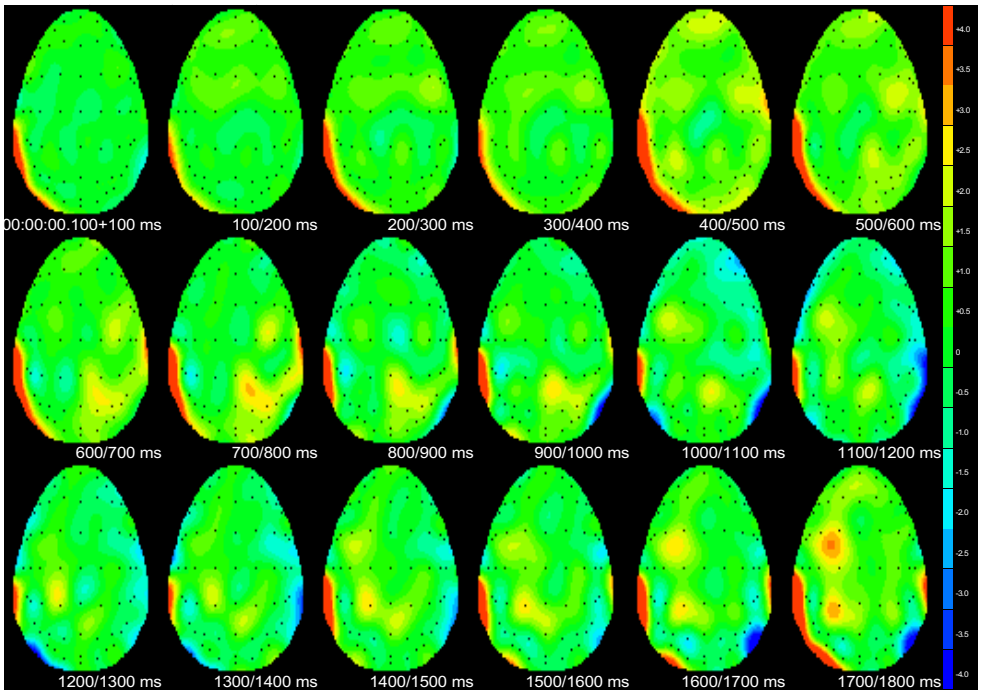
Green represents non-significant differences (Bonferroni corrected across electrodes). Scale: Maximal positive t (6.0) is indicated by red and maximal negative t by blue (-6.0)

5.3.2.2.4 ERPs to old versus new items in the second (recognition) block, with pricing information

Figure 5.16 displayed the comparison of grand average ERPs for new and old items in Block 2, with pricing information. At frontal locations ERP waveforms to new items were more positive than those to old items between about 100-850 ms. At parietal sites, ERPs evoked by new were positive than old in the 350-650 ms interval.



(a)

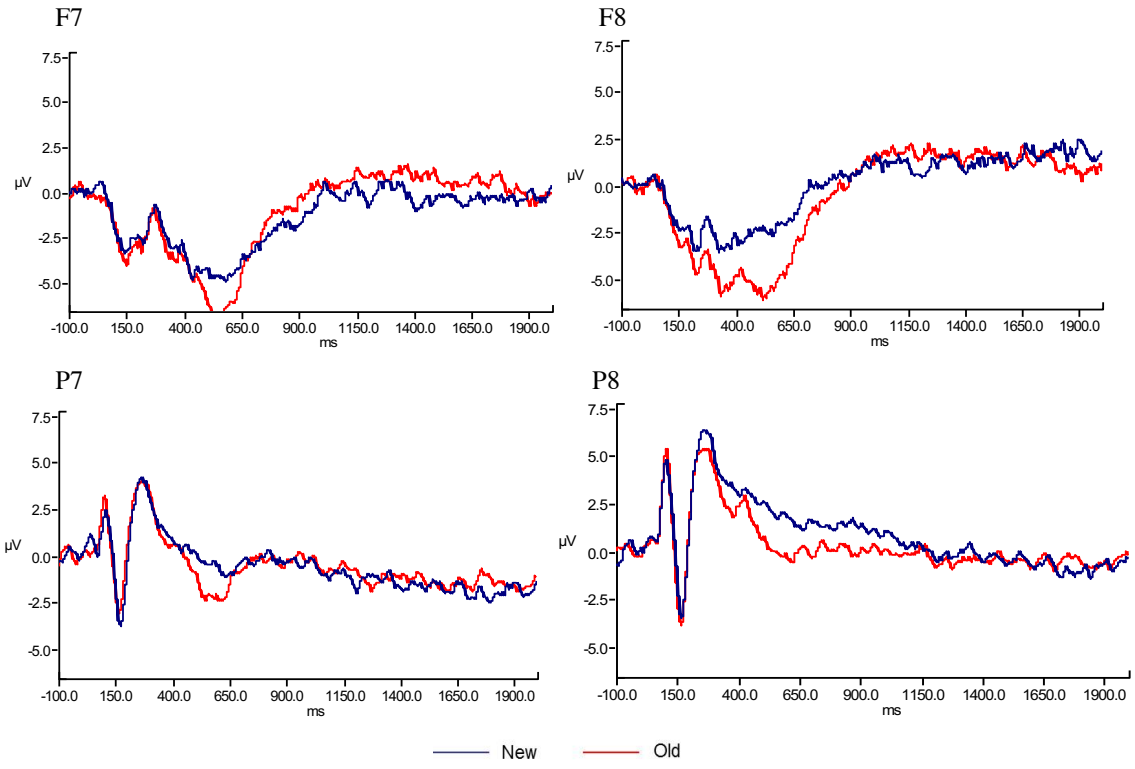


(b)

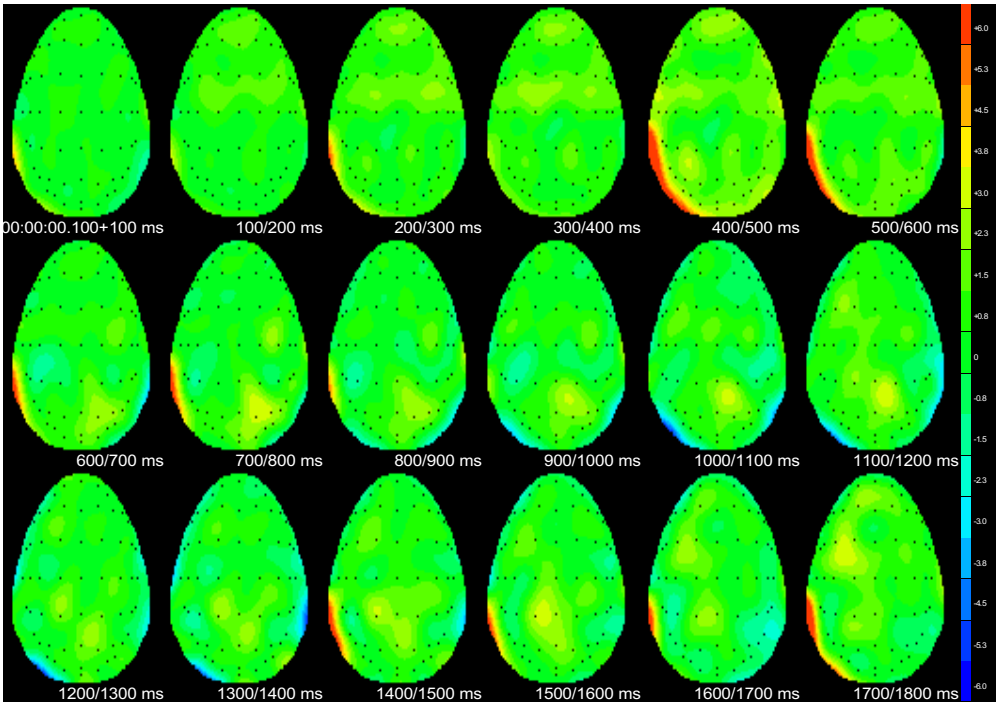
Figure 5.16 – Group 2 Block 2 new/old: (a) grand-average (n = 20) ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes evoked by new and old items in Block 2; (b) scalp t-value topographies for the difference in ERPs for old versus new items in the recognition block, with pricing information (direction of subtraction: new minus old). Scale: Green represents non-significant differences (Bonferroni corrected across electrodes). Maximal positive t (6.0) is indicated by red and maximal negative t by blue (-6.0)

5.3.2.2.5 ERPs to old versus new items in the second (recognition) block, for high sales volume products only, with pricing information

The ERPs depicted in Figure 5.17 represent the comparison of new and old items in the recognition of high sales volume products with pricing information. The waveforms elicited by old items were more negative than new items at frontal locations in the 100-700 ms interval. And at parietal sites, the waveforms elicited by old items were more negative than new items in the 300-650 ms interval.



(a)

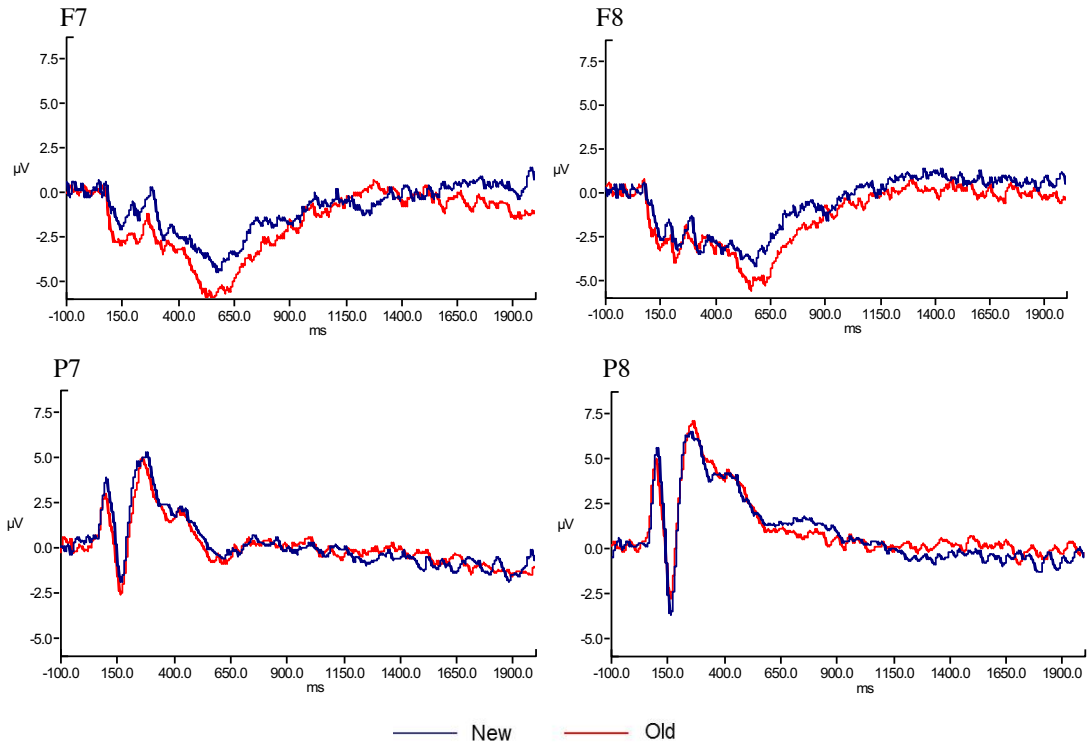


(b)

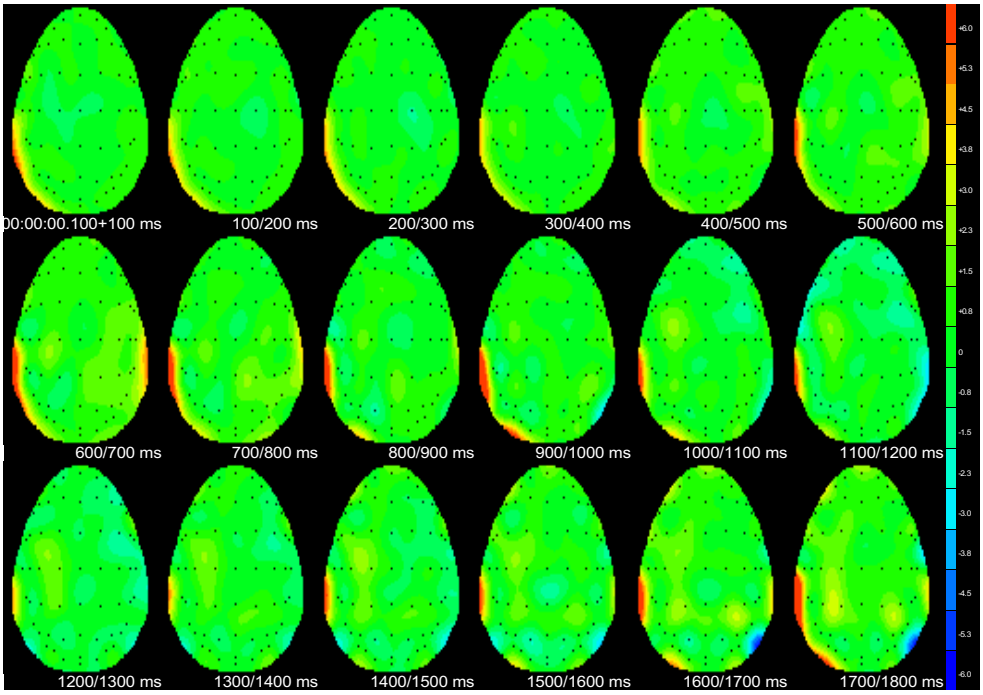
Figure 5.17 - Group 2 Block 2 new/old high sales volume: (a) grand-average (n = 20) ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes evoked by new and old high sales volume products with pricing information; (b) scalp t-value topographies for the difference in ERPs for old versus new items in the recognition block, for high sales volume products with pricing information (direction of subtraction: new minus old). Scale: Green represents non-significant differences (Bonferroni corrected across electrodes). Maximal positive t (6.0) is indicated by red and maximal negative t by blue (-6.0)

5.3.2.2.6 ERPs to old versus new items in the second (recognition) block, for low sales volume products only, with pricing information

The analysis ERPs displays in Figure 5.18 are the contrast in the recognition task between new versus old low sales volume items with pricing information. The waveforms elicited by old items were more negative than new items at F8 sites at after approximate 450 ms.



(a)



(b)

Figure 5.18 - (a) Grand-average (n = 20) ERPs waveforms from left frontal (F7), right frontal (F8), left parietal (P7) and right parietal (P8) electrodes evoked by new and old items in the condition of low sales volume products in Block 2; (b) scalp t-value topographies for the difference in ERPs for old versus new items in the recognition block, for low sales volume products with pricing information (direction of subtraction: new minus old). Scale: Green represents non-significant differences (Bonferroni corrected across electrodes). Maximal positive t (6.0) is indicated by red and maximal negative t by blue (-6.0)

5.4 Discussion

The experiment was designed to examine the effect of sales volume, pricing information, and number of variants (flavours) on recognition memory for branded food snacks. The old/new effects were quantified by comparing high sales volumes products with low sales volume ones and also comparing in the absence and presence of pricing information.

5.4.1 Behavioural results

Regarding to the subjects' behaviour, the data show that the effect of including more variants of a product is to increase similarity of non-targets (noise distribution) to targets thereby reducing d'. However, product sales volume did not affect d', rather it affected the criterion (β, c). Thus, compared with low sales volume products, products with high sales volume are more familiar and this increases their false positive recognition rate. Participant may respond

that they saw it in the first session but in fact, they did not but responded because of the strong familiarity of the item.

Multiple flavours also increase false positives because they provide non-targets that resemble targets (lures) thereby increasing false positive rate. This suggests that the expansion of a product range to include variants may be successful in increasing product familiarity, even for products with low market penetration.

The interaction terms for d' do not yet suggest an obvious interpretation. However, as shown in Figure 5.3, for single flavour items (no lures) the mean d' of high sales volume products is similar in the pricing and no pricing condition. However in the corresponding lower sales volume condition, there is a substantial reduction in the d' value with pricing information. This suggests that the addition of discounted pricing information may interfere with the encoding of these items because it represents extra information processing, whereas the addition of non-discounted pricing does not represent a substantial extra load of information processing. For conditions with lures (flavours) d' is always higher for low sales volume than the high sales volume products.

As mentioned, the product sales volume had a significant effect on the criterion (β, c). The data on the criterion measure (c) gives a more interpretable result than β because the criterion placement is always positive (conservative) for low sales volume products and for high sales volume products zero to negative (liberal). This corresponds with the idea that high sales volume products are more familiar thus participants are biased to answer "Yes" and vice-versa for low sales volume products.

5.4.2 ERPs results

5.4.2.1 Group 1 – no pricing information

5.4.2.1.1 Group 1 - old/new recognition

Comparing ERPs to hits with correct rejections tests for a memory effect, that is, how the brain distinguishes between items that the participant correctly classifies as old versus new. The classic old/new effect on ERPs consists of a greater positivity from around 300 ms onwards for old items relative to new items (Sanquist, et al., 1980; Warren, 1980) This effect

has been further subdivided in later research: a parietal positivity for old items irrespective of whether they were correctly identified or not, (parietal old/new effect); may be accompanied by a greater positivity over frontal electrodes for items that were correctly identified as old (frontal old/new effect) (Rugg & Curran, 2007). Thus the frontal ROI is relevant to comparison of hits versus correct rejections in the present study. Rugg et al. (1998) have proposed that a frontal old/new effect may reflect familiarity strength (old stronger than new) (Rugg et al., 1998). A small old/new effect on frontal electrodes can be observed in grand-average ERPs particularly at F7 (Figure 5.10(a), Figure 5.11(a), and Figure 5.12(a)). For correctly classified old and new items, the response amplitude for hits (h) was more positive for electrode locations in the left hemisphere, and the response amplitude for correct rejections (CR) was more positive for electrode locations in the right hemisphere. However, for the current study, for ANOVA on amplitudes in the frontal ROI, there was no significant main effect of hits versus correct rejections on ERP amplitudes in the frontal ROI. Instead, there were significant interactions within the region of interest with electrode position between hits and correct rejections for the P2 and P3 component peaks. There was also a significant main effect on P3 latency, with an earlier peak for hits (410 ms) than correct rejections (422 ms). This finding could be consistent with a familiarity strength account of recognition memory, since old items would have higher familiarity strength than new (Johnson, 1995; Rugg, 1995; Rugg & Curran, 2007).

Comparing FP with h tests whether the brain differentiates between new items which the participant thinks are old (FP) and items that are correctly identified as old (h). As Table 5.3 shows, that was a main effect of response type on component N1 peak amplitude, which was larger (more negative) for FP than h. Such early effects are unusual in old/new recognition studies, and would normally suggest that there were perceptual differences between stimuli giving rise to hits and false positives. However, there may have been residual baseline differences, or errors due to different numbers of FP and h trials (Thomas, et al., 2004). There was also a main effect of response categories and a significant interaction with ROI electrode position on the peak amplitude of a negative component, which we have tentatively identified as the FN400 (Rugg & Curran, 2007). FN400 is a frontal negative component thought to be associated with familiarity-based recognition (Rugg & Curran, 2007). Amplitudes were more negative for FP than for h, and this is consistent with the view that FP recognition is based on feelings of familiarity (Cadavid & Beato, 2016). This may particularly be the case where there are stimuli (known as “lures”) that are similar in appearance to the original therefore in

this study, the inclusion of different flavour variants with similar packaging may have produced this effect. Note that this negative component is considerably earlier than the late posterior negativity (LPN) which occurs in the range 1200-1800 ms in episodic memory studies (Mecklinger, et al., 2016). There was also a significant main effect of response category on P2 peak latency with an earlier peak for hits (237 ms) than false alarms (254 ms) and a significant main effect on P3 peak latency, with an earlier peak for hits (410 ms) than false alarms (422 ms); and P3 amplitude, with a lower peak amplitude for hits (-3.0 μV) than false alarms (0.51 μV). P300 is a positive ERPs component with peak latency between 300 ms and 1000 ms after the stimulus onset that provides a great deal of information about the neural activity of fundamental cognitive operations, and has especially been identified with the activity of updating of working memory (Donchin & Coles, 1988a) and the orienting response (Ritter, Vaughan & Costa, 1968). The amplitude of P300 thus reflects the allocation of attention resources (Humphrey & Kramer, 1994), and its peak latency reflects the stimulus classification time (Kutas, McCarthy, & Donchin, 1977; Magliero, Bashore, Coles, & Donchin, 1984). This result suggests that responses of both hit and false alarms process can evoke P300, but hits elicit shorter latencies and smaller amplitudes of P300 than false alarm trials.

Comparing ERPs preceding the response categories of CR with MISS (participants perceive items as both new), ANOVA results revealed main effects of response types on amplitudes of component N1 and the second negative minimum, which we tentatively identified as FN400. The larger FN400 to miss stimuli than correct rejections would be consistent with an interpretation that misses nevertheless elicit an unconscious familiarity response, whereas correct rejections do not. An alternative interpretation for the negative minimum between 300 and 420 ms is N2. A series of ERPs studies have suggested a negative component N2 reflects conflict and template mismatch (Van Veen & Carter, 2002; Folstein & Van Petten, 2008). N2 component was recorded to have a larger amplitude for MISS (-3.7 μV) than CR (-2.0 μV). This would suggest a conflict will occur and a larger N2 can be recorded on MISS trials. However, it is not necessarily the case conflict occurs on MISS trials – they are simply trials where the participant fails to recognise an old item - a target that had occurred before. However, it is possible to imagine it as a conflict in terms of the dual process theory of recognition by familiarity or recollection (Rugg & Curran, 2007). For there to be a conflict one would have to propose that for misses the target is familiar but is not explicitly recollected.

For the comparison of old versus new stimuli, regardless of the participants' recognition responses, ERPs to old stimuli were more positive than new after 650 ms at frontal electrodes in second block. As for the comparison of hits and correct rejections in the previous section of this discussion, this finding could be consistent with a familiarity strength account of recognition memory, since old items would have higher familiarity strength than new (Johnson, 1995; Rugg, 1995). Familiarity is correlated with an old/new difference (where old ERPs are more positive) occurring 300-500 ms at mid-frontal electrodes, called the FN400. By contrast, new items appeared to give rise to more prominent positive activity than old items after 350 ms post-stimuli at right parietal electrodes (P8) in second block and also in the comparison of both high sales volume stimuli and low sales volume stimuli. This right-hemisphere or bilateral positivity must therefore differ from the left parietal positivity that has been associated with recollection as opposed to familiarity (Cadavid & Beato, 2016). In another word, a positive P300 component was found in this contrast. Also the amplitude of new items was larger than old items. P300 represented greater event categorization activity in the working memory, and larger P300 amplitude would result due to the allocation of cognitive resources (Humphrey & Kramer, 1994).

Although parietal cortex was not chosen as part of an ROI to conduct ANOVA on N400 and P3 peaks, the t-maps (Bonferroni corrected across all electrodes) showed significant old/new differences in parietal cortex. Old items produced significantly more negative ERPs at parietal locations from 500 ms with both left, right and midline parietal locations involved. Partitioning the data for high and low sales volume items showed a similar distribution of significant differences in the t-maps (Figure 5.10(b), Figure 5.11(b), and Figure 5.12(b)). The parietal old/new effect has been associated with recollection, as opposed to familiarity (Rugg & Curran, 2007), or more generally, with memory retrieval (Vilberg & Rugg, 2009), however in the present data it is reversed in polarity. This relative negativity for new items may reflect the cognitive effort required to identify that a flavour is a new item when it is a close variant of an old item.

5.4.2.1.2 Effects of product sales volume on ERPs in the initial (inclination to purchase) and second (old/new recognition) blocks

During the neurophysiological process in Block 1 (inclination to purchase), low sales volume products gave rise to more positive ERPs than high sales volume products at parietal electrode locations from 250 ms post-stimulus. In other words, regarding to ERPs components, a smaller negativity in the range 300-420ms and less positive P300 component were found in high sales volume products than in low sales volume products (e.g. Figure 5.7(a)). This result is opposite to and inconsistent with an old/new recognition interpretation, for example, if one makes the assumption that there is implicit recognition of products that the participant has noticed or purchased before, which is more likely to be the case for high sales-volume products. The different task instructions mean that this is not primarily a memory task but a decision task based on evaluation, which entails different brain processes. An alternative explanation of the apparent reversal of the old/new effects could be advanced in terms of perceptual conflict. N2 is an event-related potential with a negative wave peaking between 200 and 400 ms post stimulus (Folstein & Van Petten, 2008; Dickter & Bartholow, 2010). The N2 component can reflect conflicting information processing (Van Veen & Carter, 2002; Folstein & Van Petten, 2008), perception conflict could evoke the N2 component. For instance, in brand extension studies, a greater N2 amplitude was observed when participants perceived a stronger conflict between the brand and the extension product (Ma et al., 2007; Ma et al., 2010). The authors suggested that this perceived conflict effect resulted from the comparison of the product attribute to the brand's product attribute in the brand memory (Ma et al., 2007). In the current studies, low sales volume products may elicit more perceived conflict than higher sales volume products, or because of unfamiliarity they may require greater perceptual processing in order to extract attributes relevant to the purchase decision. In addition, P300 represents different aspects of the stimulus evaluation (Yeung & Sanfey, 2004; Xu et al., 2011). Low sales volume items may require more cognitive resources devoted to the categorization process in the working memory than high sales volume items.

Conversely, in Block 2, positive activity post 250 ms was most prominent in the ERPs elicited by high sales volume products than low sales volume products at frontal electrodes. Thus, high sales volume products elicit strong familiarity in a recognition task compared to low sales volume. This is consistent with the classical old/new effect (Sanquist, et al., 1980; Warren, 1980; Rugg & Curran, 2007) if one makes the assumption that there is implicit

recognition of products that the participant has noticed or purchased before, which is more likely to be the case for high sales-volume products.

5.4.2.2 Group 2 – with pricing information

5.4.2.2.1 Group 2 - old/new recognition

Results from the participant group tested with pricing information in the first (inclination to purchase) block may be regarded as a partial replication of results from the group tested without pricing information in the first (inclination to purchase) block, because the second (recognition memory) block was identical for the two groups. Therefore, the discussion of these results will be briefer, concentrating on the main similarities and differences.

The comparison of hits (h) with correct rejections (CR) is taken as an indication of memory processes. For the comparison of hits (h) versus correct rejections (CR), similar results were found with and without pricing information for P2 frontal amplitude, P3 frontal amplitude and P3 frontal latency (compare Results Table 5.2 with Table 5.5, and Figure 5.6 with Figure 5.14). A significant difference was found in N1 parietal amplitude for hits versus correct rejections in Group 2 that was not significant in the no-pricing group. However in the absence of a direct statistical comparison of the two groups' results it is not possible to say at present whether N1 at the recognition stage differs due to the presence or absence of pricing information at the encoding stage. Hits generated larger (more negative) amplitudes than correct rejections. A larger N1 is usually interpreted as representing greater allocation of perceptual or attentional resources (Woodman, 2010). Therefore, in the comparison of hits and correct rejections, the main results concerning ERP components linked to recognition memory were replicated, and h versus CR difference in the N1 component, which has no obvious link to recognition memory, was not replicated. The comparison of responses to hits and false positives differentiates between ERPs to items that are old, and ERPs to items that are new but which the participant thinks are old. For the comparison of hits (h) with false alarms (FP) only the FN400 showed a significant difference in Group 2, with a larger amplitude for false positives than for hits. This result therefore replicates the corresponding result for Group 1. As for Group 1, amplitudes were more negative for FP than for h, and this is consistent with the view that FP recognition is based on feelings of familiarity and this may

have been increased by the presence of "lures" (flavour variants) amongst the new items (Cadavid & Beato, 2016). Other significant effects in Group 1 on N1 parietal amplitude, P2 frontal latency, P3 frontal amplitude and P3 frontal latency were not replicated in Group 2 (compare Table 5.3 with Table 5.6).

The comparison of responses to correct rejections (CR) with MISS focuses on items which the participants regard as new, though MISS items are in fact old. Both Group 1 and Group 2 showed differences in the FN400 component, which is considered to be related to familiarity. However, MISS responses were more negative in both cases, which contradicts the familiarity hypothesis, but is more consistent with an interpretation as N2 as an indicator of cognitive conflict.

5.4.2.2.2 Effects of product sales volume on ERPs in the initial (inclination to purchase) and second (old/new recognition) blocks

In Group 2 (with pricing information), Block 1, at P8 electrode site, high sales volume products elicited more positive ERPs than low sales volume products at 250 ms post-stimuli (which amplitude of low sales volume items larger than high sales volume items in Group 1). Pricing information changed the N2 and P300 component amplitude (low sales volume products have larger N2 and P300 than high sales volume products in Group 1, therefor high sales volume products have larger N2 and P300 than low sales volume products in Group 2). This result suggests that pricing information will increase conflict information processing and event categorization activity in the working memory.

In Group 2, Block 2, there was a negative ERPs at frontal electrodes between 250-550 ms which was evoked by high and low sales volume products. Moreover, the amplitude of this component for high sales volume items was larger than for low sales volume items. At parietal sites, positive ERPs were recorded between approximately 250-600 ms, and the amplitude of low sales volume items was larger than for high sales volume items, as shown in Figure 5.15. Compared with the result of Group 2, there is an overlap with the amplitude of low sales volume and high sales volume items between approximately 250-600 ms in the result of Group 1, as shown in Figure 5.9(a).

In Block 2, regarding to the new versus old, old items elicited larger amplitude than new items between 150-750 ms at frontal electrodes. This finding also could be consistent with a familiarity strength take account of recognition memory, since old items would have higher familiarity strength than new (Johson, 1995; Rugg, 1995).

Some studies have suggested that a later aspect of ERP (400-800 ms) over parietal electrodes may be related to recollection (Rugg et al., 1988). In the present study, new items evoked more positive ERPs than old items between 350-650 ms at parietal electrodes in the second block and in the condition of high sales volume products only. This is reverse of the usual old/new effect. This can be referred that participants take more time to recall more specific information to recognize new items compared old items.

Both Group 1 and Group 2, comparing correct rejections versus misses, larger N2 was evoked in misses; comparing false alarms versus hits, larger N2 was recorded in false alarms. N2 reflects conflict and template mismatch (Van Veen & Carter, 2002; Folstein & Van Petten, 2008), this revealed that when participants make a wrong response, a conflict will occur and a larger N2 can be recorded.

To conclude: The classical ERP old/new effect in recognition memory consists of greater positivity over frontal electrodes from 300 ms onwards, apparent in the comparison of hits (correct identification of old items) and correct rejections (of new items). However in the current experiment what was seen was greater positivity to hits over left frontal electrodes and greater positivity to correct rejections over right frontal electrodes. This effect was replicated in two participant groups under different encoding conditions (with and without prices) but identical stimuli in the recognition stage, and therefore seems to represent a new ERP phenomenon. One possibility would be that the common average reference used in the present study gives a different scalp distribution from the average mastoid reference common in early old/new recognition studies. This could be tested by re-referencing the data.

Comparisons of true and false recognition (hits versus false positives) highlighted a negative peak occurring typically around 360 ms in the frontal ROI. In the attention literature this might be identified as N2 or N200 but more plausibly, in the old/new recognition literature it would correspond to FN400 if distributed frontally. This component generated larger amplitudes to false positives than hits in both participant groups. FN400 is associated with familiarity, so the question arises how false recognition could be based on higher levels of

familiarity than true recognition. One possibility is that the presence of “lures” amongst the new items in the form of flavour variants of target “old” items generated high levels of familiarity (Cadavid & Beato, 2016).

Comparisons of time course and scalp topography in comparisons of high and low sales volume items in the second (recognition) interval showed a consistent pattern of greater positivity for high sales volume items from 300 ms onwards in lateral parietal and frontal (particularly left frontal) areas. This is perhaps the most plausible neuromarketing “marker” from these results since it is a reflection in a small sample of participants of market sales volumes.

Chapter 6 General Discussion, Conclusions and Future Work

Neuromarketing is an interdisciplinary field of study concerning the application of neuroimaging tools to analyse and understand human behaviour related to markets or marketing stimuli (Lee, Broderick, & Chamberlain, 2007). In recent years, neuromarketing research has gained more interest and attention as an alternative to traditional market research. The latter focuses on questionnaires or surveys based research to access behavioural intention, such as focus groups which simply ask to the persons their preferences in front of marketing stimuli. However, there are limitations of the traditional market research due to a number of reasons. For instance, consumers may not be able or willing to explain their preference. Therefore, neuroimaging tools can access information within consumer's brain during the generation of a preference or the observation of commercial advertising (Vecchiato et al., 2011), or detect what is happening when they are thinking and feeling.

In present thesis, three series of experiments have been carried out. At a very early beginning, I wanted to get a deep insight of the decision making, so the experiment regarding to the behavioural intention on the influence of magazine context and car model on a "desire to purchase" decision was performed, and then followed by using the fMRI to find out the underlying process of human beings' purchase decision. This experiment still focused on the field of decision making, which was to investigate the effect of sales volume and price offer on decision making of food products. Both the sales volume of products and pricing information were seen as the emotional and economic influence elements, which have been considered as classic commercials effectiveness mediators, but little was compare them at the same time. Lastly, those two factors considered as classic influence factors, an EEG study was continued to investigate the event-related potentials to the effect of emotional and economic factors on the recognition of branded food products.

6.1 A behavioural study on the influence of magazine context and car mode on a decision making

The first experiment was the behavioural study on car preference to investigate the influence of different formats advertisements on consumers' decision making. The findings of ANOVA showed that there was no difference in product preference for a car, whether the advertisement appeared in a car magazine (technical context), in a fashion magazine (non-technical context), or showed the plain images of the car (no context). Non-significant trends showed that, the mean value of likelihood to purchase decision of the plain images was higher than the one of car magazine and fashion magazine. However, the fashion magazine did have slightly higher rating than the car magazine.

However, a more detailed analysis, using logistic regression showed that when the variance due to relative preferences for different models of car and the order of test blocks was accounted for, context emerged as a significant predictor of purchase decisions, but in an unexpected way. The plain images were associated with the highest proportion of "yes" decisions to purchase, followed by the fashion magazine context, and finally the car magazine context.

The reasons to explain these unexpected results could be due to the different image quality; the manipulation of context in the experimental design may have been ineffective because they were not equivalent to the experience of reading a magazine; the gender of participants was all males which could not represent all people's performance; the subject of this experiment were luxury cars, meaning that people may have a special feeling or emotion on each type of car, which led to some of participant, focus on the car itself and ignore the different contexts; or, this result could well be a real effect. Perhaps, the plain images could be more direct and free from distraction – luxury cars are obviously designed to produce a pleasurable visual effect in themselves. People might read car magazines because they wanted more information on which to base their decision and this might be to eliminate cars that only looked good but didn't perform as well. So a car magazine might appeal more to their critical faculties.

6.2 An fMRI study on the effect of sales volume and price offer on decision making

The purpose of the second experiment was to study, using the fMRI, the brain processes underlying purchase decisions in which the effect of product sales volume and pricing information were investigated. The behavioural data showed there was a strong influence of the pricing information on inclination to purchase. The main effect of pricing versus no pricing information was significant, as was the interaction between product sales volume and pricing. Addition of pricing information produced a strong decrease in the inclination to purchase the popular items, whereas for the less popular items, the addition of discounted pricing information produced a non-significant change in inclination to purchase. Meanwhile, on the other hand, in the fMRI data revealed that the product sales volume produced significant effects on brain activations, whereas the pricing manipulation did not produce detectable differences in the BOLD responses. Although the pricing information was known from previous research to modulate affective systems in the brain (Plassmann et al., 2008), this effect did not reach significance in the current study's ANOVA. Future research on testing the emotional or rational processes of purchase decisions will be required in order to determine the conditions that make a price difference effective in changing fMRI activations significantly between the different experimental manipulation conditions. In addition, the behavioural results of the present study showed clearly that the price manipulation was effective in changing choices. Thus, it may be supposed that prices would change the consumers' mind as well as their final decision making, depending on how strong is the emotional level towards products. The further work will focus on detecting the onset threshold of emotional response to a product on which pricing might be of importance to decide a final decision making. This would need an independent measurement of the emotional response to a product such as a rating or semantic differential test, and additionally, brain regions of interest could be identified as part of an affective brain system, and their activation levels could be used as predictors of the simulated purchase decision in a regression model.

6.3 An EEG study on the effect of sales volume and price offer on memory recognition

Preference for a branded product depends on being able to recognise the brand, that is, upon recognition memory. The third experiment employed the EEG technique to build upon the fMRI experiment in order to measure recognition memory perform an old/new task, that was to test the effect of the sales volume of products and pricing information on memory recognition, in addition, as snack foods commonly arise in different flavours, and because flavour is an important variable in snack choice, the number of variants (flavours) were added as another variable of the effect on recognition memory for branded food snacks. The experiment was replicated in two participant groups under encoding conditions with and without pricing information. Moreover, each group undertook two blocks of trials, one being a learning block, in which participants indicated whether they would consider buying the items; and the other being a memory testing block, in which participants needed to judge it as new or old.

6.3.1 Behavioural results

The behaviour results indicated that the effect of including more variants of a product was to increase similarity of non-targets to targets thereby reducing d'. Multiple flavours also increased false positives because they provided non-targets that resembled targets (lures) thereby increasing false positive rate. This suggested that the expansion of a product range to include variants could be successful in increasing product familiarity, even for products with low market penetration. In terms of product sales volume, it did not affect d', rather it affected the criterion (β, c). Thus, compared with low sales volume products, products with high sales volume were more familiar and this increased their false positive recognition rate. Participant might respond that they saw it in the first session but in fact, they did not but responded because of the strong familiarity of the item.

Further research could explore the relationship between brand recognition and decision to purchase. This could be carried out through further data analysis of existing data using regression models. Given that earlier events cause later events rather than vice versa, the logical way to set this up would be to use the "old/new" response in the second block as the dependent variable, and the "likely to purchase" response in the first block as a predictor,

together with high or low sales volume, and number of variants. It would be expected that items that the participant is inclined to purchase would also be recognised as "old", more so than items the participant was disinclined to purchase.

For future research, the experiment could be re-run in order to study the effect of brand recognition on inclination to purchase. Brands could initially be judged as familiar or unfamiliar in the first block, and inclination to purchase measured in the second block.

6.3.2 ERPs result – Group 1

In Group 1, in terms of ERP result, old stimuli were more positive than new after 650 ms at frontal electrodes in second block, this finding could be consistent with a familiarity strength account of recognition memory, since old items would have higher familiarity strength than new (Johnson, 1995; Rugg, 1995). A positive P300 component was found in this contrast, the amplitude of new items was larger than old items. P300 represented greater event categorization activity in the working memory, and larger P300 amplitude would result due to the allocation of cognitive resources (Humphrey & Kramer, 1994).

The t-maps showed old items produced significantly more negative ERPs at both left, right and midline parietal locations from 500 ms. Moreover, data for high and low sales volume items showed a similar distribution of significant differences in the t-maps. The parietal old/new effect has been associated with recollection, as opposed to familiarity (Rugg & Curran, 2007), or more generally, with memory retrieval (Vilberg & Rugg, 2009); however, in the present data it was reversed in polarity. This relative negativity for new items might reflect the cognitive effort required to identify that a flavour was a new item when it was a close variant of an old item.

In Block 2, positive activity post 250 ms was most prominent in the ERPs elicited by high sales volume products than low sales volume products at frontal electrodes. The frontal positivity has been associated with familiarity (Rugg & Curran, 2007). Thus, high sales volume products elicited stronger familiarity effects in a recognition task compared to low sales volume.

6.3.3 ERPs result – Group 2

The low sales volume products showed larger N2 and P300 than high sales volume products in Group 1, therefore, in Group 2, Block 1, high sales volume products showed larger N2 and P300 than low sales volume products. This result suggested that the pricing information will increase conflict information processing and event categorization activity in the working memory.

In Block 2, in terms of the new versus old, old items elicited larger amplitude than new items between 150-750 ms at frontal electrodes. This finding could be consistent with a familiarity strength take account of recognition memory, since old items would have higher familiarity strength than new (Johson, 1995; Rugg, 1995). This result supports the hypothesis that market-aggregate statistics such as sales volume can have an effect on individual brain activity due to the greater familiarity of higher sales volume products.

In this experiment, some results on the effect of sales volume and pricing information were inconsistent with the classical old/new effect, this could well be due to the number of variants (flavours) of the branded food snacks acting as "lures" in the recognition task. The reversed parietal old/new effect is very interesting but it would require further research to determine what causes the reversal.

6.4 Conclusion

The fields of decision neuroscience and consumer neuroscience are academic disciplines that use a multimodal perspective to tackle its research questions. There is no magic and so called "buy button", we can't peek inside a decision maker's head and predict individual's selection of goods (Yoon et al., 2012). However, neuroimaging study could help us to have a chance to understand the basics of decision making mechanism and to investigate the underlying process of human being's decision making and to know consumers' recognition better.

Lindstrom (2010) indicates that goal of neuromarketing is the understanding of how consumers behave and make decisions, while accessing the unconscious thoughts, emotions, feelings and desires, and it can find out which trigger the purchase decision. Neuromarketing is helpful for us to understand how unconscious mind processing influence the decision to

purchase, providing a better understanding of the consumers' thoughts, emotions, feelings, needs and motivation in relation to the marketing products.

In this research, three experiments were carried out. The research contributes the neuromarketing, it explains the influence on consumers' choice of various kinds of social information in neuroscientific ways rather than the traditional methods. The first experiment focused on the influence of magazine contexts that included plain images, car magazine advertisements and fashion magazine advertisements, on purchase decisions (refer to Chapter 3), the purpose of which was to study on the influence of different advertisements formats on decision making. Although this was a behavioural intention study, the results to a certain extent contribute to marketing research and give an insight into how a variety of advertisement formats have an influence on decision making, but not always in the way that might be predicted. Secondly, the fMRI was employed to investigate the underlying neural processes accompanying a purchase decision. This experiment was designed to take account of two elements related to commercial effectiveness: sales volume of products and pricing information. This was considered to be an innovative research in which to make a comparison between the two mediators at the same time. Moreover, the experimental results can make a contribution to neuromarketing research that seeks to understand the importance of emotional and economic elements on decision making (refer to Chapter 4). Finally, the EEG technique was applied to investigate on the ERPs to the effect of products' sales volume and pricing information factors on recognition memory. In relation to social neuroscience (Cacioppo & Berntson, 1992), the fMRI experiment identifies neural correlates of a society level variable: the market sales volume of products. The EEG experiment indicates that familiarity effects in recognition memory can be one way in which a society level variable such as sales volume influences a consumer's brain activity. The experimental results are also contributed to social neuroscience research in regard to demonstrating an influence at the level of market sales volume of products and pricing information on recognition memory and its neural correlates (refer to Chapter 5).

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Appendix A Questionnaire for "Car Preference" Study

1. What is your gender?
   - ○ Female
   - ○ Male

2. What is your age?
   - ○ 18 to 24
   - ○ 25 to 34
   - ○ 35 to 44
   - ○ 45 to 54
   - ○ 55 to 64
   - ○ 65 to 77
   - ○ 75 or older

3. Which of the following best describes your current situation?
   - ○ College of engineering, Design and Physical Sciences.
   - ○ College of business, Arts and Social Sciences.
   - ○ College of Health and Life Sciences.
   - ○ Institute of Energy Futures.
   - ○ Institute of Environment, Health and Societies.
   - ○ Institute of Materials and Manufacturing.

4. Do you own a car or are you going to buy a car?
   - ○ I had a car now.
   - ○ I had a car but I am going to change a new one.
   - ○ I haven't got a car now but I am going to buy a car.
   - ○ I don't have a plan to buy a car.

5. Evaluated how much you familiar car knowledge?
   - ○ Very much
   - ○ Nature
   - ○ Not much

6. Do you have a drive licence now?
   - ○ Yes
   - ○ No

7. Which of the following option is the best to describe your personality?
   - ○ Strong character
   - ○ Cowardice
   - ○ Enthusiasm
   - ○ Unsocial
   - ○ Out-going
   - ○ Introverted
   - ○ Creative

8. Which of the following reason is difficult for you to make a decision when you would like to buy a car? (Please rate the following options from 1 to 4, where 1 is the most important and 4 is the least important- Ensure that each rating value is used only once.)
   - ☐ Price
   - ☐ Brands name
   - ☐ Performance of car
   - ☐ Design of car

9. What type of advertisements do you like?

	Strongly Dislike	Dislike	Neither Dislike Nor Like	Like	Strongly Like
Poster.	○	○	○	○	○
TV commercial.	○	○	○	○	○
Outdoor billboard.	○	○	○	○	○

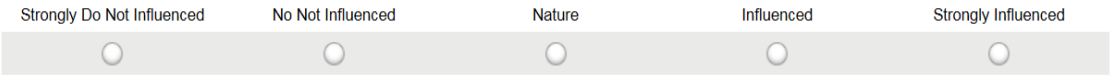
10. Evaluated what is most favourable car body style to you?

	Strongly Dislike	Disleke	Neither Dislike Nor Like	Like	Strongly Like
Sedan.	○	○	○	○	○
MPV.	○	○	○	○	○
SUV.	○	○	○	○	○
Sports.	○	○	○	○	○

11. Does social information (e.g. the advertisement of a car) influence your purchasing preference?
   - ○ Yes
   - ○ No

12. Which following channel do you prefer to receive information?
   - ○ comprehensive channel
   - ○ Professional channel

13. Evaluated how does social information influence your decision making on purchasing a car?



Appendix B Design stimulus of the experiment on a "desire to purchase" decision

Fashion magazine advertisements

Item1 AUDI-QUATTROMOI

Item2 AUDI-RS7

Item3 AUDI-S6

Item4 BMW-3 series

Item5 BMW-5 series

Item6 BMW M3

Item7 FORD-NEW-FOCUS

Item8 FORD-MUSTANG

Item9 JAGUAR

Item10 Mercedes Benz

Item11 Toyota

Item12 Volkswagen Golf

Car magazine advertisements

Item1 AUDI-QUATTROMOI

Item2 AUDI-RS7

Item3 AUDI-S6

Item4 BMW-3 series

Item5 BMW-5 series

Item6 BMW M3

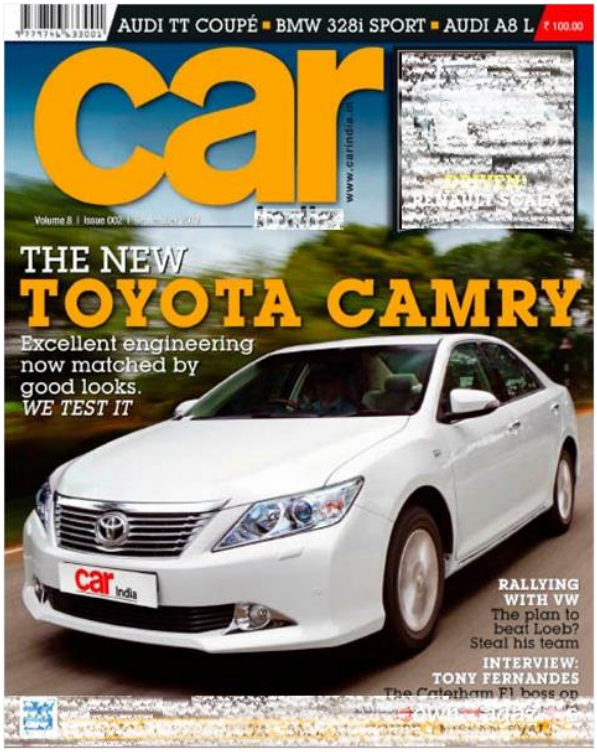
Item7 FORD-NEW-FOCUS

Item8 FORD-MUSTANG

Item9 JAGUAR

Item10 Mercedes Benz

Item11 Toyota



Item12 Volkswagen Golf

Plain images

Item1 AUDI-QUATTROMOI

Item2 AUDI-RS7

Item3 AUDI-S6

Item4 BMW-3 series

Item5 BMW-5 series

Item6 BMW M3

Item7 FORD-NEW-FOCUS

Item8 FORD-MUSTANG

Item9 JAGUAR

Item10 Mercedes Benz

Item11 Toyota

Item12 Volkswagen Golf

Appendix C Research Ethics Review Checklist

Part 1

Section I: Project details

1. Project title: The influence on consumers' choices of various kinds of social information with application to automobile consumption decision making	
2. Proposed start date: 10/11/2014	3. Proposed end date: 31/03/2015

Section II: Applicant details

4. Name of researcher (applicant)	Lin Li
5. Student Number	1108752
6. Status	PGR Student
7. Department	Select From Drop Down List.
8. Brunel e-mail address	Lin.Li@brunel.ac.uk
9. Telephone number	07778233742

Section III: For students only

10. Module name and number:	PhD student
11. Supervisor's name:	Professor Michael Wright
12. Brunel supervisor's e-mail address:	Michael.Wright@brunel.ac.uk

	Yes	No
13. Does this research involve human participants?	◉	○
14. Does this research raise any ethical or risk concerns as set out in the University Code of Research Ethics or relevant disciplinary code?	○	◉
15. Risk Assessment – are there any elements of risk related to the proposed research? (See Risk Assessment – FAQs)	○	◉

If you have answered **Yes** to any of questions 13-15, you must **complete Part 2** of this form.

Students: If you have answered No, please email this document to your supervisor who will confirm that the research does not involve ethical issues. Once electronically signed by your supervisor, please submit Part 1 of this form via BBL within 1 week. Please keep a copy for yourself and bind it into your dissertation/thesis as an appendix.

Staff: If you have answered No, please sign below and submit your form via BBL. Please keep a copy for yourself.

If your research methodology changes significantly, you must submit a new form.

For Supervisor's/Staff e- signature

I confirm that there are no ethical or risk issues relating to this research and the applicant can proceed with the proposed research.
e-signature/ Date:

Part 2

Section IV: Description of project

Please provide a short description of your project:
The aim of this project is to figure out how social information will influence consumers' preferences. Generally speaking, the project will provide car advertisements from different channels, i.e. specialist car magazine and ''other interest'' magazine. Some images of cars either in car advertisements or against a plain background will be provided as stimuli. These would be presented in different conditions, and the subjects asked to rate the cars and their purchase preference for each car after showing the images.

Section V: Research checklist

Please answer each question by ticking the appropriate box:

	YES	NO
1. Does the project involve participants who are particularly vulnerable or unable to give informed consent (e.g. children/ young people under 18, people with learning disabilities, your own students)?	○	◉
2. Will the research involve people who could be deemed in any way to be vulnerable by virtue of their status within particular institutional settings (e.g., students at school, residents of nursing home, prison or other institution where individuals cannot come and go freely)?	○	◉
3. Will it be necessary for participants to take part in the study without their knowledge and consent (e.g., covert observation of people in non-public places)?	○	◉
4. Will the study involve discussion of sensitive topics (e.g., sexual activity, drug use) where participants have not given prior consent to this?	○	◉

	YES	NO
5. Will the study involve work with participants engaged in breaking the law?	○	◉
6. Will the publications/reports resulting from the study identify participants by name or in any other way that may identify them, bring them to the attention of the authorities, or any other persons, group or faction?	○	◉
7. Are drugs, placebos or other substances (e.g. food substances, vitamins) to be administered to the study participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind?	○	◉
8. Will the study involve the use of human tissue or other human biological material?	○	◉
9. Will blood or tissue samples be obtained from participants?	○	◉
10. Is pain or more than mild discomfort likely to result from the study?	○	◉
11. Could the study induce psychological stress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life?	○	◉
12. Will the study involve prolonged or repetitive testing?	○	◉
13. Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?	○	◉

	YES	NO
14. Will the study require the co-operation of another individual/ organisation for initial access to the groups or individuals to be recruited? If yes please attach the letters of permission from them.	○	◉
15. Will you be undertaking this research as part of a work placement or in conjunction with an external organisation? If Yes and the organisation have conducted its own research ethics review, please attach the ethical approval.	○	◉

If you have answered 'yes' to any of questions 1-13, you will need to complete the University Application Form for Research Ethics Approval.

Students: If you have answered 'No' to all of questions 1-13, please **sign below and submit this completed Checklist, consent form, information leaflet and any other documents and attachments for your supervisor's approval by email. Once you have received it back from your supervisor you will be able to submit via BBL. Forms that do not have your supervisor's approval will be rejected.**

Staff: If you have answered 'No' to all of questions 1-13, please **sign below and submit this completed Checklist, consent form, information sheet and any other documents and attachments via BBL.**

Please note that it is your responsibility to follow the University's Code of Research Ethics and any relevant academic or professional guidelines in the conduct of your study. **This includes providing appropriate information sheets and consent forms, and ensuring confidentiality in the storage and use of data.** Any significant change in protocol over the course of the research should be notified to the Departmental Ethics Coordinator and may require a new application for ethics approval.

Applicant (Principal Investigator) Name: Lin Li
Applicant's e-signature: Lin Li
Date: 21/10/2014

Supervisor Section (for students only)

Please tick the appropriate boxes. The study should not be submitted until all boxes are ticked:

☑	The student has read the University's Code of Research Ethics
☑	The topic merits further research
☑	The student has the skills to carry out the research
☑	The consent form is appropriate
☑	The participant information leaflet is appropriate
☑	The procedures for recruitment and obtaining informed consent are appropriate
☐	An initial risk assessment has been completed
☐	If there are issues of risk in the research, a full risk assessment has been undertaken in line with the 'School of Social Sciences Risk Assessment– FAQs' document and a risk assessment is attached.
☐	A DBS check has been obtained (where appropriate)
☑	The debriefing form is appropriate (NB for psychology only - please refer to BBL)

Any comments from supervisor:

Supervisor or module leader (where appropriate):
E-signature: 
Date: 27/10/2014

Supervisors: Please **email** this form to the student who will then need to submit it and related appendices via BBL.

Student: Once you have received this form back from your supervisor, submit this completed Checklist, consent form, information sheet and any other documents and attachments via BBL.

Departmental Ethics Coordinator section:

This request for expedited review has been:	☐ Approved (No additional ethics form is necessary)
	☐ Declined (Full University Ethics Form is necessary)
	☐ Declined (Please give reason below)

Departmental Ethics Coordinator Name:
E- signature
Date:

Appendix D Sample Consent Form to be Adapted as Appropriate

The participant should answer every question

	YES	NO
1. I have read the Research Participant Information Sheet.	☐	☐
2. I have had an opportunity to ask questions and discuss this study.	☐	☐
3. I understand that I am free to withdraw from the study:		
- at any time (Please note that you will unable to withdraw once your data has been included in any reports, publications etc)	☐	☐
- without having to give a reason for withdrawing	☐	☐
- without it affecting my future care	☐	☐
4. I understand that I will not be referred to by name in any report/publications resulting from this study	☐	☐
5. I agree that my comments can be quoted as long as they do not directly identify me when the study is written up or published	☐	☐
6. I agree to take part in this study	☐	☐

Research Participant Name:
Research Participant signature:
Date:

Principal Investigator name:
Principal Investigator signature:
Date:

One copy to be kept by the participant and one by the researcher

Appendix E Sample Participant Information Leaflet - Checklist

Study title

The influence on consumers' choices of various kinds of social information with application to automobile consumption decision making

Invitation Paragraph

Whether or not you are an expert on cars, you would be welcome to be a participant as a volunteer in this study. Through taking part in this behavioural study, you will learn something about our research that might be of interest to you.

What is the purpose of the study?

The aim of my study is going to figure out how social information will affect consumers' choice behaviour. This study is designed to help shed light on what factors will influence consumers' preference.

Why have I been invited to participate?

It is an easy and relaxing behavioural study, and everyone (18+) who might be interested is welcome to become involved in this research study.

Do I have to take part?

Participation is voluntary and you have right to withdraw from the study at any time without penalty. You do not have to explain your reasons for withdrawing.

What will happen to me if I take part?

You will view pictures of cars on a computer screen.

What do I have to do?

After each picture you will be asked to do a rating of each car by pressing keys.

What are the possible disadvantages and risks of taking part?

There are no risks or disadvantages of taking part.

Will my taking part in this study be kept confidential?

Yes. Your name will not be associated with study. Your responses will be kept confidential and they will be stored under an anonymous code.

What will happen to the results of the research study?

The results of the study will be written up as part of a PhD thesis to be submitted to Brunel University. The results may in addition be submitted for publication in research journals.

Who is organising and funding the research?

There is no commercial funding or sponsorship of this research. The research is resourced by Brunel University and by the principal investigator.

Who has reviewed the study?

The study has been reviewed by the Department of Psychology Ethics Committee at Brunel University.

Contact for further information

If you have any questions about this research you can contact the principal investigator; Lin.Li@brunel.ac.uk If you have any concerns, you can contact the ethics committee;
Achim.schuetzwohl@brunel.ac.uk
bridget.dibb@brunel.ac.uk
martina.reynolds@brunel.ac.uk

Appendix F Questionnaire for the fMRI Experiment

1. What is your gender?
   - ○ Female
   - ○ Male

2. What is your age?
   - ○ 18 to 24
   - ○ 25 to 34
   - ○ 35 to 44
   - ○ 45 to 54
   - ○ 55 to 64
   - ○ 65 to 77
   - ○ 75 or older

3. Which of the following reason is difficult for you to make a decision when you would like to buy snack foods and drinks? (Please rank the following options from 1 to 7, where 1 is the most important and 7 is the least important- Ensure that each rating value is used only once.)

   - ☐ Price
   - ☐ Brand name
   - ☐ Familiarity
   - ☐ Packaging
   - ☐ Taste
   - ☐ Health related issues
   - ☐ Weight control considerations

4. Have you eaten any of the foods shown in the experiment?

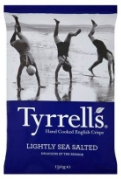
Yes, nearly everything (81-100%)	Most (61-80%)	Around half (41-60%)	Some of them (21-40%)	Few or none (Below 20%)
○	○	○	○	○

5. Evaluate how much you do like the food listed below.

	Product description	Product Image	Rating
1	Carte D'or Strawberry Ice Cream Dessert		Strongly dislike · Dislike · Neither like nor dislike · Like · Strongly like
2	Carling Zest Citrus		Strongly dislike · Dislike · Neither like nor dislike · Like · Strongly like
3	Nestle Smarties Ice Cream Cone		Strongly dislike · Dislike · Neither like nor dislike · Like · Strongly like
4	Carlsberg		Strongly dislike · Dislike · Neither like nor dislike · Like · Strongly like
5	Fosters Gold		Strongly dislike · Dislike · Neither like nor dislike · Like · Strongly like
6	Fosters		Strongly dislike · Dislike · Neither like nor dislike · Like · Strongly like
7	Boddingtons Draught Bitter		Strongly dislike · Dislike · Neither like nor dislike · Like · Strongly like

8	Heineken Lager		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
9	Corona Extra		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
10	Grolsch		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
11	Belvita honey nut		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
12	Belvita Milk& cereals		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
13	Cadbury-fingers		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
14	Cadbury-fingers		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
15	Mc-vities-Jaffa cake		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
16	Rich tea		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
17	Bahlsen Milk Choco Leibniz		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
18	Kellogg's		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like

19	Lyons Toffypops		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
20	Mcvities Krackawheat		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
21	Weetabix		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
22	Dairy Milk		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
23	Aero Milk Chocolate		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
24	Lindt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
25	Revels Bag		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
26	Galaxy		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
27	Kinder-Bueno		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
28	Kit Kat Chunky Milk Chocolate		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
29	Rolo		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
30	Mars		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like

31	Snickers		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
32	Smarties		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
33	Toffee Crisp		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
34	Ben And Jerry's Cookie Dough Ice Cream		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
35	Del Monte 100% Juice Orange Ice Lollies		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
36	Nestle Fab Strawberry Ice Lollies		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
37	Tyrrells sea salt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
38	McCoy's Cheese & Onion Flavour Crisps		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
39	popchips-Thai sweet chilli		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like

40	Innocent Apple Juice		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
41	Benecol Strawberry Yoghurt Drink		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
42	Yoomoo Strawberry Frozen Yoghurt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
43	Yoomoo Vanilla Frozen Yoghurt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
44	Cornetto Classico Ice Cream Cone		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
45	Haagen-Dazs Cookies & Cream Ice Cream		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
46	Haagen-Dazs Dairy Vanilla Ice Cream		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
47	Magnum Black Espresso Ice Cream		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
48	Magnum Pink Raspberry Ice Cream		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
49	Activia 0% Fat Peach Yoghurt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like

50	Benecol Light Natural Yoghurt Drink		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
51	Rachel's Organic Greek Style Natural Yogurt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
52	Weightwatchers Greek Strawberry Yoghurt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
53	Muller Corner Crunch Vanilla Chocolate Balls Yoghurt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
54	Muller Light Banana And Custard Yoghurt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
55	Doritos Chilli Heatwave		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
56	Kettle-red onion		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
57	Guinness chips		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
58	Popchips-salt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
59	Walkers Baked Cheese And Onion		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
60	Walkers Baked Salt And Vinegar		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like

61	Walkers Ready Salted Crisps		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
62	Coca Cola Regular		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
63	Coca Cola Diet Coke		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
64	Pepsi		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
65	Innocent Apple And Raspberry Juice		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
66	Ribena Blackcurrant		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
67	Ribena Blackcurrant Bottle		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
68	Ribena Pineapple And Passion Fruit		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
69	Volvic Touch Of Fruit Strawberry No Added Sugar		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
70	Volvic Touch Of Fruit Summer Fruits		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
71	Ben & Jerry Chocolate Fudge Brownie Ice Cream		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like

72	Toffifee		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
73	Del Monte Raspberry Smoothie Lollies		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
74	Carte D'or Chocolate Hazelnut Ice Cream		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
75	Mcvities-dark chocolate		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
76	Cornetto Strawberry Ice Cream Cone		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
77	Weight Watchers Summer Fruit Yoghurt		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
78	Ribena Strawberry		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
79	Guinness-beef chilli		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like
80	Maltesers		Strongly dislike — Dislike — Neither like nor dislike — Like — Strongly like

Appendix G Consent Form for the fMRI Experiment

Rev. 2009

ROYAL HOLLOWAY, UNIVERSITY OF LONDON
MAGNETIC RESONANCE IMAGING UNIT

CONSENT FORM

NAME OF PARTICIPANT……

Please read the following statement carefully and then add your signature. If you have any questions, please ask the person who gave you this form. You are under no pressure to give your consent and you are free to withdraw from the MRI examination at any time.

I agree to participate in an MRI examination conducted for research purposes by

……. (name of operator) on ……

…… (name of project).

I understand that the examination is not part of any medical treatment. I have completed two screening forms and I have been given an opportunity to discuss any issues arising from it. The nature of the examination has been explained to me and I have had an opportunity to ask questions about it. I consent to my general practitioner being contacted in the unlikely event that the scan reveals any suspected abnormality**.** I understand that the scans will be done solely for research purposes, and that the Investigators are not experts in MRI diagnosis and cannot provide a 'clean bill of health'.

Signature …… Date……

FOR STAFF USE:

Statement by a witness, who must be either an authorised person or a scientific collaborator who is familiar with the experimental procedure and is able to answer questions about it.

I certify that the above participant signed this form in my presence. I am satisfied that the participant fully understands the statement made and I certify that he/she had adequate opportunity to ask questions about the procedure before signing.

Signature……. Date……

Name ……..

Address of witness (if not an Authorised Person):

Appendix H Information Form for the fMRI Experiment

ROYAL HOLLOWAY, UNIVERSITY OF LONDON

MAGNETIC RESONANCE IMAGING UNIT

INFORMATION FORM

These notes give some information about an fMRI study in which you are invited to take part.

FMRI is a method for producing images of the activity in the brain as people carry out various mental tasks. It involves placing the participant inside a large, powerful magnet which forms part of the brain scanner. When particular regions of the brain are active, they require more oxygen, which comes from red corpuscles in the blood. As a result, the flow of blood increases. This can be detected as changes in the echoes from brief pulses of radio waves. These changes can then be converted by a computer into 3D images. This enables us to determine which parts of the brain are active during different tasks.

As far as we know, this procedure poses no direct health risks. However, the Department of Health advises that certain people should NOT be scanned. Because the scanner magnet is very powerful, it can interfere with heart pacemakers and clips or other metal items which have been implanted into the body by a surgeon, or with body-piercing items. If you have had surgery which may have involved the use of metal items you should NOT take part. You will be asked to remove metal from your pockets (coins, keys), remove articles of clothing which have metal fasteners (belts, bras, etc), as well as most jewellery. Alternative clothing will be provided as necessary. Watches and credit cards should not be taken into the scanner since it can interfere with their operation. You will be asked to complete a questionnaire (the Initial Screening Form) which asks about these and other matters to determine whether it is safe for you to be scanned. You will also be asked to complete a second, shorter, screening form immediately before the scan.

To be scanned, you would lie on your back on a narrow bed on runners, on which you would be moved until your head was inside the magnet. This is rather like having your head put inside the drum of a very large front-loading washing machine. The scanning process itself creates intermittent loud noises, and you would wear ear-plugs or sound-attenuating headphones. We would be able to talk to you while you are in the scanner through an intercom. If you are likely to become very uneasy in this relatively confined space (suffer from claustrophobia), you should NOT take part in the study. If you do take part and this happens, you will be able to alert the experimenters by activating an alarm and will then be removed from the scanner quickly. It is important that you keep your head as still as possible during the scan, and to help you with this, your head will be partially restrained with padded headrests. We shall ask you to relax your head and keep it still for a period that depends on the experiment but may be more than one hour, which may require some effort on your part. If this becomes unacceptably difficult or uncomfortable, you may demand to be removed from the scanner.

You may be asked to look at a screen through a small mirror (or other optical device) placed just above your eyes and/or be asked to listen to sounds through headphones. You may be asked to make judgements about what you see or asked to perform some other kind of mental task. Details of the specific experiment in which you are invited to participate will either be appended to this sheet or else given to you verbally by the experimenter. Detailed instructions will be given just before the scan, and from time to time during it.

The whole procedure will typically take about 1 hour, plus another 15 minutes to discuss with you the purposes of the study and answer any questions about it which you may raise. You will be able to say that you wish to stop the testing and leave at any time, without giving a reason. This would not affect your relationship with the experimenters in any way. The study will not benefit you directly, and does not form part of any medical diagnosis or treatment. If you agree to participate you will be asked to sign the initial screening form that accompanies this information sheet, in the presence of the experimenter (or other witness, who should countersign the form giving their name and address, if this is not practical). It is perfectly in order for you to take time to consider whether to participate, or discuss the study with other people, before signing. After signing, you will still have the right to withdraw at any time before or during the experiment, without giving a reason.

The images of your brain will be held securely and you will not be identified by name in any publications that might arise from the study. The information in the two screening forms will also be treated as strictly confidential and the forms will be held securely until eventually destroyed.

The study involves the recording of typical brain function. Since we are only studying healthy volunteers, there is no intended clinical benefit to you from taking part in this study. The scans are not intended to provide a medical diagnosis or a clean ‘bill of health’ – and the person conducting your scans will not be able to comment on the results of your scans. The researchers involved do not have expertise in MRI diagnosis, as they are psychologists or allied scientists and are not doctors. We ask you to give the name and address of your Family Doctor. This is because occasionally, when we image healthy participants, the researchers may be concerned that a potential abnormality may exist on the scan. In such

case, we will send a copy of the image to your Family Doctor, so that they can decide what course of action is best. By signing the consent form, you authorise us to do this. If you are not willing to authorise this, you will not be able to participate in the study. It is important that you realise that these research scans are NOT a medical screening procedure, and will not provide any information that may help in the diagnosis of any medical condition. If you do have any health concerns, you should contact a qualified medical practitioner in the normal way.

Further information about the specific study in which you are invited to participate may have been appended overleaf, if the experimenter has felt that this would be helpful. Otherwise, he/she will already have told you about the study and will give full instructions prior to the scan. Please feel free to ask any questions about any aspect of the study or the scanning procedure before completing the initial screening form.

Appendix I Initial Screening Form for the fMRI Experiment

ROYAL HOLLOWAY, UNIVERSITY OF LONDON
MAGNETIC RESONANCE IMAGING UNIT

INITIAL SCREENING FORM

NAME OF PARTICIPANT …… Sex: M / F

Date of birth…… Approximate weight in kg…… (one stone is about 6.3 kg)

Please read the following questions CAREFULLY and provide answers. For a very small number of individuals, being scanned can endanger comfort, health or even life. The purpose of these questions is to make sure that you are not such a person.

You have the right to withdraw from the screening and subsequent scanning if you find the questions unacceptably intrusive. The information you provide will be treated as strictly confidential and will be held in secure conditions.

Delete as appropriate

1. Have you been fitted with a pacemaker or artificial heart valve?	YES/NO
2. Have you any aneurysm clips or shunts in your body, or a cochlear implant?	YES/NO
3. Have you ever had any metal fragments in your eyes?	YES/NO
4. Have you ever had any metal fragments, e.g. shrapnel in any other part of your body?	YES/NO
5. Have you any surgically implanted metal in any part of your body, other than dental fillings and crowns (e.g. joint replacement or bone reconstruction)	YES/NO
6. Have you ever had any surgery that might have involved metal implants of which you are not aware?	YES/NO
7. Do you wear a denture plate or brace with metal in it?	YES/NO
8. Do you wear a hearing aid?	YES/NO
9. Do you use drug patches attached to your skin?	YES/NO
10. Have you ever suffered from any of: epilepsy, diabetes or thermoregulatory problems?	YES/NO
11. Have you ever suffered from any heart disease?	YES/NO
12. Is there any possibility that you might be pregnant?	YES/NO
13. Have you been sterilised using clips?	YES/NO
14. Do you have a contraceptive coil (IUD) installed?	YES/NO
15. Are you currently breast-feeding an infant?	YES/NO

Please enter here the name and address of your doctor (general practitioner):

I have read and understood the questions above and have answered them correctly.

SIGNED…… DATE……

In the presence of …….. (name) ……..(signature)

Address of witness, if not the experimenter:

Appendix J Sample Consent Form to be Adapted as Appropriate for fMRI Experiment

Appendix 1

SAMPLE CONSENT FORM TO BE ADAPTED AS APPROPRIATE

The participant should answer every question

	YES	NO
1. I have read the Research Participant Information Sheet.	☐	☐
2. I have had an opportunity to ask questions and discuss this study.	☐	☐
3. I understand that I am free to withdraw from the study:		
- at any time (Please note that you will unable to withdraw once your data has been included in any reports, publications etc)	☐	☐
- without having to give a reason for withdrawing	☐	☐
- without it affecting my future care	☐	☐
4. I agree to my interview being recorded	☐	☐
5. I understand that I will not be referred to by name in any report/publications resulting from this study	☐	☐
6. I agree that my comments can be quoted as long as they do not directly identify me when the study is written up or published	☐	☐
7. I agree to take part in this study	☐	☐

Research Participant Name:
Research Participant signature:
Date:

Principal Investigator name:
Principal Investigator signature:
Date:

Appendix K Participant Information Sheet for the EEG Experiment

College of Engineering, Design and Physical Science

Department of Mechanical, Aerospace and Civil Engineering

PARTICIPANT INFORMATION SHEET

This research ethics approval has been obtained from the relevant Research Ethics Committee

Study title

An emotional-economic investigation of event-related potentials to food product recognition

Invitation Paragraph

You are being invited to take part in this EEG experiment study will last the total time approximately 1 hour, which include applying the cap, and removing the cap. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

Most of previous research works into recognition memory based on the different and various contexts. This study will be focusing on how sales volume and price of food-related products effect on recognition memory.

Why have I been invited to participate?

It's an interesting EEG study, and everyone (18+) who might be interested is welcomed to get involved in this research.

Do I have to take part?

No. Participation is entirely voluntary, and there are no adverse consequences, academic or otherwise if you decide not to take part, or if you withdraw from the study before during or after the experiment. If you decide to take part you will be asked to sign a consent form. After this, you may still withdraw at any time, without giving a reason.

What will happen to me if I take part?

EEG is a recording of the electrical activity of the brain. It is a safe, non-invasive procedure. It involves wearing a cap that contains 32 electrodes or 64 electrodes; the latter as a newer generation than the former should provide better recordings. Each electrode is a small ceramic disc with a sintered silver coating sitting in a small rubber cup. To make electrical contact with the scalp, saline gel (similar in consistency to hair gel) is squirted into the cup. The gel is hypoallergenic and harmless to normal hair and skin and is certified for this use. However you should not take part if you have any skin problems affecting your scalp or face such as cuts, grazes, spots, inflammation or soreness.

Once the electrodes have been filled, the cap is connected to the recording system to check whether the electrodes will record (impedance testing). There is usually some adjustment of the cap and re-filling of the electrodes to make sure that a good recording can be obtained. In the experiment itself, there are two blocks will being carried out. For each block, food-related products are presented briefly and repeatedly (160 times per block), and you will carry out a simple task such as indicting your likelihood of this products by a button press. The tiny electrical signals from your scalp are passed into a powerful amplifier, and a computer records the EEG signal from each electrode. After the experiment, we average the activity to each stimulus to obtain a 3D map (two spatial dimensions plus time) of the brain's response to the stimulus, known as an event related potential (ERP). Each block would typically last 15 min, and there would be breaks in between the blocks in which you can move around, stretch, talk, drink some water, etc. The experiment part would last about 30 min include viewing and responding to the stimuli and the preparation and removal of the EEG cap would last about 30 min making about 1 hour for the whole procedure. To remove the gel, it will be necessary to wash your hair soon after the experiment. There is a shower room nearby, with shampoo and a clean towel available, or if you prefer, you can remove most of the gel with a tissue and wash hair when you get home. It is also advisable to wash hair on the morning or night before the experiment for your own comfort and to obtain good recordings. We cannot record from people wearing a hijab or other head covering, with hair extensions, weave, thick plaited hair, or hair styled using wax, hair spray or similar products.

What do I have to do?

The experiment will involve observing 2 blocks of stimuli and pressing buttons while keeping seated, still, relaxed and attentive. Normal activities can resume between blocks.

What are the possible disadvantages and risks of taking part?

There are no additional risks to taking part beyond everyday activities.

What if something goes wrong?

You can stop the experiment at any time. If a fire alarm sounds, you will need to leave the building while still wearing the cap.

Will my taking part in this study be kept confidential?

Your name will not be associated with study. Your responses will be kept strictly confidential and they will be stored under an anonymous code. The information will be kept in a secure location, accessible only to the researchers.All references to participants in the report and any subsequent publications/presentations will be anonymous.

What will happen to the results of the research study?

The results of the study will be presented in appropriate peer-reviewed scientific journals and conferences. If you take part in this research, you can obtain copies of these publications from the research team although it will be more than one year from the end of the study to publication.

Who is organising and funding the research?

The project does not have any external funding. The running costs are supported by Brunel University.

What are the indemnity arrangements?

Brunel University holds Public liability insurance policies which apply to this study. If you can demonstrate that you experienced harm as a result of you participation in this study, you may be able to claim compensation. Please contact Prof Peter Hobson, the Chair of the University Research Ethics Committee (res-ethics@brunel.ac.uk) if you would like further information about the insurance arrangements which apply to this study.

Who has reviewed the study?

This study has been reviewed by the College Research Ethics Committee.

Brunel University is committed to the UK Concordat on Research Integrity

The University seeks to ensure that good practice in research is an integral part of its research strategy and associated policies. This code states that the general principle of integrity should inform all research activities. Honesty should be central to the relationship between the researcher, the participant and other interested parties.

Contact for further information and complaints

For further information on the research study please contact Lin.Li@brunel.ac.uk. If you have any complaints or concerns, please contact the chair of the Department of Life Sciences ethics committee, Dr. Richard Godfrey, Richard.godfrey@brunel.ac.uk

Appendix L EEG Pre-Screening Form

EEG pre-screening

Initials:

Gender:

Age:

Date of EEG:

Do you have a neurological disorder?	Y/N
Are you currently unwell?	Y/N
Do you have skin allergies?	Y/N
Do you suffer from migraine or tension headaches?	Y/N
Do you have any cuts, soreness or inflammation on your face or scalp?	Y/N

Appendix MConsent Form for EEG Experiment

College of Engineering, Design and Physical Science
Department of Mechanical, Aerospace and Civil Engineering

CONSENT FORM
(This research ethics approval has been obtained from the relevant Research Ethics Committee)

An investigation of event-related potentials to influence on recognition memory based on emotional and economical factors

The participant should complete the whole of this sheet		
	Please tick the appropriate box	
	YES	NO
Have you read the Research Participant Information Sheet?		
Have you had an opportunity to ask questions and discuss this study?		
Have you received satisfactory answers to all your questions?		
Who have you spoken to?		
Do you understand that you will not be referred to by name in any report concerning the study?		
Do you understand that you are free to withdraw from the study:		
• at any time?		
• without having to give a reason for withdrawing?		
• (where relevant, adapt if necessary) without affecting your future care?		
Do you agree to take part in this study?		
Signature of Research Participant:		
Date:		
Name in capitals:		
I am satisfied that the above-named has given informed consent.		
Witnessed by:		
Date:		
Name in capitals:		

Researcher name:	Signature:
Supervisor name:	Signature:

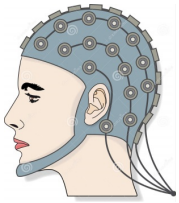
Appendix N Recruiting Ads for fMRI Experiment

Are you interested in how the brain works?

- A PhD research is recruiting participants for an fMRI study on decision making.
- The experiment would involve you viewing various photos of food whilst lying in an MRI scanner for around 30minutes.
- Participants will be offer **£20**.

- Contact email: Lin.Li@brunel.ac.uk

Appendix O Recruiting Ads for EEG Experiment



Are you interested in how the brain works?

- A PhD research is recruiting participants for an EEG study on recognition memory.
- The experiment would involve you to do a simple task by pressing button during viewing various food-related photos.
- The entire study will take approximately 1 hour.

Participants will be offered **£12**

Contact email: Lin.Li@brunel.ac.uk

Lin.Li@brunel.ac.uk
Lin.Li@brunel.ac.uk
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Lin.Li@brunel.ac.uk
Lin.Li@brunel.ac.uk
Lin.Li@brunel.ac.uk

Appendix P List of Publications

Li, Li., Wright, M., & Yang, Q. P. (2016). *Effect of popularity, pricing information, and number of variants (flavours) on recognition memory for branded food snacks*. 2nd Annual CHLS PhD Research Conference.

Li, Li., Wright, M., & Yang, Q. P. (2016, June 2). *Effect of popularity and price offer on decision making of food products: fMRI study*. NeuroPsychoEconomics Conference Program: Consumer neuroscience, Nachtigallenweg 86, 53127 Bonn, Germany.

Li, Li., Wright, M., & Yang, Q. P. (2015). *The influence of magazine context and car model on a "desire to purchase" decision*. 1st Annual CHLS PhD Research Conference.