THE ROLE OF PREFRONTAL CORTEX IN PURCHASING DECISIONS: AN OPTICAL BRAIN IMAGING STUDY

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THE ROLE OF PREFRONTAL CORTEX IN PURCHASING DECISIONS: AN OPTICAL BRAIN IMAGING STUDY

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ABSTRACT

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AN OPTICAL BRAIN IMAGING STUDY

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In economic decisions, an agent has to determine the expected utility of each option. Decision making processes during purchasing are based on the evaluation of costs and benefits of the products. Past research shows that the prefrontal cortex region of the brain is activated while individuals evaluate the qualities and the prices of products in order to make purchasing decisions. The aim of this study is to use functional near-infrared spectroscopy (fNIRS) to investigate the activations in the prefrontal cortex and particularly in the medial prefrontal cortex during purchasing decisions. The participants were asked to state their purchasing preferences for a series of products based on their prices in a decision making task. Throughout the task, the oxygenation levels in different parts of the prefrontal cortex were measured via the fNIRS method. The participants also filled out surveys about their daily usage and price evaluation for each product. Participant decisions, fNIRS data and survey results were analyzed together to investigate the relationship between various aspects of purchasing preferences and prefrontal cortex activations. The results of the study revealed that there is a significant difference in the level of oxygenation of the prefrontal cortex areas between positive and negative purchasing decisions.

Keywords: Decision making, Purchasing, Prefrontal cortex, fNIRS

ÖZ

SATIN ALMA KARARLARINDA PREFRONTAL KORTEKSİN ROLÜ:
BİR OPTİK BEYİN GÖRÜNTÜLEME ÇALIŞMASI

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Ekonomik kararlar sırasında, bir ajan her seçeneğin tahmini değerini belirlemek zorundadır. Satın alma sırasındaki karar verme süreçleri ürünlerin fayda ve bedellerinin değerlendirilmesi üzerinde temellenir. Bireyler satın alma kararları vermek amacıyla ürünlerin niteliklerini ve fiyatlarını değerlendirirken beynin prefrontal korteks bölgesinin aktive olduğu geçmiş araştırmalarda gösterilmiştir. Bu çalışmanın amacı, satın alma kararları sırasında prefrontal korteks ve özellikle de mediyal prefrontal korteksteki aktivasyonların fonksiyonel yakın-infrared spektroskopisi (fNIRS) metodu kullanımıyla araştırılmasıdır. Bir karar verme görevinde katılımcılardan bir dizi ürünün fiyatlarını göz önünde bulundurarak satın alma tercihlerini belirtmeleri istenmiştir. Görev boyunca prefrontal korteksin çeşitli kısımlarındaki oksijenlenme seviyeleri fNIRS metodu ile ölçülmüştür. Ayrıca katılımcılar her bir ürün için günlük kullanımları ve fiyat değerlendirmelerine dair anketler doldurmuştur. Katılımcı kararları, fNIRS verileri ve anket sonuçları satın alma tercihlerinin ve prefrontal korteks aktivasyonlarının çeşitli yönlerinin araştırılması amacı ile bir arada incelenmiştir. Çalışmanın sonuçları pozitif ve negatif satın alma kararları arasında prefrontal korteks bölgelerinin oksijenlenme seviyelerinde belirgin bir farklılık olduğunu göstermiştir.

Anahtar Kelimeler: Karar verme, Satın alma, Prefrontal korteks, fNIRS

To My Family

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CHAPTER 1

INTRODUCTION

All human beings have to go through several decisions and conflicts everyday. Regardless of their significance, each decision plays a role in shaping a person's life. In particular, financial decisions carry an importance since they facilitate commercial exchange between individuals. Because of this reason, there has been an increasing interest towards the cognitive processes underlying financial decisions, especially in the fields of psychology, neuroscience and economics.

In classical economics, individuals are seen as rational agents in regards to decision making. According to this view, the process of decision making is based on the evaluation of the costs and benefits of each option and the corresponding probability of the occurrences of these options (Edwards, 1954). Empirical research of human decision making demonstrated a significant conflict between this view of rational decision making and actual human behavior. Subsequently, several theories of decision making were developed in an effort to form a more realistic framework which can account for human behavior. Among these theories, the theory of Expected Utility (EU) describes a set of axioms to explain the subjective aspect of option evaluation (Neumann & Morgenstern, 1944) and the Prospect Theory accounts for the inconsistencies observed in risk taking behavior across various settings of options (Kahneman & Tversky, 1979).

On the other hand, the framework of bounded rationality opposed the view that humans use advanced decision making algorithms to optimize the utility of theoutcomes (Simon, 1956). Herbert Simon proposed that it was not feasible to optimize the decision processes due to the fact that the ability of our cognitive faculties is finite and also it is not possible to have complete information of our environment and alternatives in many decision settings. Instead of optimizing, he proposed that the application of a set of simple decision rules could be enough to achieve highly successful outcomes (Gigerenzer&Selten 2002).

In the last decades, the studies of decision making in the field of consumer behavior have explored the behaviors in relation to product selection processes. In a typical shopping setting, a consumer has to solve a decision problem which involves many alternative product attributes and categories. It has been shown that people generally collect information regarding the product alternatives from mainly two sources: sensory information and memory retrieval (Biehal&Chakravarti, 1983). This process of product evaluation can be influenced by a variety of factors such as product categorization (Moreau et al., 2001) or brand comparison (Huber et al, 1982). During the decision making process, the selection of the product can be based on specific attributes of the products (Sanbonmatsu& Fazio, 1990) or the subjective feelings of the consumer regarding the products (Pham et al., 2001).

Decision making processes have been extensively studied in the field of neuroscience in an effort to provide a neurobiological basis for psychological constructs such as bounded rationality and satisficing that are not easy to quantify. The literature on brain functions that are responsible for the evaluation and selection of the options show that there are two main networks which play a role in guiding our decisions. One of these networks is the limbic system which is comprised of a number of subcortical structures. These areas of the brain are generally responsible for affective functions and emotional processing. The second network is the prefrontal cortex which is located in the frontal part of the brain. The subcomponents of the prefrontal cortex carry out the executive functions during decision making behavior (Sanfey *et al.*, 2006).

Among the areas of the prefrontal cortex, the medial prefrontal cortex (MPFC) and the dorsolateral prefrontal cortex (DLPFC) have been consistently shown to be involved in the decision making processes. The medial prefrontal cortex is responsible for the evaluation of options. In decision making experiments, MPFC is activated during product evaluation (Paulus & Frank, 2003) and financial decisions (Basten*et al.*, 2010). The dorsolateral prefrontal cortex is involved in working memory (Jonides et al., 1996) and executive functions. The activation of DLPFC is closely related to the activation of MPFC (Deppe*et al.*, 2005) and it regulates MPFC functions during decision making (McClure *et al*.,2004).

The research method used in this study is Functional near-infrared spectroscopy (fNIRS) which is a non-invasive, low-cost, optical brain imaging method. It is a neuroimaging method which utilizes near-infrared light to detect the change in the oxygenation levels in the brain tissue (Bunce*et al.*, 2006). fNIRS has been successfully used in many types of experimental studies in the domain of cognitive science. It has been used in order to investigate numerous aspects of neural activation such as the magnitude of cognitive load (İzzetoglu et al, 2004), task expertise (Leff et al, 2007) and impact of stress on mental performance (Nakao*et al*., 2013).

fNIRS has also been used in decision making research. There have been a number of fNIRS studies which investigate the role of prefrontal cortex activations in executive functions such as product selection (Kumagai, 2012), risk assessment (Holper, 2014), financial investment (Shimokawa*et al.*, 2009) and price prediction (Mitsuda et al., 2012). Although the decision making processes regarding economic behavior have been extensively studied via fNIRS and other imaging methods such as fMRI in the field of cognitive neuroscience, there has not been many studies investigating the activation patterns in the prefrontal cortex regarding the behavior of consumers within a realistic purchasing environment.

In order to address this issue, the current study aims to investigate the role of prefrontal cortex regions in a product purchasing setting. Additionally, the relation of participant preferences and the usage frequency of the products in daily life and the participants' perception of the monetary value of the products are also measured. To this end, a purchasing preference task was designed and the brain activations during the experiment were recorded via the fNIRS method. Participants were presented with 78 products, each with a suggested price, and were asked whether they would like to buy the product for its suggested price. Initially, a pilot study with 14 participants was conducted. The results of the pilot experiments led to the main study with larger number of participants, an enhanced task design and two participant surveys regarding their daily usage of the products and the price they would be willing to pay to purchase each product. The main study was carried out in two stages. In the first stage, 28 participants were asked to state their purchasing preferences for a group of products and their corresponding prices. In the second stage, 30 people participated in the experiment and they were given money to purchase some of the products they were presented during the task

There are four main hypotheses of the study:

H1: There is a significant difference between the positive and negative purchasing decisions among the oxygenation level of MPFC and DLPFC.

H2: Participants will show an increased preference of purchasing for the products which they are more familiar with (products with higher frequency of daily usage)

H3: The reaction times for positive and negative preference responses are significantly different.

H4: The effects mentioned in the Hypotheses 1, 2 and 3 are more pronounced in the monetary condition in which the participants were given money to create real purchasing decisions compared to the non-monetary condition.

In the following chapter, the literature on the decision making processes, purchasing preferences and their neurological underpinnings are reviewed. Chapter 3 explains the method of the study in detail, Chapter 4 describes the results of the study and Chapter 5 discusses the findings of the study in the light of the literature.

CHAPTER 2

LITERATURE REVIEW

In this chapter, theories of decision making from the perspectives of psychology and economics will be briefly reviewed. After that, neuroscientific findings on decision making mechanisms will be explained. Lastly, the studies that influenced this thesis research will be summarized.

2.1 Economic Approaches to Decision Making

The classical theory of expected value assumes that during the decision making process, the rational decision maker estimates the utility of each option by multiplying the amount of payout and its probability of occurrence (Edwards, 1954). However, this view of decision making often fails to account for the majority of decision making in our lives.

The St. Peters Paradox, which was proposed by Nicolas Bernoulli was an example of such a conflict between expected value theory and human behavior. The paradox describes a gambling game comprised of a sequence of coin flips. The game starts with a bet of 1 dollar. If the head appears in the first flip of the coin, the player wins a dollar. In the next game the bet is doubled and if the head side of the coin appears, the player wins 2 dollars. In every repetition of the game the bet is doubled in this way. The game can be repeated as long as the player wants until the tail side of the coin appears. If the tail appears, the player loses the game and has to give up all the money he has acquired until that point. According to the expected value theory, the price of joining this game can be calculated by the multiplication of 50% and the payoff of each repetition and adding all the values of repetitions to calculate the total value of the game. This would result in the estimation of an infinite amount for the value of joining this game. However a reasonable decision maker would not be willing to pay a huge amount of money to join this game. The paradox stems from the conflict between the calculated infinite value of the game and the unwillingness of humans to pay such a price.

In 1738, Daniel Bernoulli proposed an explanation for this conflict. He suggested that the value of the game should not be determined in absolute terms, but it should be calculated by taking into account the subjective value attributed to the game by the decision maker. According to this view, the subjective value would be the utility of the game for the player, which was called the expected utility. The magnitude of the expected utility changes logarithmically in a negative relation to the current financial wealth of the player. The utility of the game would decrease as the current wealth of the player increases. Thus, the game has a subjective value and this value is always less than infinite since no one has negative infinite amount of money. In his article, Bernoulli wrote: “There is no doubt that a gain of one thousand ducats is more significant to the pauper than to a rich man though both gain the same amount” (Bernoulli, 1738).

John von Neumann and Oskar Morgenstern wrote their seminal book on decision theory called “Theory of Games and Economic Behavior” in 1944 and examined decision making strategies in various settings. In this book, they proposed four axioms, namely completeness, transitivity, independence and continuity, which can be used to describe a rational decision maker from an expected utility theory perspective. The completeness axiom states that the decision maker has well-defined options and can always decide between any two alternatives. Transitivity suggests that the decision maker is consistent in his/her choices. For instance if among A and B, B is the better option and among B and C, C is the better option, then the rational decision maker is expected to choose C over B. The independence axiom guarantees that when two options with a certain preference order are mixed with a third option, then the order is preserved. Continuity suggests that if A,B,C are options in increasing utility, then there is a p such that B has the same utility as pA + (1-p)C. If all these assumptions are satisfied, then the decisions can be represented by a utility function. If the decision of the agent is in line with these axioms, then it could be regarded as a rational decision.

The empirical research on decision making in the subsequent years showed that individuals behaved in significantly different ways than predicted by the expected utility theory. In 1953, Maurice Allais described a game, later called the Allais Paradox, where people would decide in a way that would be in conflict with expected utility theory. The paradox is comprised of two gambles, each with two options that have the following payoffs and probabilities:

Gamble 1:

Option A:	100%	-	100 million
Option B:	10%	-	500 million
	89%	-	100 million
	1%	-	Nothing

Gamble 2:

Option C:	11%	-	100 million
	89%	-	Nothing
Option D:	10%	-	500 million
	90%	-	Nothing

Under these experimental conditions, the behaviors of the participants in this game showed that most people choose Option A over Option B and they also choose Option D over Option C. The expected gain/utility for option A is 100 million, whereas in option B the utility is 0.1*500 + 0.89*100 = 139 million. Similarly, the utility of option C is 0.11*100 = 11 million, whereas option D yields an expected gain of 0.1*500 = 50 million. The fact that subjects' choices conflict with the predictions of expected utility theory suggest that most people may not be deciding along the factors proposed by this theory (Moskowitz, 1974; Oliver, 2003)

Another paradox that violates expected utility theory was described by Daniel Ellsberg (1961). In this paradox, there is an urn which contains 30 red balls and 60 black and some yellow balls. The ratio of black balls to yellow balls is unknown. Under this condition a ball will be drawn and the following gambles are offered:

Gamble 1:

Option A: Red - $100

Option B: Black - $100

Gamble 2:

Option C: Red or Yellow - $100

Option D: Black or Yellow - $100

Ellsberg reports that most people choose A over B in gamble 1 even though

$$EU(A) = 100 * \frac{30}{90 + y} < EU(B) = 100 * \frac{60}{90 + y}$$

and D over C in gamble 2as predicted by utility theory where

$EU(D) = 100 * \frac{30+y}{90+y} < EU(C) = 100 * \frac{60+y}{90+y}$.

Therefore, the behavioral responses for the two gambles are not consistent with the predictions of the expected utility theory.

In 1979, Kahneman and Tversky published an article which examined further the incompatibility between the expected utility theory and the human behavior. They suggested a new theory called the Prospect Theory to account for the ways in which humans deviate from the norms of rational decision making described by the expected utility theory. They observed that there were some recurring patterns in how people deviate from the expected utility theory in financial decision experiments. For example, they showed that even though people should weight outcomes in proportion to their probabilities according to the expected utility theory, most of the time they significantly overweighted the outcomes which are certain compared to the other options. They called this tendency “the certainty effect”. Another tendency they observed was that during the examination of the options, people separate each option into their components and then compared the options in regard to their different parts and disregard their similarities. However, since options can be divided into their components in different ways according to different criteria, this causes inconsistencies in people’s preferences. They called this process “the isolation effect”.

Kahneman and Tversky put forward the prospect theory in an attempt to create a descriptive framework which could account for the decision making processes in a realistic manner. According to the prospect theory, the decision making process takes places in two stages: the editing stage and the evaluation stage.

In the editing stage, people analyze the options and create a representation of each of them by simplifying their attributes. The editing stage is comprised of several subprocesses. In this stage, a reference point is selected to represent the current state and the options are defined not in terms of final states of wealth but rather they are defined in terms of their relation to the reference point. This process is called *coding*.

Furthermore, identical options can be combined and represented as a single item. As an example, if there are two identical options of $200 with 25% probability, these can be represented as a single option of $200 with 50% probability. This process is called *combination.* Options can be reshaped in a new way to separate their riskless part. For example, two options of $300 for 80% and $200 for 20% can be represented as a riskless gain of $200 and a second option of $100 with 80% risk (*segregation*). Some options can be simplified by rounding. For instance, an option of $100 for 49% can be represented as an even chance of gaining $100 (*simplification*). If an option is significantly dominated by other options, then it can be disregarded without further analysis (*detection of dominance*).

In the evaluation stage, one of the options is chosen according to their representations created in the editing stage. The process of evaluation is based on two factors: the decision weights and the value function. The decision weights affect the weight of the probability of each option in terms of how much each event will impact the desirability of the prospects.

The value function determines the subjective value of each option. It is not a measure of the final states that the options provide. Instead, it is a measure of gains and losses in terms of their deviations from the reference point. Kahneman and Tversky find this process to be similar to our other perceptual and judgment faculties. We generally gather and consolidate information from our environment not in terms of absolute magnitudes, but we do it in terms of change. Similarly, the value function evaluates the options in terms of change from the reference point.

In 1956, Herbert Simon created the theory of Bounded Rationality and he opposed the view that humans used complex algorithms to make decisions. According to him, we do not need any utility functions in order to choose among various alternatives. In order to make decisions, we do not try to "optimize" but rather we try to "satisfice", which means that because of the limitations in our cognition and limited information in our environment we try to reach satisfactory goals rather than finding optimal solutions.

Simon stated that an organism needed only simple perceptual and choice mechanisms to satisfy its needs (Simon, 1956; Gigerenzer&Selten 2002). According to the theory of Bounded Rationality, decision making processes can be comprised of three types of functions:

Search Rules:

The search process occurs in a step-by-step fashion, where each step involves the acquisition of a piece of information and then this process is repeated until reaching a state that would satisfy the stopping rule.

Stopping Rules:

The search function is stopped when a sufficient amount of information is acquired.

Decision Rules:

Rather than calculation the weights of all options for every criteria to find the optimal solution, a simple decision rule such as "Select the option that is favored by the most important criterion" is applied.

By using these three types of functions, an organism with limited cognitive abilities can satisfy its various needs in a complex and uncertain environment (Gigerenzer & Selten 2002).

2.2 Decision Making and Consumer Behavior

The decision making process in a shopping setting involves many different options, each with different attributes and costs. The decision maker has to process a big amount of information to evaluate the options in order to reach a conclusion. In doing so, the consumers have to rely on their limited cognitive resources. There have been many studies to investigate the consumer decision process and how it is influenced by the different types of external factors and marketing settings.

During the process of product choice, the alternatives are grouped in categories according to their attributes. After the creation of the categories, new options are placed within the existing categories and this process of categorical placement influences the expectations and preferences of the consumers (Moreau *et al.*, 2001).

The ways the products are presented to the consumer especially have a major effect on the consumer's perception and evaluation of the products. For instance, it has been shown that customers evaluate products differently in relation to which products they are comparing with the target product. If the consumer compares the target product with a product from an inferior brand, then the target product seems more attractive and when the customer evaluates a target product with another product from a superior brand, then the target product is evaluated as being less attractive (Huber et al, 1982).

In a similar way, a product which has been perceived as average in comparison with other products in a group can have a higher probability of being a purchased. If the product does not rank badly in any of the product attributes, costumers tend to perceive them as less riskier choices and they can be more likely to buy that product (Simonson, 1989).

Generally, consumers collect information about choices from two distinct types of sources. The first source is their sensory perception. This type of information is gathered from the decision maker's immediate environment. The second source is the consumer's memory. Information retrieval from the memory provides previously collected information about options which can not be obtained from the customer's sensory environment. In a setting where products with these two types of information are in competition, products with sensory information have dominance over the products which have information only in memory. When consumers make a choice between products which they can perceive directly and other products which they can only remember from their previous encounters, they have a tendency to choose products which have sensory information (Biehal & Chakravarti, 1983).

The decision between products can be distinguished as two different types of processing: "attribute-based decisions" and "attitude-based decisions". In attribute-based decisions, the evaluations of the products are based on how preferable they are on each of the product attributes. On the other hand, attitude-based decisions are based not on specific attributes but rather based on how preferable they are in general (Sanbonmatsu & Fazio, 1990).

The attitude-based decision processes often involve the conscious monitoring of feelings. Decisions which rely on the monitoring of emotions are found to be not only faster but also more stable and consistent across decision makers (Pham *et al.*, 2001).

Attribute-based decisions can cause information overload if there are many attributes to evaluate for a set of options. If there is no conflict along the attributes of the products, picking only one attribute for evaluation can be sufficient for the decision process. It has been shown that selecting only the most important attribute and then selecting the product with the highest value for that attribute has led to good decisions (Fasolo *et al.*, 2007).

A framework that was proposed to investigate attribute and attitude-based decisions was the MODE model which signifies that motivation and opportunity to deliberate are determinants of decision making. According to this model, the level of motivation is correlated with how much the decision is personally relevant to the decision maker, and the level of opportunity is correlated with the amount of time and resources they have to process the information regarding the decision. When motivation and opportunity is high, the decision maker is more inclined towards attribute-based decision making. When the motivation and opportunity is low, the decision maker is more inclined towards attitude-based decision making (Fazio, 1990).

This thesis study investigates the decision processes as they relate to purchasing and product preference. Consequently, an experimental paradigm which measures participants' purchasing decisions and surveys about product familiarity and subjective valuation was created. The research literature on consumer behavior guides the design of the study as the experimental setting investigates how consumer's previous experience and subjective valuation of the products influence their purchasing decisions.

The study also used neuroscientific measures to investigate the neural underpinnings of decision making and consumer behavior. Functional near-infrared spectroscopy was used to collect the neural signals from the brain regions involved in decision making during the purchasing experiment. In order to provide a background regarding the neural underpinnings of decision processes and the related neuroscientific research methods, the following section reviews the literature on the neuroscience of decision making.

2.3 The Role of Prefrontal Cortex in Decision Making

Neuroscientific studies of decision making use various methods to investigate the neural underpinnings of our decisions. Imaging techniques such as functional magnetic resonance imaging and functional near infrared imaging, experimental data from populations with neurological disorders, lesion studies and animal models are brought together to shed light on the brain functions which carry out decision processes.

As a result of these studies, a number of different brain regions are found to be involved during decision making processes (Figure 1). The prefrontal cortex is responsible for the executive functions, while the subcortical regions are mainly responsible for the emotional aspects of decision making.

Nucleus accumbens activation correlates with reward anticipation, medial prefrontal cortex (MPFC) activation correlates with gain outcomes (Knutson *et al.*, 2001); anterior cingulate cortex activation correlates with conflict monitoring (Botvinick*et al.*, 1999); dorsolateral prefrontal cortex (DLPFC) activation correlates with executive working memory (Jonides*et al.*, 1996); and insula activation is correlated with negative arousal (Buchel and Dolan, 2000; Paulus & Frank., 2003).

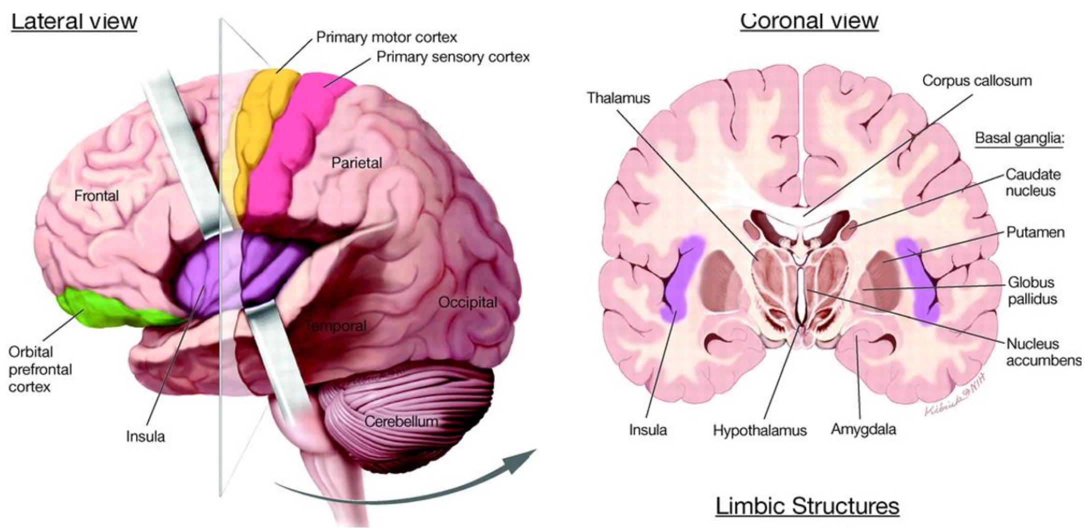

Figure 1 Cortical and subcortical regions of the human brain (Lane *et al.*, 2009)

The areas of the prefrontal cortex are found to be involved in various types of decision processes such as option valuation, probability estimation, reward and cost anticipation and strategy formation. The research on the medial and dorsolateral parts of the prefrontal cortex will be reviewed in this section since they are shown to be responsible for the option valuation and risk management parts of decisions which are of interest in this thesis study.

MPFC has been shown to play a role in the calculation of values of options in a variety of experiments. In a study of product preference, Paulus and Frank (2003) asked participants to state their preference within the presented products and they observed that medial prefrontal cortex activation was correlated with subjective product preference.

Similar results were obtained by Hare et al. (2011) regarding the MPFC. Participants were asked to choose between healthy and unhealthy food items. The values of the options were estimated by the activation in the MPFC. Furthermore, the activity of the MPFC was regulated by the dorsolateral prefrontal cortex depending on the cues provided in the task.

The option valuation carried out by the MPFC is not exclusive to product valuation. Rather, similar patterns of activation have been observed in many decision making studies conducted with monetary options. For example, Basten et al. (2010) showed that MPFC was activated during decisions between monetary options with different financial values.

In another experiment, monetary options were presented with varying risk and ambiguity levels. In the context of this experiment, risk was defined as a situation where the probabilities of different outcomes can be estimated, whereas ambiguity is defined as a situation where it is not possible to estimate the probabilities of outcomes. Although the level of subjective aversion towards risky or ambiguous options changed across the group of participants, MPFC activation was sensitive for both risky and ambiguous decisions (Levy *et al,* 2010).

Value calculation by MPFC is also apparent in regard to the temporal qualities of the options. When participants are presented with monetary options which differ in the aspect of delayed acquisition, temporal changes between options were correlated with MPFC activation in the experiment (Kable&Glimcher, 2007).

These results show that the medial part of the prefrontal cortex is responsible for option valuation regardless of the type of options. Whether the decision is made between commercial goods or monetary options, the valuation process generally involves MPFC activation. In a study conducted by Boorman et al. (2009) MPFC activation was observed in decisions between options which denoted only statistical probabilities and reward magnitudes. In another study, Chib et al. (2009) found that a region in the ventral part of the medial prefrontal cortex was activated in correlation with participant preferences across different groups of options such as food products, non-food products and monetary gamble. MPFC activation has also been observed in social decisions. Participants deciding between charities to make a donation showed increased activation due to valuation of charity options (Hare *et al,* 2010).

Bechara et al. (2000 a) investigated MPFC functions in patients with MPFC lesions.In a card selection task, healthy participants and participants with MPFC lesions were asked to select cards from 4 alternative decks with rewards and losses which of two were more riskier than the other two decks. During the experiment, the skin conductance of the participants was also measured. The researchers concluded that MPFC lesions caused insensitivity for positive or negative future consequences. These results led Bechara*et al*. (2000 b) to put forward the Somatic Marker Hypothesis which states that "decision making is a process that is influenced by marker signals that arise in bioregulatory processes, including those that express themselves in emotions and feelings" (page 295).

In many studies, it has been demonstrated that the function of MPFC is regulated by DLPFC activation. McClure et al (2004) conducted an fMRI study with a decision making task to investigate the effect of brand perception on product preference and brain activations. In the first condition, the participants received Coke and Pepsi and made a product preference test without the knowledge of brand. The results showed that MPFC activation was related to sensory perception of the drinks when the participants did not have brand knowledge. However the second group with knowledge of brands showed differences in both behavioral preference and brain activations. When the participants had brand knowledge, DLPFC was activated in addition to MPFC. Furthermore, the activation of DLPFC changed the level of activation in the MPFC causing the difference in subjective valuation of the products. The authors suggested that the bias of cultural information may have its neural underpinnings in the manipulation of MPFC activation via DLPFC as well.

Similar results were found in the study of Deppe et al. (2005) in a produdct choice experiment. Participants were presented with pairs of products and stated their preferences. When the target product was from the participant's favorite brand, the activation of the DLPFC was decreased and the activation of the MPFC was increased. The researchers suggested that brand information had an effect on the interaction between DLPFC and MPFC.

Although decisions are frequently studied in positive and appetitive contexts, it has been demonstrated that prefrontal cortex activations occur in a similar fashion in aversive contexts too. Plassmann et al. (2010), conducted a study with a bidding task where the participants decided to bid either to eat the foods they liked or avoid the foods they disliked. In both appetitive and aversive contexts, MPFC and DLPFC were activated, suggesting that the functions of these areas are independent of the appetitive aspect of the context.

DLPFC activation has also been observed in decision making experiments with primates. Kim and Shadlen(1999) conducted an experiment with rhesus monkeys by recording the neural activation in their DLPFC region during a motion discrimination task and demonstrated that the DLPFC was involved in the judgment of direction. In a similar studyWallis and Miller (2003) recorded DLPFC activation in rhesus monkeys while they were shown pictures associated with different types of juice rewards and demonstrated that the DLPFC activation encoded the amount of option reward.

Seo et al.(2007) recorded DLPFC activation in rhesus monkeys during a matching pennies game and showed that the DLPFC is an important part of the decision making network of the brain in primates. Since humans share many similarities in brain functions and basic behavioral patterns with other primate species, the common functions of DLPFC observed both in humans as well as other primates show this brain region's significance in decision processes.

The functions of the DLPFC are not limited to decision making processes. The DLPFC has been shown to have a role in cognitive control (Miller, 2000) and working memory (Levy and Goldman-Rakic, 2000; Curtis and D'Esposito, 2004; Petrides, 2000)

In the research on the neuroscientific basis of decisions, fMRI has been heavily utilized due to its high spatial resolution. However, the fMRI method has many drawbacks as it is a quite expensive and non-portable research method. In the recent years, functional near-infrared spectroscopy has been adapted for the investigation of brain activations and it has also been successfully used to study the neural basis of decision making.

2.4 Functional near-infrared spectroscopy (fNIRS)

fNIRS is a non-invasive, portable and cost-effective method that can be used to measure brain activity with high temporal resolution (Irani*et al.*, 2007). The basic principle of fNIRS method is to measure the level of oxygen in the target tissue. When there is neural activity in a certain part of the brain, glucose and oxygen consumption at that region increases. Oxygen is carried by hemoglobin molecules that are located in red blood cells. Oxygenated and deoxygenated hemoglobin molecules have specific optical properties and thus it is possible to measure the difference of oxygenation levels of neural tissue by using near-infrared light.

A light source is attached to the head of the participant by fiber-optical bundles or light-emitting diodes (LEDs) called optodes. As the photons emitted by optodes go through the skull and the brain, they are scattered or absorbed by the neural tissue. The scattered photons follow a curved trajectory towards the skin and can be measured via photodetectors at the scalp (Bunce*et al*., 2006).

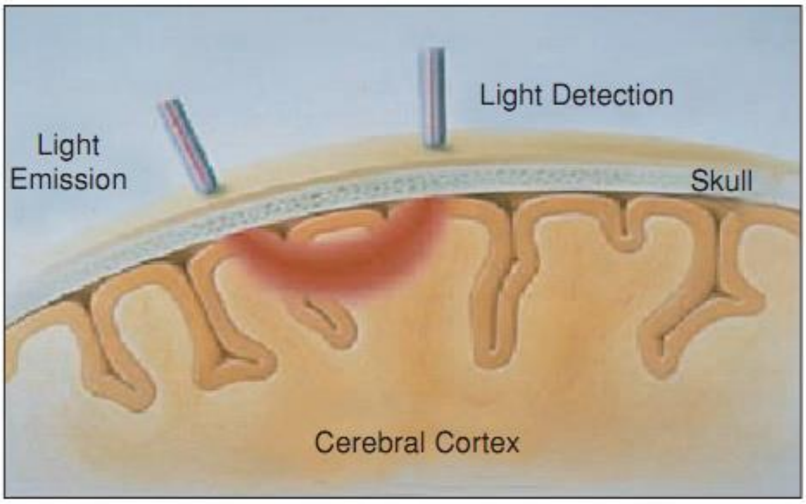

Figure 2 Principle of fNIRS recording (Bunce*et al.*, 2006)

The fNIRS method has been utilized to investigate various cognitive faculties. Cognitive load experiments conducted via fNIRS recordings have shown that the results of fNIRS measurements were congruent with the measurements of other neuroscientific research methods such as fMRI (İzzetoglu*et al*, 2004). İzzetoglu*et al.* (2007) used fNIRS in a series of experiments to study brain activations during several types of tasks that measure cognitive output. They used a videogame-like task called the Warship Commander Task in which the participants tried to manage varying numbers of airplanes and the amount of cognitive load of the participants was quantified by fNIRS.

In other experiments the n-back task was used to investigate working memory load on the prefrontal cortex and anagram problems of varying difficulty were used to measure brain activations correlated to problem solving efforts. fNIRS was also used in a visual oddball paradigm to assess attention levels of the participants. Across this series of studies, fNIRS was shown to be a reliable method for quantification of prefrontal cortex activations (İzzetoglu*et al*, 2004).

fNIRS has also been used to measure the changes in activation patterns in the PFC regarding the expertise level of the participants. Level of expertise was manipulated by familiarization of participants during several sessions of a knot tying task. As the sessions progressed, the level of adaptation in the prefrontal cortex has been detected via fNIRS (Leff*et al*, 2007).

Nakao*et al* (2013) used fNIRS to investigate the effect of early life stress on brain activation. The early life stress of the participants was determined via using a child abuse and trauma scale. Prefrontal cortex activations were recorded during a color-preference judgment tasks (self-oriented task) and a color-similarity judgment task (control task) as well as during resting state. fNIRS data analysis showed that early life stress had a negative effect on MPFC activation during self-oriented judgments and resting state.

fNIRS method has been used widely in decision making and economic preference research. Since economic decisions are carried out mostly in the prefrontal cortex, fNIRS emerges as a viable method to investigate the role of prefrontal brain areas in tasks such as product preference and financial decision making.

Kumagai (2012) investigated personal product preference in an fNIRS study. Subjects were asked which one of the two products presented they would prefer and then were shown the same products consecutively before making a final decision. Researchers were able to classify product preferences by analyzing fNIRS data by conducting t-tests and discriminant analysis.

A similar study was conducted by Luu and Chau (2009) to detect product preference via fNIRS in a single-trial task. Subjects evaluated two possible products to state their preference and a single-trial task was adequate to use fNIRS signal for discriminant analysis to achieve preference detection.These two aforementioned studies utilized brain-computer interface (BCI) analysis methods to analyze the change in blood flow in the cortex to detect a decision maker's preferences. Development of BCI technologies can help people with disabilities to state their preferences and judgements with the aid of tools that can measure brain signals. Moreover, the signal processing methods developed within this field can be used for the progress in other research areas such as the investigation of brain function underlying executive functions. fNIRS proves to be a useful method for the employment of BCI methods.

Holper (2014) used fNIRS in combination with electrodermal activity to assess individual risk taking. Eelectrodermal activity is a method which is used in investigation of processes related to decision making and affect. In addition to the fNIRS recordings and electrodermal activity, participants also completed a risk-taking task for an assessment of risk-seeking and risk-averse individuals. fNIRS data analysis showed that the lateral prefrontal cortex activation correlated with subjective valuation of risk. The authors concluded: "High risk elevated hemodynamic responses only in risk-seeking subjects but suppressed them in risk-averse subjects". The fNIRS results were also found to be congruent with electrodermal activity results.

Another area of fNIRS research in relation to economic decisions is financial investment. Shimokawa et al (2009) conducted a decision making study where participants made investment decisions and prefrontal cortex activation was measured via fNIRS. The participants chose an investment option according to the information regarding their past stock market record. The authors stated that the goal of this study was to prove the usefulness of the fNIRS method in decision making research. In order to this they created a model which uses prefrontal cortex oxygenation levels to make prediction about participant choice of risky investment. The model was a Bayesian neural network which could make predictions of individual decisions based on fNIRS signal. The neural activation data, particularly collected from the dorsolateral prefrontal cortex and the orbitofrontal cortex was used to make predictions with the aid of the Bayesian model.

The studies reviewed above have utilized the fNIRS method to examine the neural basis of decision making. It has been shown that the changes in the level of oxygenation in the regions of the prefrontal cortex can be measured via fNIRS to investigate how the brain functions carry out the processes related to subjective preferences, risk taking, cognitive load and working memory. Based on this body of work, the motivation of the current study is to use fNIRS and behavioral experimentation to investigate decision making processes in a simulated shopping environment with a product purchasing task. In particular, there have been three studies in the literature that influenced the creation of the current study with their methods and findings. In the following section, these studies are reviewed in order to provide a better understanding regarding the roots of this thesis study.

2.5 Preceding Studies

The first of these studies, conducted by Knutson and colleagues in 2007, was comprised of an fMRI experiment involving a purchasing task. Participants were shown a series of products with suggested prices and made purchasing decisions by using the money given to them by the researchers. The prices of the products were discounted by 75% of their real market prices. Participants also filled out a survey stating how much they would be willing to pay for each product.

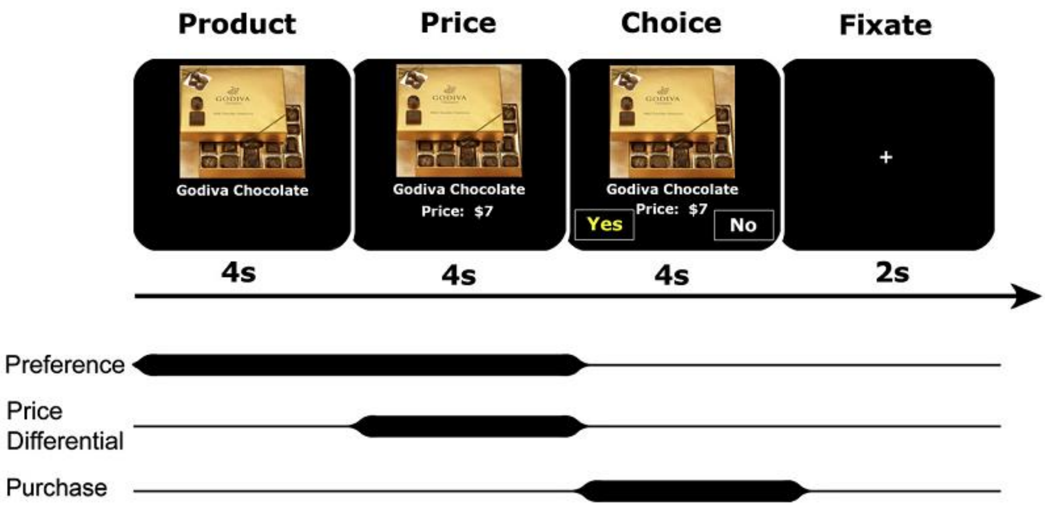

Figure 3 Purchasing task in Knutson et al., 2007

The findings showed that the nucleus accumbens was activated during the product and price periods of the task and its activation correlated with product preference. Additionally, medial prefrontal cortex was activated during the price period and the difference between the prices suggested during the task and the prices that the participants were willing to pay correlated with MPFC activation.

The second study was a product preference experiment conducted via the fNIRS method (Shimokawa*et al*, 2008). Participants were shown two products first sequentially and then concurrently. When they saw the two products together on the screen they made a selection between the products.

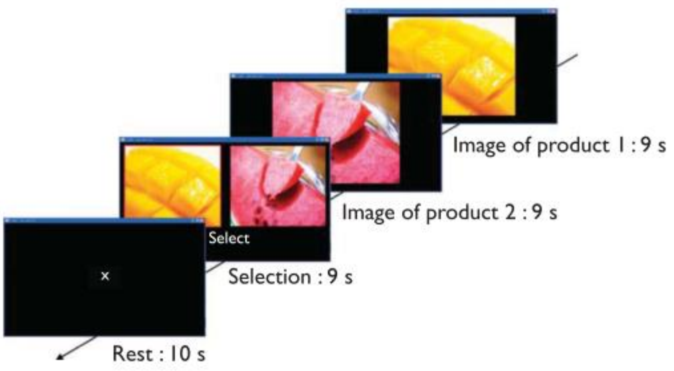

Figure 4 Product preference task in Shimokawa et al., 2008

The activation of the medial part of the prefrontal cortex during the single display of the preferred product was found to be similar to the activation pattern during the preference screen.

The third study of influence was a price prediction experiment which was also conducted via fNIRS(Mitsuda*et al*., 2012). Participants were asked to predict the price of the presented product, then these were shown the price of the product (which was either decreased or increased compared to the market prices) and then the participants typed their own predicted price for the product.

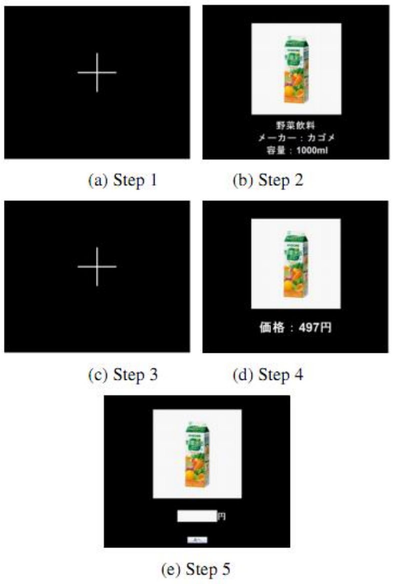

Figure 5 Price prediction task in Mitsuda et al., 2012

The fNIRS data showed that the rate of divergence for oxygenation in the prefrontal cortex and the relationship between the predicted and presented prices were similar.

Taken together, these three studies shaped the structure of this thesis work. The study of Shimokawa et al. and Mitsuda et al. provided the basis for the usability of the fNIRS method in the investigation of purchasing decisions by showing the ability of the method to precisely detect the neural activation underlying the processes of product evaluation and cost analysis. The work of Knutson et al. provided the basis for the shopping task developed in this study for the investigation of prefrontal cortex activations during purchasing behavior. However, the task developed in this study differs from the experiment in Knutson et al. by using daily consumption items and real market prices with the goal of creating a more realistic shopping simulation. All in all,this thesis study brings the fNIRS experimentation and consumer research together with the aim of providing insight into the neural basis of purchasing decisions.

CHAPTER 3

METHOD

The current study involves a decision making task in which the participants stated their purchasing preferences for a variety of products of daily use. During the task, prefrontal cortex activation was measured via the fNIRS method. At the beginning of the thesis research, a pilot study was conducted with the purpose of preliminary observation.

3.1 Pilot Study

The experimental design was similar to the one in the study by Knutson *et al*. (2007), but the main difference was the preference of fNIRS method instead of fMRI. The task was comprised of 78 trials where participants were asked to make purchasing preferences based on the suggested products and prices. In each block, the participants had 3 seconds for viewing a picture of the product, 4 seconds for viewing the price of the product and 4 seconds to respond according to their preference to purchase or not to purchase, followed by a fixation for 6 seconds.

Figure 6 Task design

Each block lasted for 20 seconds. The total duration of the experiment was 26 minutes (78 x 20 seconds). The products consisted of 3 main groups (food, cleaning and personal care products). There were 39 products in the food group (e.g. milk, cheese, Coke), 17 products in the cleaning group (e.g. detergents) and 22 products in the personal care group (e.g. deodorant, shampoo, toothpaste). The prices of the products were taken from local supermarkets around Ankara. 14 subjects participated in the study (7 females, 6 males). Exclusion criteria for participation were left handedness and having a history of psychiatric disorders.

The fNIRS Imager 1000 device used in the experiment had a sensor with 16 voxels which monitors prefrontal cortex activity through hairless scalp.

Figure 7 The main hardware box of the fNIRS Imager 1000 device

Figure 8 The scalp sensor of the fNIRS Imager 1000 device

The sensor was attached to the forehead of the participants in order to monitor frontal cortex activation.

Figure 9 fNIRS sensor pad attached to the participant

The fNIRS data was collected in 0.5 second intervals during the study. The task was shown to participants on a 17'' LCD monitor. Participant responses were recorded via a keyboard. SAN Suite software was used for task presentation and response collection. COBI Studio software was used for fNIRS data collection.

Figure 10 Experiment setup

fNIRSoft software was used to eliminate artifacts in the data and to calculate the oxygenation in the blood flow (Ayaz, 2010). A finite impulse filter was applied in order to eliminate heart pulsation artifacts and a sliding window motion artifact filter was applied to eliminate motion artifacts. The data collected during different parts of the task was tagged as “picture”, “price”, “decision” and “fixation”. By using the fixation data as a baseline activation level, the amount of oxygenation change in the neural tissue during the product, price and fixation periods were calculated. Two types of calculations were made for each period: the local oxygenation difference between the fixation part and each of the subsequent parts of the trial; and the global oxygenation difference between the average of all fixation periods and the subsequent parts of each block. Modified Beer Lambert Law (Chance *et al*., 1998) was applied for this calculation.

An independent t-test was conducted to investigate the difference of oxygenation between the products which the participants showed a positive or negative purchasing preference. Throughout the test results, Voxel 9 showed a significant activation in the local price and decision data, whereas Voxel 14 showed a significant activation in the global product, price and decision data. The localization of Voxel 9 corresponds to the medial prefrontal cortex which has previously shown to be activated during valuation of costs (Knutson *et al*., 2007). The localization of Voxel 14 corresponds to the DLPFC which is involved in executive functions and working memory. The activation levels observed in Voxels 9 and 14 were in line with the expectations of the pilot study which led to the main study of the thesis.

3.2 Main Study

The main study had two conditions. In the first condition, participants were not provided money for real purchasing of the products. In the second condition, the group of participants were given 40 TL. and were asked to make real purchasing decisions.

28 people participated in the first group. All of the participants were METU students between ages of 19 – 25 (10 females, 18 males). The participants were awarded 10 TL. for their participation in the study. Each participant filled out a consent form, a personal information form and a handedness inventory (Oldfield, 1971). To increase experiment engagement, the participants were told before the beginning of the experiment that they will receive one of the products which they had stated that they would prefer to purchase during the experiment as a prize.

E-Prime software was used for the presentation of the experiment due to its timing precision and randomization capabilities. Contrary to the product order in the pilot study, the products in the main study task were divided into 12 distinct product groups and although the order of the group presentation was the same for each participant, the order of products within each group was randomized to prevent any confounding factors which could emerge as a result of the product presentation order. The left – right localization of the purchasing preferences presented in the decision part of each block was also randomized to avoid lateralization biases.

At the end of the experiment, two surveys were given to the participants. The first survey asked the participants to rate their usage frequency of each product in their daily lives. The purpose of this survey was to measure the familiarity of the participant with the products.

<u>Lütfen aşağıda gördüğünüz ürünleri *kullanma sıklığınıza göre* tablonun ikinci satırındaki boşluklardan birine “x” işareti koyarak değerlendiriniz:</u>

1 (Hiç tüketmem)	2	3 (Orta sıklıkta tüketirim)	4	5 (Çok tüketirim)
		X		

Figure 11 Survey for product usage frequency

The second survey asked the participants their preferred prices for each product. The purpose of this survey was to measure the relative difference between our suggested prices and the expectation of the participants.

<u>Lütfen aşağıdaki ürünler için uygun gördüğünüz satış fiyatlarını ilgili boşluklara yazınız:</u>

Uygun Satış Fiyatı:

Figure 12 Survey for preferred prices

30 people participated in the second condition of the experiments. In addition to the 10 TL participation money, the participants were given 40 TL to use for purchasing. The task did not provide information about how much money the participants have spent during the experiment in order to avoid increased information load in the task. The participants were informed that in the case of excessive spending, a set of products valuing 40 TL among the purchased products would be randomly selected and given to the participants. After the exclusion of some of the data due to artifacts, data from 22 people (8 females, 14 males) were used in the statistical analysis.

CHAPTER 4

RESULTS

4.1 fNIRS Results

The aim of the fNIRS data collection was to measure the activations in the prefrontal cortex, particularly in the MPFC and in the DLPFC regions during the purchasing experiment. A significant difference between the positive and negative purchasing preferences was expected regarding the level of MPFC and DLPFC activations.

The experiment was conducted in two different conditions. In the first condition, the participants were not provided money to make real purchasing decisions. They were only asked to state whether they would prefer or would not prefer to buy each product for the given price. In the second condition the participants were given experiment money and were asked to purchase some of the products.

The fNIR data collected in the monetary condition were in line with the expected results of the experiment. However, the results of the non-monetary condition did not reveal the same significant effect of purchasing decisions on the prefrontal cortex regions. The statistical analysis and the findings regarding the fNIRS data are explained in detail in the rest of the section.

For the analysis of the fNIRS data, the mean values for each block were used for the repeated measures ANOVA test. The signal collected from some of the voxels violated the assumption of sphericity. In these cases, Greenhouse-Geisser correction was used to analyze the data.

The results of the experiments in the monetary condition showed significant activation in the prefrontal cortex depending on the choice of the participant. In particular, Voxels 1, 9 and 11 were found to be activated in relation to the decision making task.

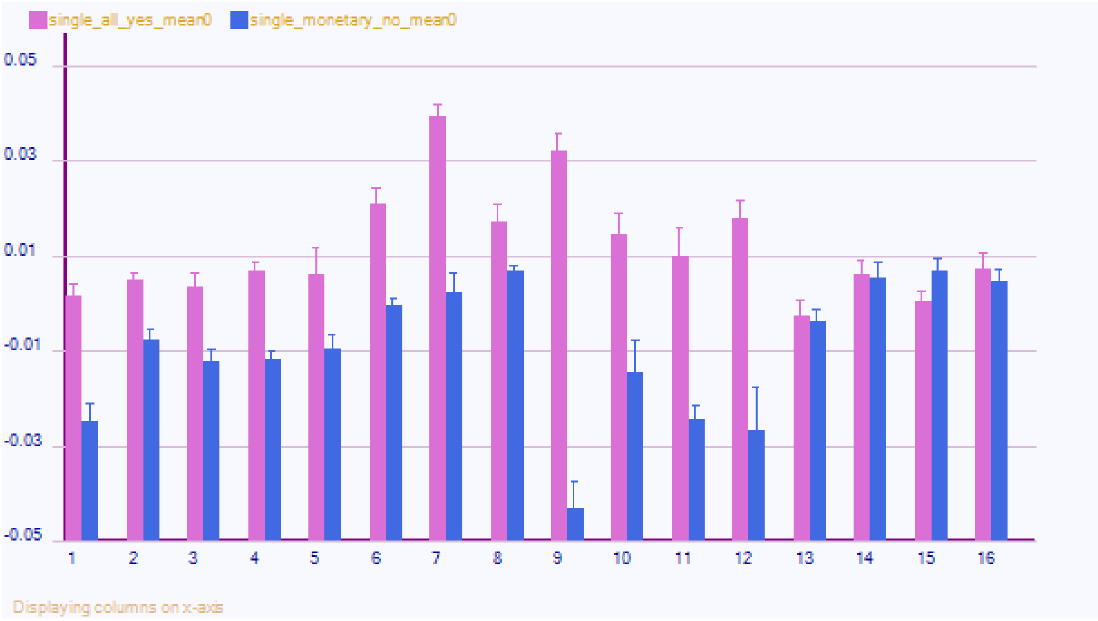

Figure 13 Mean oxygenation values in the prefrontal cortex for the purchased and not purchased products

In the monetary condition (N=22), Voxels 9 and 11, which correspond to the MPFC, showed significant activation in relation to decision type: Voxel 9, $F(1, 12) = 8{,}81$, $p < .05$ (Greenhouse-Geisser corrected); Voxel 11, $F(1, 16) = 5{,}94$, $p < .05$ (Greenhouse-Geisser corrected). There was also significant activation in the DLPFC in relation to decision type: Voxel 1, $F(1, 18) = 6{,}25$, $p < .05$ (Greenhouse-Geisser corrected).

In the non-monetary condition (N=23), the voxels corresponding to the MPFC did not show any significant activation in relation to the positive and negative purchasing preferences; Voxel 9, $F(1, 20) = .14$, $p > .05$, Voxel 11, $F(1, 21) = .05$, $p > .05$.

The voxels corresponding to the DLPFC also did not show any significant difference in activation in relation to purchasing preferences, Voxel 16, $F(1, 21) = .00$, $p > .05$.

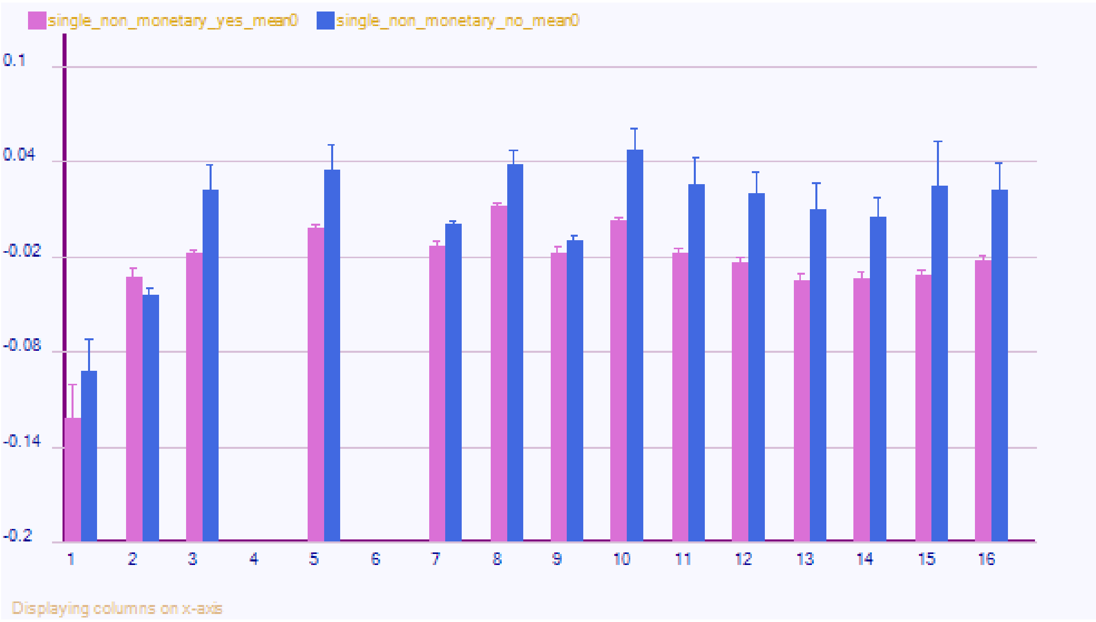

Figure 14 Mean oxygenation values in the prefrontal cortex for the purchased and not purchased products in the non-monetary condition.

The following plots compare the average oxygenation levels observed at Voxels 1, 9 and 11 during positive (YES) and negative (NO) decisions. Error bars indicate the standard error. The waveforms averaged over 22 subjects show a significant separation between oxygenation levels during the positive and negative decisions.

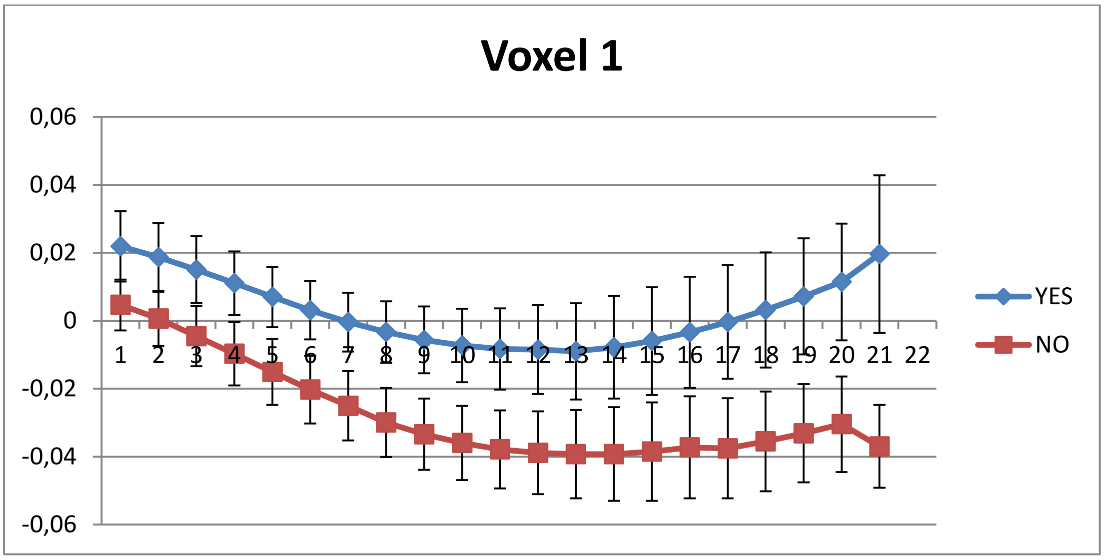

Figure 15 Mean values of oxygenation and standard error bars for Voxel 1 during positive and negative purchasing decisions in the monetary condition

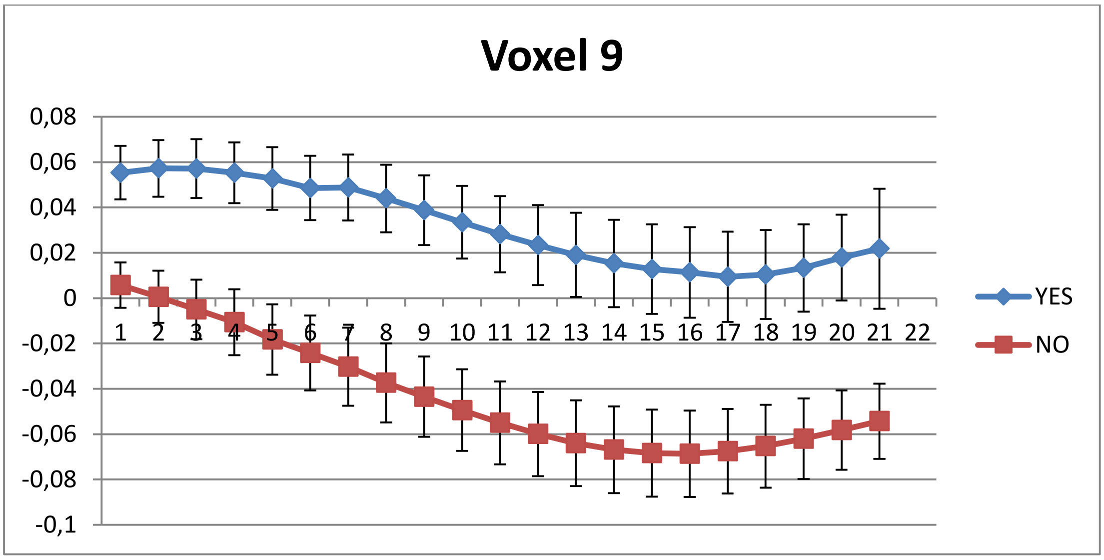

Figure 16 Mean values of oxygenation and standard error bars for Voxel 9 during positive and negative purchasing decisions in the monetary condition

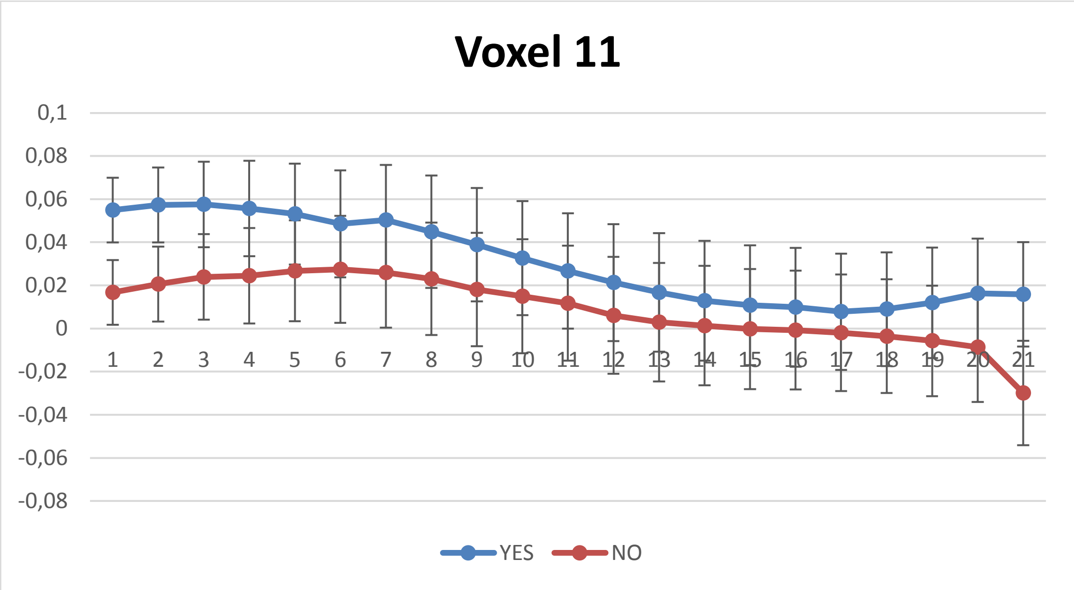

Figure 17 Mean values of oxygenation and standard error bars for Voxel 11 during positive and negative purchasing decisions in the monetary condition

On the other hand, the mean oxygenation values for the same voxels in the non-monetary condition did not show a significantly different waveform between the positive and negative purchasing decisions.

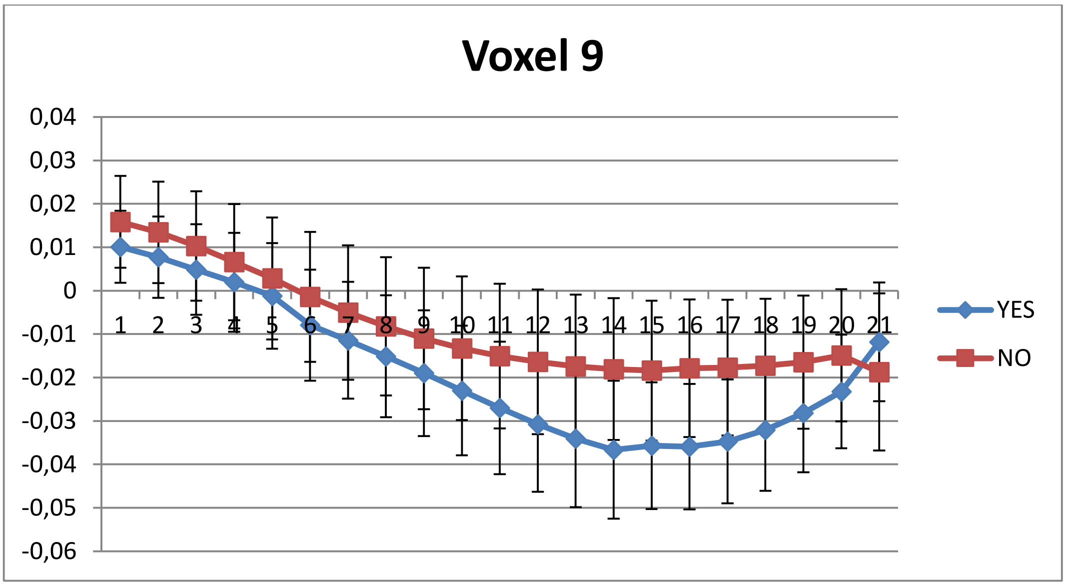

Figure 18 Mean values of oxygenation and standard error bars for Voxel 9 during positive and negative purchasing decisions in the non-monetary condition

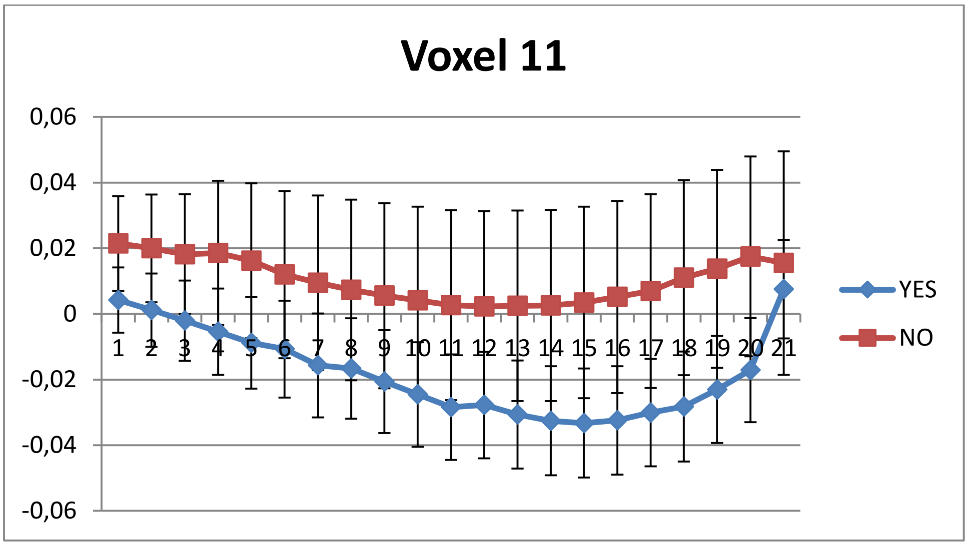

Figure 19 Mean values of oxygenation and standard error bars for Voxel 11 during positive and negative purchasing decisions in the non-monetary condition

Topographic maps for the prefrontal oxygenation were created via spatial registeration of fNIR data to prefrontal cortex image by using the method in Ayaz *et al.* (2006)

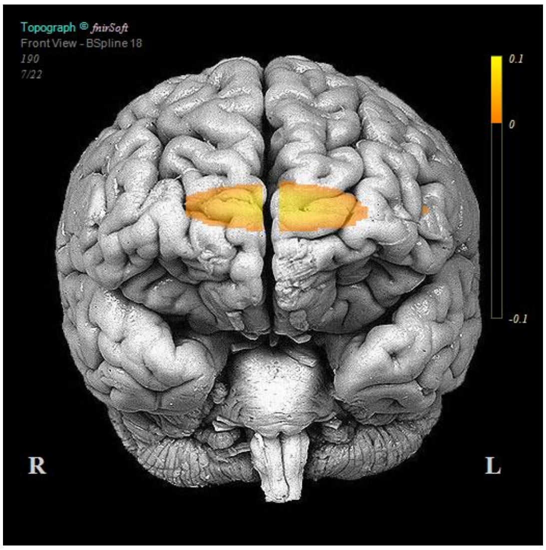

Figure 20 Topographic map of the average prefrontal cortex activation values related to positive purchasing decisions in the monetary condition

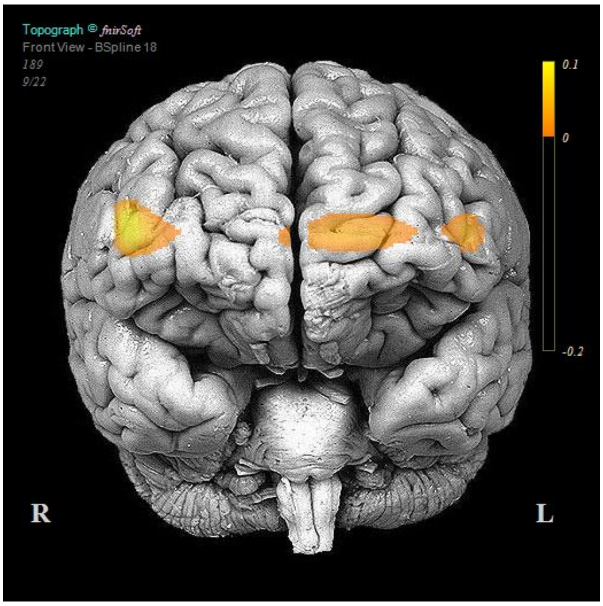

Figure 21 Topographic map of the average prefrontal cortex activation values related to negative purchasing decisions in the monetary condition

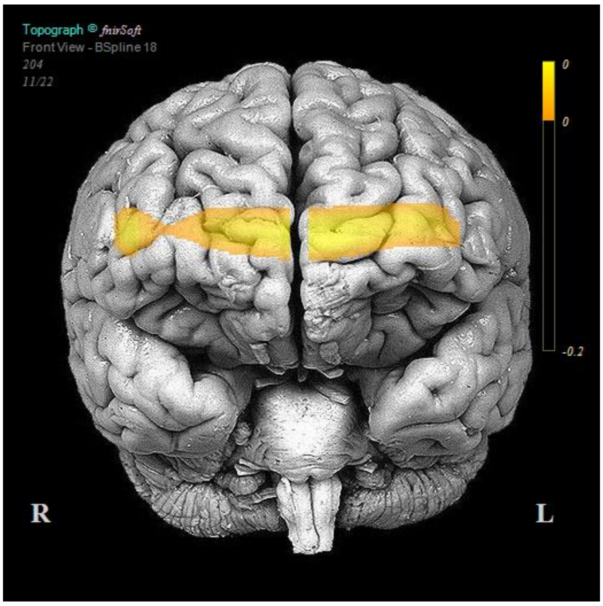

Figure 22 Topographic map of the average prefrontal cortex activation values related to positive purchasing decisions in the non-monetary condition

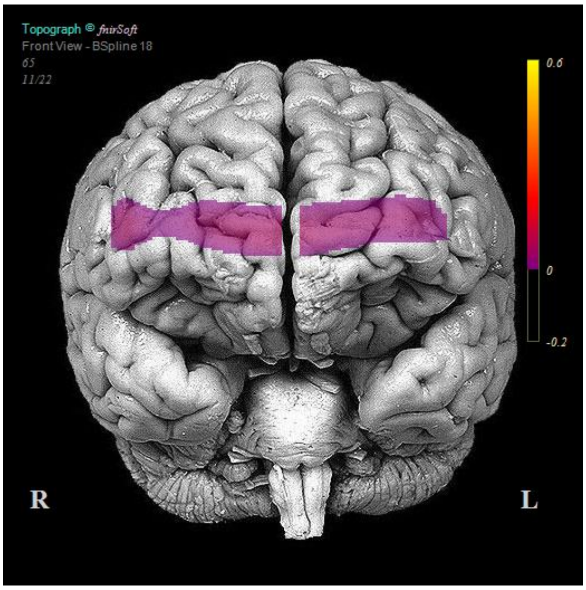

Figure 23 Topographic map of the average prefrontal cortex activation values related to positive purchasing decisions in the non-monetary condition

4.2 Behavioral Results

In the non-monetary condition, participants stated positive purchasing preferences for 33,4 products on average, (M = 33,4; SD = 9,12). Average reaction times were not significantly different between positive purchasing decisions (M = 1469; SD = 239) and negative purchasing decisions (M = 1442; SD = 223); t(22) = 0,97 , $p > .05$. Usage frequency of purchased versus non-purchased products were significantly different t(1770) = -22.45, $p < .05$.

The price differences between the proposed prices during the experiment and the preferred price by the participant for each product were calculated (Proposed price – Preferred price = Price difference). The price difference comparison between purchased and non-purchased products also showed a significant difference t(1768) = 12.71, $p < .05$.

In the monetary condition, participants chose to purchase 28 products on average (M = 28,13; SD = 11,40). Since the participants were not informed regarding how much they had spent during the experiment, most of the participants exceeded their 40 TL budget. The average amount of overspending of these participants (N=21) were 88 TL (M = 88,67; SD = 59,01).

77 out of 78 products were chosen to be purchased by at least one participant and the most purchased product was purchased by 19 participants (M = 7,93; SD = 3,97).

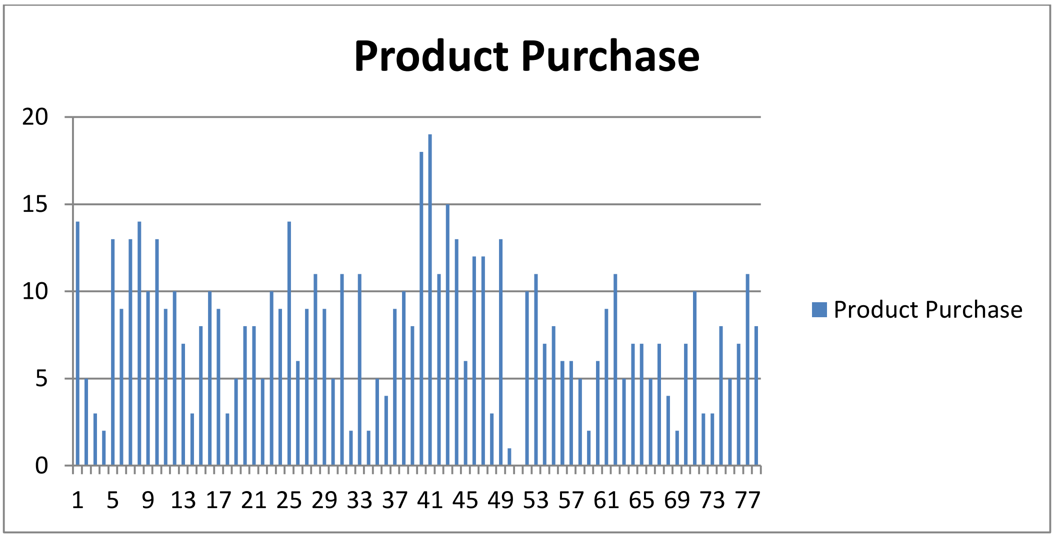

Figure 24 Number of purchasing decisions given by participants for each of the 78 products

In the monetary condition, average reaction times were significantly different between positive purchasing decisions (M = 1616; SD = 285) and negative purchasing decisions (M = 1540; SD = 271); t(21) = 3.05 , *p* < .05.

The average usage frequency of the purchased products (Mean = 3,03, SD = 1,36) were significantly higher than the daily usage frequency of the not purchased products (Mean = 1,68, SD = 1.06), t(1714) = 22.70, p < .05. The price difference comparison between purchased and non-purchased products were also significantly different, t(1714) = -7,28, p < .05.

CHAPTER 5

DISCUSSION

5.1 fNIRS Results

The main goal of this study was to investigate the neural correlates of purchasing decisions. To this end, a task of product preference was designed. The task was used in order to determine the negative or positive purchasing decisions of the participants. During the task, the neural activations of the participants were recorded via a 16-channel fNIRS device. Throughout the task, the participants were presented with 78 products with corresponding prices. For each product they were asked to make a choice whether to buy or not to buy that particular product. After each decision there was a 6 second rest period.

The activations of the MPFC were assessed in relation to participants' purchasing decisions. It was expected that the level of oxygenation would be sensitive to the willingness of the person to purchase the product. This expectation was based on the previous studies regarding the role of the MPFC in the evaluation of product alternatives and monetary options. The task used in the study was similar to the study of Paulus and Frank (2003) in the way that it involved the evaluation of products. Furthermore the participants tried to assess the products in terms of their attributes.

Some of the products in the task were food items. Previous studies have showed that MPFC showed activation while choosing between healthy and unhealthy food options (Hare *et al.*,2011). In that study the comparison of the food items was carried out based on the attribute of healthiness. Similarly, the current study presents many products which have common attributes that the participants had to compare in order to make selections within each product category.

The results of the study showed that the MPFC activation was closely related to participant decision on product purchasing only in the real purchasing condition. This shows that this region is especially sensitive to cost analysis. In particular, during the price block of the task, MPFC was activated in relation to the cost analysis regarding each option. This finding is congruent with the findings of Knutson et al.(2007) in regards to the role of MPFC in evaluating the monetary cost of products.

The second region of interest in the fNIRS data was the dorsolateral prefrontal cortex. DLPFC is known to be a region with an important role in decision making. Its activity has been found to be coupled to the activity of the MPFC (Deppe et al., 2005) and additionally it has been found that the activation of the DLPFC regulates the activation of the MPFC (McClure et al.,2004).The activity of the DLPFC in the current study was observed as concurrent with the MPFC activity. The change in DLPFC activation related with purchasing decisions only appeared in the real purchasing condition and was mostly present in the price block of the task. The similarity of the DLPFC activation and MPFC activation was in line with the findings in the literature.

Furthermore, DLPFC is a very important brain region for information storage and manipulation. It is known to play a major role in working memory functions (Jonides et al., 1996). In the current study, participants had to compare similar products and their prices. The process of comparison requires that the decision maker holds information regarding the attributes of the products and their respective prices in working memory to make decisions in the given time frame. This cognitive function of storing the product and price information in memory and manipulating that information in order to make a series of decisions requires an intensive use of

DLPFC. Moreover, the participants needed to compare their past memories regarding to their daily usage of the products in order to make informed decisions.

This process may also have an effect on DLPFC activation. As expected, DLPFC activation was related to participant responses. This may be due to the fact that the participants relied on DLPFC activity in order to gather and manipulate information both regarding to product attributes and costs and also their subjective experiences with the products in the past.

Another aspect of these neural findings is that they are closely related to the Somatic Marker Hypothesis which suggests that decisions are influenced by information previously stored in the body as biomarkers which may manifest themselves as feelings related to the options and their risks (Bechara et al., 2000 b). According to this view, the prefrontal cortex and particularly MPFC is where this information is analyzed and used to guide future decisions. Similarly, the current study showed that decision makers used MPFC activation to analyze the information they collected in the task and in their past experiences with the products.

Overall, the fNIRS results confirmed the role of prefrontal cortex as an important brain region in making decisions. In particular the MPFC activation is highly related to monetary cost analysis and product evaluation. Additionally the activity of DLPFC when the participants had to make costly decisions by analyzing a great amount of information in a short period of time was congruent with the well-known role of the DLPFC in information storage and manipulation. The relation between the activities of these two prefrontal cortex regions supports the view that the prefrontal cortex works as a network of subcomponents in order to carry out executive functions (Sanfey*et al.*, 2006).

5.2 Behavioral Results

In order to simulate a real purchasing experience, there were a few rival products with similar attributes for each target product in the same product category. Along each category, the products were not only similar in terms of their attributes, but they were also in the same price range. Additionally, the prices of the products were directly acquired from the grocery stores to ensure the similarity of the costs to daily purchasing settings.

During the task, the reaction times of the participants were recorded via the E-Prime presentation software. Participants stated their purchasing decisions by pressing one of the two designated keys on the keyboard during the decision block of the experimental task. After the price block, the decision block had two options presented on the screen to request a response from the participants. The locations of the options were randomly reversed for each product to avoid any spatial tendency of the participant. After the appearance of the options on the screen, the participants had 4 seconds to make a choice. The data for the reaction time of the participants showed that the duration of 4 seconds was a sufficient time to reach a decision for each product. Although it could be argued that the participants would start the decision making process as soon as they saw the price of the product on the screen, the difference between the reaction times of the positive and negative decisions suggest that they continued to the decision process even in the decision block of the task.

It is particularly interesting to see that this effect is absent in the first set of experiments which did not involve real purchasing decisions. It is possible that the presence of a real monetary cost caused a longer analysis of the balance between the cost of money and the benefit of that product. Since money is a finite resource, each purchase that a participant made meant that they were forgoing the future ability to use that resource. Since the participants did not know which products they would be presented in the subsequent portion of the task, each positive purchasing decision could have meant a missed chance of buying a favorite product in the later product categories.

It is also possible that there was a relation between the presence of monetary costs and the magnitude of cognitive load of the task. It has been shown that the increase in prefrontal cortex activation can be a result of an increase in cognitive load and this relation has been demonstrated via the fNIRS method (İzzetoglu et al., 2007). In a similar way, the introduction of monetary cost to this experimental task could have led to an increase in cognitive demand of the task by causing the participants to think their choices more thoroughly.

After the task, participants filled out two surveys which aim to collect information regarding the subjective value of each product to each participant. The first survey asked the participants how frequently they used these products in their daily lives. The second survey asked the participants how much they would be willing to pay for each product.

The goal of the first survey, which asked about the frequency of daily usage was to assess the familiarity of the participant to the product. This was important for two reasons: Firstly, the amount of previous memory of a consumer about a particular product heavily influences their future decisions for purchasing that product (Biehal & Chakravarti, 1983). Second, a participant's familiarity of a product signals a high subjective value that person holds for that product. It is very likely that a person who consistently prefers to use the same product among other alternatives signals a high subjective value for that product. In turn, this high subjective value was expected to influence the willingness of the participant to buy the product in the experiment. The results showed a significant relationship between the participants' level of familiarity of the products and their willingness to purchase the products in the experiment.

The behavioral results of the experiment was closely related to the framework of bounded rationality which suggests that agents use simple heuristics to make satisfactory decisions when they are in a complex environment with limited information and limited resources. In this experimental setting, the general motivation of the participants was to make sensible decisions among several purchasing options. The nature of the task presented the participants incomplete knowledge since there was no detailed information about the attributes of the products except the pictures of their packages. Furthermore, they had access to this visual information for a duration of just a few seconds which can be considered a quite short period of time if a consumer wants to base their decisions on visual cues. In that period of time they also had to retrieve information about their past experiences with the product and evaluate these experiences. They also needed to decide whether the proposed price was a good bargain for the product. Moreover, they had to compare all this information with the information they gathered for the other products in the same category to make an overall assessment of each option and they had just a few seconds to do all this information processing. The participants had a limited amount of money to use during the experiment, so they had to make an effort to make decisions which would yield a high benefit in terms of product satisfaction.

Overall, the experimental design created a setting of incomplete knowledge and finite resources. Consequently, it would be safe to assume that the participants relied on a few rules of thumb instead of complex decision making algorithms such as the ones proposed in the field of economics. Indeed, during the post-experiment interviews, the participants described their strategies in terms of a few simple yet selective rules. These strategies usually took the form of evaluating the products in a few attributes sequentially. For instance, a participant's strategy could be described such as: "If it is a product that I use frequently and the proposed price is not overly expensive, then buy it!". Or some of the participants relied on a few rules to dismiss the alternatives such as: "If it is not from a brand I already know, do not even assess the price and directly reject the offer". Or the decision could be based on purely monetary considerations such as: "Buy the product only if it is cheaper than its general market price". Theparticipants' self-assessment of their own choices after completing the experiment suggests that the evaluation process carried out by the decision makers in this experiment show a pattern similar to the heuristic rules proposed by the theory of bounded rationality.

5.3 Comparison with the Preceding Studies

An important study in the literature related to this thesis study was conducted by Knutson et al. (2007). By using fMRI, they investigated the neural structures underlying purchasing decisions. One of the main findings of that study was the involvement of the MPFC during price evaluation. The results of this thesis led to the same observations regarding the MPFC activation in purchasing decisions.

Specifically, the absence of MPFC activation during the condition without purchasing and the appearance of MPFC activation in the real purchasing condition further proved its role in cost evaluation during decision making. Even though the prices were comparably lower than the study of Knutson et al. (2007) , the MPFC activation was still significant in price evaluation blocks.

The second influential work for this thesis was conducted by Shimokawa et al., (2008) where they managed to detect product preferences by analyzing prefrontal cortex activations via fNIRS. The current study was similar in the way that participants were asked to evaluate product options. However, they were also given prices to evaluate during each purchasing decision and this added price evaluation processwas the main source of the neural activation observed in the results, since the MPFC is known to play a major role in cost analysis during decision making processes.

The current study was also similar to the study of Mitsuda et al. (2007) where they asked the participants to predict the prices of products while they measured activations in the prefrontal cortex. The additional factor considered in this thesis study is the purchasing decision related to each product. The participants not only try to estimate the price by relating to their knowledge and subjective evaluation of the product, but they also have to decide whether to spend their monetary resource for the acquisition of the product. The findings were consistent with Mitsuda et al. regarding the role of the prefrontal cortex during the evaluation of the products and estimation of the prices.

Following the aforementioned two fNIRS studies, the current study is an addition to the body of work investigating the role of prefrontal cortex activations in purchasing decisions. The ability of fNIRS to detect the signals in the cortical areas of the brain with high precision for the investigation of decision processes shows the utility of the method as a viable research tool with low costs and high mobility which can be used to test and validate the findings of conventional neuroimaging methods used in decision making experiments such as fMRI and to further explore the neural underpinnings of decision making.

5.4 Limitations of the Study

The study had a few limitations. First, the duration of the experiment can be considered to be long as a cognitive science experiment. The presentation of each of the 78 products lasted for 17 seconds, resulting in a total duration of 22 minutes. This pace of 17 seconds was necessary for the acquisition of the neural signal in a reliable manner. Like fMRI, fNIRS monitors hemodynamic changes in the blood which is an indirect measure of neural activity that reaches its peak activity and returns to baseline levels in the order of 8-10 seconds. The reasoning for the high number of 78 products was to gather sufficient data for the analysis and also to provide the participants with a diverse scale of products in various categories to imitate a realistic shopping experience. However these factors resulted a long duration for the task, resulting in exhaustion and habituation with some of the participants which can be a factor that may influence the data.

Second, despite the filtering functions of our data analysis software, there were artifacts and loss of data in the signal collected along the experiment. However this is a common occurrence in cognitive neuroscience research and can be overcome by increasing the number of the participants to compensate for the loss of data. The amount of data collected in the study was sufficient to test its main hypotheses.However, increasing the sample size would lead to a clearer separation among the fNIRS signals observed during purchasing decisions, which may ultimately lead to a predictive model that capitalize on the time course of activations observed at the implicated voxels.

Third, some participantsreported that they were not familiar with some of the products, which led them to make uninformed purchasing decisions in some cases. Furthermore, some of the participants were not informed about the real market prices of some of the products even though they were familiar with the products and have previous experiences in using them.

However the same situation can be present in real life purchasing experiences where consumers may have limited knowledge regarding the attributes or average prices of the products. This study was designed with the aim to mimic real shopping experiences so that this type of limiting factors of decision making is an inherent part of the experiment's nature.

5.5 Future Directions

Future work for this line of investigation can be pursued in a few directions. One of these can be a construction of a model which can successfully predict consumer behavior based on the collected neuroscientific and behavioral data. This has been achieved by Knutson et al. (2007) by bringing together the fMRI data, participant responses and surveys. A similar model with predictive power may be constructed by using fNIRS data which produces similar results to fMRI dataover cortical areas close to the scalp. This would lead to a powerful model which can produce reliable estimations of decision behavior from a comparably smaller amount of data collected from only 16 voxels and only from the prefrontal cortex region.

Another direction can be pursued by the integration of additional research tools such as Eye–Tracking or mouse movement tracking. These methods can aid the understanding of consumer decision processes provided by neuroscientific measures such as fNIRS in a realistic shopping experiment such as the one conducted in this study.

REFERENCES

Allais, M. (1953). Le comportement de l'hommerationneldevant le risque: Critique des postulatsetaxiomes de l'écoleAméricaine. Econometrica: Journal of the Econometric Society, 503-546.

Ayaz, H., Izzetoglu, M., Platek, S. M., Bunce, S., Izzetoglu, K., Pourrezaei, K., &Onaral, B. (2006, August). Registering fNIR data to brain surface image using MRI templates.In Engineering in Medicine and Biology Society, 2006.EMBS'06. 28th Annual International Conference of the IEEE (pp. 2671-2674). IEEE.

Ayaz, H. (2010). Functional Near Infrared Spectroscopy based Brain Computer Interface. PhD Thesis, School of Biomedical Engineering Science& Health Systems, Drexel University, Philadelphia.

Bechara, A., Tranel, D., & Damasio, H. (2000). Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. Brain: A journal of neurology, 123 (Pt 11) (11), 2189-2202.

Bechara, A., Damasio, H., &Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. Cerebral Cortex, 10(3), 295-307.

Biehal, G., &Chakravarti, D. (1983). Information accessibility as a moderator of consumer choice. Journal of Consumer Research, 1-14.

Bernoulli, D. (1954). Exposition of a new theory on the measurement of risk.Econometrica: Journal of the Econometric Society, 23-36.

Boorman, E. D., Behrens, T. E., Woolrich, M. W., &Rushworth, M. F. (2009). How green is the grass on the other side? Frontopolar cortex and the evidence in favor of alternative courses of action. Neuron, 62(5), 733-743.

Botvinick, M., Nystrom, L. E., Fissell, K., Carter, C. S., & Cohen, J. D. (1999). Conflict monitoring versus selection-for-action in anterior cingulate cortex. Nature, 402(6758), 179-181.

Bunce, S. C., Izzetoglu, M., Izzetoglu, K., Onaral, B., &Pourrezaei, K. (2006). Functional near-infrared spectroscopy. IEEE engineering in medicine and biology magazine : the Quarterly Magazine of the Engineering in Medicine & Biology Society, 25(4), 54–62.

Büchel, C., & Dolan, R. J. (2000). Classical fear conditioning in functional neuroimaging Early studies using PET. Current Opinion in Neurobiology, 10(2), 219-223.

Chib, V. S., Rangel, A., Shimojo, S., &O'Doherty, J. P. (2009).Evidence for a common representation of decision values for dissimilar goods in human ventromedial prefrontal cortex. The Journal of neuroscience, 29(39), 12315-12320.

Curtis, C. E., & D’esposito, M. (2004). The effects of prefrontal lesions on working memory performance and theory. Cognitive, Affective, & Behavioral Neuroscience, 4(4), 528-539.

Deppe, M., Schwindt, W., Kugel, H., Plassman, H., & Kenning, P. (2005). Nonlinear responses within the medial prefrontal cortex reveal when specific implicit information influences economic decision making. J. Neuroimaging 15, 171–182.

Edwards, W. (1954).The theory of decision making.Psychological bulletin, 51(4), 380.

Ellsberg, D. (1961). Risk, ambiguity, and the Savage axioms. The Quarterly Journal of Economics, 643-669.

Fasolo, B., McClelland, G. H., & Todd, P. M. (2007). Escaping the tyranny of choice: When fewer attributes make choice easier. Marketing Theory, 7(1), 13-26.

Fazio, R. H. (1990). The MODE model as an integrative framework. Advances in experimental social psychology, 23, 75-109.

Gigerenzer, G., & Selten, R. (2002).Rethinking rationality. Bounded rationality: The adaptive toolbox, 1-12.

Hare, T. A., Camerer, C. F., Knoepfle, D. T., O'Doherty, J. P., & Rangel, A. (2010).Value computations in ventral medial prefrontal cortex during charitable decision making incorporate input from regions involved in social cognition. The Journal of Neuroscience, 30(2), 583-590.

Hare, T. A., Malmaud, J., & Rangel, A. (2011). Focusing attention on the health aspects of foods changes value signals in vmPFC and improves dietary choice. The Journal of Neuroscience, 31(30), 11077-11087.

Huber, J., Payne, J. W., &Puto, C. (1982). Adding asymmetrically dominated alternatives: Violations of regularity and the similarity hypothesis. Journal of consumer research, 90-98.

Holper, L., Wolf, M., & Tobler, P. N. (2014). Comparison of functional near-infrared spectroscopy and electrodermal activity in assessing objective versus subjective risk during risky financial decisions. NeuroImage, 84, 833-842.

Irani, F., Platek, S. M., Bunce, S., Ruocco, A. C., & Chute, D. (2007). Functional near infrared spectroscopy (fNIRS): an emerging neuroimaging technology with important applications for the study of brain disorders. The Clinical neuropsychologist, 21(1), 9–37.

Izzetoglu, K., Bunce, S., Onaral, B., Pourrezaei, K., & Chance, B. (2004). Functional optical brain imaging using near-infrared during cognitive tasks. International Journal of Human Computer Interaction, 17(2), 211-227.

Izzetoglu, M., Bunce, S. C., Izzetoglu, K., Onaral, B., & Pourrezaei, K. (2007). Functional brain imaging using near-infrared technology. *IEEE Engineering in Medicine and Biology Magazine*, *26*(4), 38.

Jonides, J., Reuter-Lorenz, P., Smith, E.E., Awh, E., Barnes, L., Drain, M., Glass, J., Lauber, E., Patalano, A., Schumacher, E.H. (1996). Verbal and spatial working memory, In D. Medin (Ed.). The Psychology of Learning and Motivation, 43-88.

Kable, J. W., & Glimcher, P. W. (2007).The neural correlates of subjective value during intertemporal choice.Nature neuroscience, 10(12), 1625-1633.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. Econometrica: Journal of the Econometric Society, 263-291.

Kim, J. N., & Shadlen, M. N. (1999). Neural correlates of a decision in the dorsolateral prefrontal cortex of the macaque. Nature neuroscience, 2(2), 176-185.

Kumagai, M. (2012, August). Extraction of personal preferences implicitly using NIRS. In SICE Annual Conference (SICE), 2012 Proceedings of (pp. 1351-1353).IEEE.

Knutson, B., Fong, G. W., Adams, C. M., Varner, J. L., & Hommer, D. (2001). Dissociation of reward anticipation and outcome with event-related fMRI.NeuroReport, 12(17), 3683-7.

Knutson, B., Rick, S., Wimmer, G. E., Prelec, D., & Loewenstein, G. (2007). Neural predictors of purchases. Neuron, 53(1), 147–56.

Lane, R. D., Waldstein, S. R., Chesney, M. A., Jennings, J. R., Lovallo, W. R., Kozel, P. J. & Cameron, O. G. (2009). The rebirth of neuroscience in psychosomatic medicine, Part I: historical context, methods, and relevant basic science. Psychosomatic medicine, 71(2), 117-134.

Leff, D. R., Elwell, C. E., Orihuela-Espina, F., Atallah, L., Delpy, D. T., Darzi, A. W., & Yang, G. Z. (2008). Changes in prefrontal cortical behaviour depend upon familiarity on a bimanual co-ordination task: an fNIRS study. Neuroimage, 39(2), 805-813.

Levy, R., & Goldman-Rakic, P. S. (2000). Segregation of working memory functions within the dorsolateral prefrontal cortex. In Executive Control and the Frontal Lobe: Current Issues (pp. 23-32). Springer Berlin Heidelberg.

Levy, I., Snell, J., Nelson, A. J., Rustichini, A., & Glimcher, P. W. (2010). Neural representation of subjective value under risk and ambiguity. Journal of neurophysiology, 103(2), 1036-1047.

McClure, S. M., Li, J., Tomlin, D., Cypert, K. S., Montague, L. M., & Montague, P. R. (2004). Neural Correlates of Behavioral Preference for Culturally Familiar Drinks. Neuron, 44(2), 379-387.

Miller, E. K. (2000). The prefontral cortex and cognitive control. Nature reviews neuroscience, 1(1), 59-65.

Mitsuda, Y., Goto, K., Misawa, T., & Shimokawa, T. (2012). Prefrontal cortex activation during evaluation of product price: A NIRS study. Proceedings of the Asia Pacific Industrial Engineering & Management Systems Conference 2012, 1453–1459.

Moreau, C. P., Markman, A. B., & Lehmann, D. R. (2001). “What Is It?” Categorization Flexibility and Consumers' Responses to Really New Products. Journal of Consumer Research, 27(4), 489-498.

Moskowitz, H. (1974). Effects of Problem Representation and Feedback on Rational Behavior in Allais and Morlat-Type Problems. Decision Sciences, 5(2), 225-242.

Nakao, T., Matsumoto, T., Morita, M., Shimizu, D., Yoshimura, S., Northoff, G., ...& Yamawaki, S. (2013). The degree of early life stress predicts decreased medial prefrontal activations and the shift from internally to externally guided decision making: An exploratory NIRS study during resting state and self-oriented task. Name: Frontiers in Human Neuroscience, 7, 339.

Oldfield, R. (1971). The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia 9, 97-113.

Oliver, A. (2003). A quantitative and qualitative test of the Allais paradox using health outcomes. Journal of economic psychology, 24(1), 35-48.

Paulus, M. P., & Frank, L. R. (2003). Ventromedial prefrontal cortex activation is critical for preference judgments. NeuroReport, 14(10), 1311-1315.

Petrides, M. (2000). The role of the mid-dorsolateral prefrontal cortex in working memory. In Executive Control and the Frontal Lobe: Current Issues (pp. 44-54). Springer Berlin Heidelberg.

Pham, M. T., Cohen, J. B., Pracejus, J. W., & Hughes, G. D. (2001). Affect monitoring and the primacy of feelings in judgment. Journal of consumer research, 28(2), 167-188.

Plassmann, H., O'Doherty, J. P., & Rangel, A. (2010). Appetitive and aversive goal values are encoded in the medial orbitofrontal cortex at the time of decision making. The Journal of neuroscience, 30(32), 10799-10808.

Sanbonmatsu, D. M., & Fazio, R. H. (1990). The role of attitudes in memory-based decision making.Journal of Personality and social Psychology, 59(4), 614.

Seo, H., Barraclough, D. J., & Lee, D. (2007). Dynamic signals related to choices and outcomes in the dorsolateral prefrontal cortex. Cerebral Cortex,17(suppl 1), i110-i117.

Shimokawa, T., Misawa, T., & Suzuki, K. (2008). Neural representation of preference relationships. NeuroReport (Vol. 19, pp. 1557–1561).

Shimokawa, T., Suzuki, K., Misawa, T., & Miyagawa, K. (2009). Predictability of investment behavior from brain information measured by functional near-infrared spectroscopy: A bayesian neural network model. Neuroscience, 161(2), 347-358.

Simon, H. A. (1956). Rational choice and the structure of the environment. Psychological review, 63(2), 129.

Simonson, I. (1989). Choice based on reasons: The case of attraction and compromise effects. Journal of consumer research, 158-174.

Von Neumann, J., & Morgenstern, O. (2007). Theory of games and economic behavior (commemorative edition). Princeton university press.

Wallis, J. D., & Miller, E. K. (2003). Neuronal activity in primate dorsolateral and orbital prefrontal cortex during performance of a reward preference task. European Journal of Neuroscience, 18(7), 2069-2081.

APPENDICES

APPENDIX A

List of the Products and Proposed Prices Used in the Experiment

1,6 TL

1,49 TL

1,3 TL

1,15 TL

1,4 TL

1,6 TL

5,95 TL

8,45 TL

7,45 TL

9,95 TL

6,75 TL

11,45 TL

12,99 TL

11,25 TL

9,35 TL

10,45 TL

9,95 TL

2,1 TL

1,9 TL

2,1 TL

2 TL

2 TL

1,69 TL

6,5TL

9,9TL

6,95TL

8,9TL

15,25TL

6,75TL

7,90TL

6,90TL

11,9TL

9,75TL

2,45TL

2,70TL

3,25TL

2,75TL

2,75TL

1,95TL

1,5TL

1,5TL

1TL

1TL

2TL

2TL

3,9TL

3,5TL

6,4TL

11,9TL

10,5TL

11,9TL

7,95TL

7,9TL

4,5TL

1,35TL

1,35TL

11TL

5,25TL

7,9TL

5,9TL

7,9TL

8,9TL

8,9TL

1,75TL

1,8TL

1,94TL

2,95TL

9,75TL

12,25TL

1,6TL

1,35TL

1,6TL

APPENDIX B

Participant Information Form

KATILIMCI BİLGİ FORMU

İsim:

Yaş:

Cinsiyet: □Erkek □Kadın

Meslek:

Eğitim Durumu:

Sağ el / Sol el kullanımı: □Sol El □Sağ El

Tanısı konulmuş olan herhangi bir nörolojik/psikiyatrik rahatsızlığınız var mı veya psikiyatrik ilaç kullanıyor musunuz?

□ Evet □Hayır

Telefon:

E-posta adresi:

Tarih: ----/----/-----İmza: