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The Functional Magnetic Resonance Imaging and the Consumer Behaviour: Reviewing Recent Research

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***Abstract*—**In the first decade of the twenty-first century, advanced imaging techniques began to be applied for neuroscience research. The Functional Magnetic Resonance Imaging (fMRI) is one of the most important and most used research techniques for the investigation of emotions, because of its ease to observe the brain areas that oxygenate when performing certain tasks. In this research, we make a review about the main research carried out on the influence of the emotions in the decision-making process that is exposed by using the fMRI.

***Keywords*—**Decision making, emotions, fMRI.

I. The Relation between fMRI and Emotions

PRESENCE of emotions in the decision-making process is researched by one of the principal researchers, Knutson [22]-[25]. His research focuses on the neural basis of emotional experience and expression. The methods used in its investigations include self-report, the measurement of the non-verbal behavior, compared ethology, psychopharmacology, and the functional brain image. His long-term goal is to understand the neurochemical mechanisms and neuroanatomical responsible for the emotional experience and explore the implications of these findings for the evaluation and treatment of clinical disorders of the affection and addiction, as well as economic behavior. Since he published "Anticipation of increasing monetary reward Selectively Recruits Nucleus acumens" in 2001 [23], linking the activation of the nucleus acumens with future monetary reward, his research has been continued in this line, up to the current date. In 2007, [22] he predicted the purchasing decisions of a sample of individuals before they made it. According to this research there are three fundamental brain areas in the purchase decision, the nucleus acumens bilateral (NaCC); the isle bilateral and the mesial prefrontal cortex (MPFC).

Reference [14] studied the properties of reward cars as symbols of wealth and social dominance. The authors stress that various studies have related reward mechanisms with aspects of social relations as the dominance and the social rank.

The hypothesis that poses is that sports cars, in contrast with other categories such as the family SUVs or small cars, are large social reinforcements and modulate the dopaminergic reward circuit. In an experiment carried through, twelve men observed different photographs of cars and then made a process of classification for their attractive, while a fMRI was performed on them. In the results it was observed that the sports cars are qualified significantly better than the rest, and is also observed in this category a greater activation in the ventral striatum, in the orbitofrontal cortex, in the anterior cingulate and in the occipital regions. In this way it is noted that a cultural object associated with richness causes activation of the areas of the brain related to the reward.

Reference [12] investigated the activity in the prefrontal cortex (PFC), associated with the emotional assessment and subsequent memory, with experiments of fMRI. The participants in this experiment were shown a series of images that were supposed to be emotionally positive, negative or neutral, and after this exhibition it was tested to observe which parts were remembered by the subject and which were not. To measure the emotional assessment, the authors compared the brain activity that occurs in the rating process of each one of the images to which they were exposed, in relation to some base values. In addition, the encoding process carried out a task of comparing the remembered pictures with the ones forgotten (Dm effect). The effect of excitation [43] in these measures was observed by the increased activity of the positive and negative images than the neutral and the measurement of their value was done through the calculation of the differences in the activity between the positive and negative images.

In this article, several aspects can be highlighted. On the first place, the specific regions of the left dorsolateral cortex (PFC) were more triggered with the positive images than with the negative, while regions in the right ventrolateral cortex (PFC) showed the reverse pattern. In addition, the dorsomedial prefrontal cortex was sensitive to emotional arousal, while activity in this same area was sensitive to positive valuation, in accordance with the evidence that link these regions together, respectively, with emotional processing and self-awareness or the behavior of desire. Finally, the activity of coding (Dm) of left ventrolateral prefrontal cortex and in the dorsolateral prefrontal cortex was greater for images with excitement than for neutral photos. This finding suggests that the empowering effect of emotion in memory formation is due in part to an increase of memory job operations at a semantic and strategic level in the prefrontal cortex. These results underline the fundamental role of memory in emotional assessment.

In [29], the authors consider that soft drink such as Coca Cola and Pepsi have virtually the same chemical composition, but humans have preferences very strongly stated for one or the other. According to the authors, cultural messages are combined with content to shape our perceptions, even in

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relatively basic products such as sweetened beverages. In the performed experiment, the study subjects tested these drinks while fMRI was being done on them. They observed two aspects: the blind test of Coke and Pepsi and the same test but with knowledge of the brand. In the first task, it was obtained a neuronal response that was consistent in the ventromedial prefrontal cortex that is related to the behavior of preference. In consumption with the knowledge of the brands, this had a very important influence in the preferences of behavior and in brain response measures.

According to the authors, recent fMRI studies have identified brain responses related to reward, in regards to the degree in which subjects find stimuli to be pleasant or nice [2], [23]. With this information, one might be tempted to suggest that human beings choose more pleasant stimuli over the less pleasant stimuli for evaluation and comparison, and that for the two sugary drinks present in the study, the more pleasant beverage is the one that subjectively tastes better than its competitor. This perspective offers the simplest model that connects brain responses related to the reward with the behavioral preferences expressed. However, most of the real-world situations present numerous primary sensations and influences that act together to organize a consistent behavioral preference. Various studies have clearly demonstrated that cultural information is capable of modulating the reward related to brain response [14].

In [22], the authors investigate the essential neural mechanisms that are activated in purchasing behavior. They consider that according to the existing economic theory, consumers buy mainly based on two aspects: preference and price [6], [23]. The researchers conducted a fMRI to subjects participating in the study to observe how people weigh these factors to make purchasing decisions.

The experiment consists in the exposure to a series of trials in which the subjects purchased products. First they saw the product labeling, then the price, and then they chose if they wanted to buy the product or not by choosing "Yes" or "no", presented at random in the left or right side of the screen. The subjects needed to set a cross in one of the two options before the following test. The time for each trial period was minimized intentionally for reducing distractions and to maximize affective commitment. In these results, it can be seen that before making the purchase process different parts of the brain are already activated. With regards to preference, various oxygenations the nucleus acumens (NAcc) were done when they make a prediction of correct gain, while a trigger occurs in the medial prefrontal cortex before an error of prediction of gain [25]. Excessive prices activate the isle [34] and disable the medial prefrontal cortex. The activity in these regions was a reminder of a subsequent purchase process. This suggests that before making the purchase an activation process occurs in the brain of different areas related to affection (anticipating a product purchase).

Reference [9] explained that the expectation of reward and prediction errors are critical to the dynamic settings that humans do when it comes to decision making [7]. Currently there is little information about brain representation of those features, in spite of its importance. Some neuroscientists have suggested that the forecast reward errors are encoded in such structures like the cingulate and the ventral striatum, noting that such zones are activated when the reinforcement is higher than expected in a more intense way that when the reinforcement is lower than expected [1], [33], [48]. In this study, the neuronal behavior responses are displayed during a task of decision making through a computer model and it is noted that there are individual differences in the learning process of the parameter models, which are essential to shed light on the decision-making process. In the fMRI experiment done by the author, the subject must choose between rewards with high risk and then with reduced risk, observing the prediction errors and the values obtained for each individual in each attempt. The results show a strong activity in each task in the different limbic regions as well as the prefrontal cortex, of great importance in the individual differences of each subject, according to their difference with the rest of the subjects in the learning process. These findings suggest that the brain performs a learning process by reinforcement in decision-making (in this case with an aspect of added risk) and that individual differences play a crucial role in the process.

II. Studying the Brain Regions

Reference [42] proposed a framework to investigate different aspects of the neurobiology of decision-making. They unify different discoveries in the field, highlighting some lines of potential research in the future, defining a common vocabulary that can be used in this aspect of the neuroscience, and point the way for future applications that could be developed. According to the authors, the decision-making process has three components: firstly, the calculation in five phases (see Fig. 1), secondly, the valuation systems, and thirdly, the modulation of variables that affect the processes in different ways.

The process of decision-making based assessment can be divided into five basic processes: In the first place, the construction of a representation of the decision problem, which involves the internal and external identification of the different states, as well as possible types of action; secondly, the valuation of the different actions into consideration; thirdly, the selection of one of the actions based on their assessments; in fourth place, after the decision is made, the brain needs to measure the desirability of results; and, finally, evaluation of results, which is used to update other processes and improve the quality of future decisions.

The authors stress that valuation systems based on objectives contribute, for example, to choose between small immediate monetary payments or larger ones in the future [20], [29].

In [51], it is emphasized that the fMRI in humans has shown that the changes in the level of oxygen in the medial orbitofrontal cortex and in the dorsolateral prefrontal cortex are related to the objectives of the appetite, and people with damage in the medial orbitofrontal cortex have problems in making consistent decisions when presented to options of appetite [51]. This fMRI study showed that a striated

orbitofrontal cortex encodes a value signal at the time of the choice based on objectives, which is consistent with the properties of the PT (prospect theory). In addition, the study presents evidence that suggests that both appetite and the aversive aspects of decisions based on objectives can be encoded in a network of common valuation. They also pointed out that other fMRI studies show that the human isle encodes the risk prediction errors which could be used to learn about the risk involved different options, and these are complementary to forecast reward errors [41].

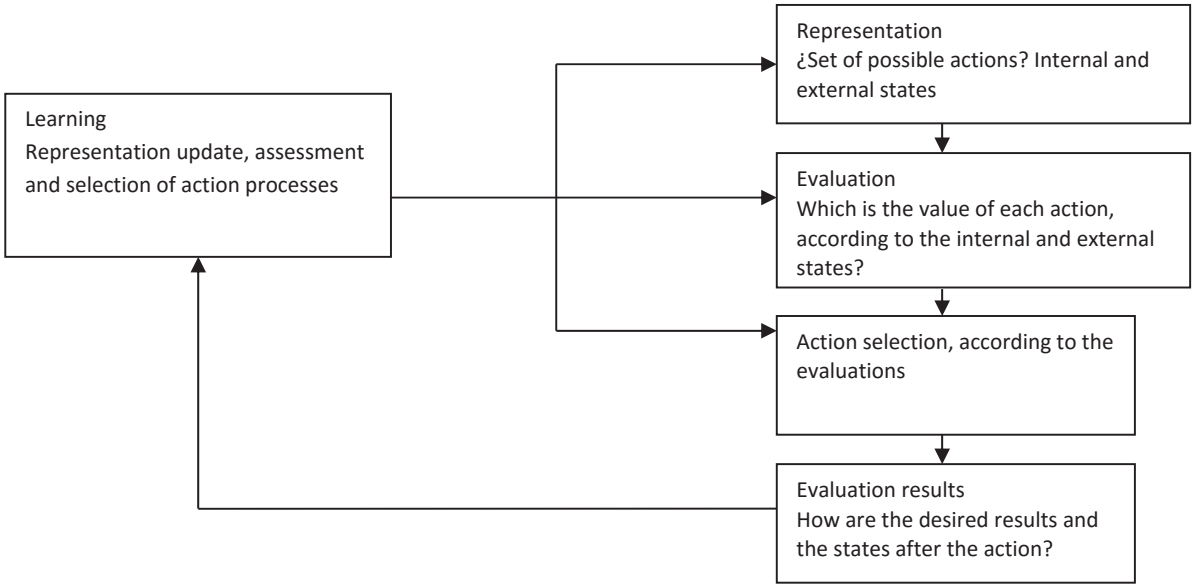

Fig. 1 Basic calculations present in decision-making [42]

Reference [35] investigated how the brain uses success and failure to optimize future decisions, an issue many times raised in the neuroscience.

One of the solutions implies the update of values of the associations of different actions carried out in various contexts and their relationship with forecast reward errors [35]. The previous evidence suggests that these calculations are expressed in the striated and represent a mechanism of unconscious learning. In this article, the authors tested this hypothesis through the study of behavior in a situation where the participating subjects were exposed to a series of stimuli in the form of context tracks, but that are not perceived consciously. The Functional Neuroimaging study revealed that during the conditioning process and prediction errors, generated from a calculation model, both tasks were related with the activity in the ventral striatum. The authors came to the conclusion that even without conscious processing of contextual signals; our brain can learn the value of reward and uses it to provide itself a guide in the decision-making process.

Reference [50] considered that there is evidence in neuroscience that the brain processes negative visual stimuli in a different manner than the positive [22], [36]. This article investigates whether it is possible to transfer these results to a specific stimulus, the packaging. For this, they measured the brain activity of subjects while they had to make decisions on the attractiveness of some packaging. According to the expected hypothesis after various studies, they have found that attractive and non-attractive packaging activate different cortical areas [2], [46]. The contrast of attractive and not attractive packaging revealed significant changes in the cortical activity of the areas of the visual occipital lobe and the precuneus, regions associated with the processing of visual stimuli and attention. In addition, the authors found significant changes in the activity within the rewards processing regions. In the task of contrast of attractive and non-attractive packaging, they found a greater activity in the areas of the frontal part of the cortex and the Isle, regions often associated with the processing of aversive stimuli such as unfair offers or nasty images. These findings may explain why attractive packaging gets more attention at the point of sale which positively influences the consumption in volume of sales of these products [32].

Reference [21] considered that the judgment that human beings make on aesthetics depend to a large extent of the place and the context in which they are observed [27], [44]. If the judgment on an item is performed while it is located in an art gallery, we will modulate the aesthetic value and assign it a higher valuation weight due to its location.

In the present study carried out by the authors using fMRI [19], the participants are exposed to a series of images of works of art. In addition, they are informed in a random way that this work of art belongs to a gallery or has been generated by the computer. The ratings given by the participants on the aesthetic quality of the images were significantly higher on the works that they believed were in an art gallery that on those who believed were generated by the computer. Thus they noted that this modulation was related to the medial orbitofrontal cortex and the prefrontal cortex [19]. While the context, regardless of aesthetic value, is related with the bilateral entorhinal cortex. The results show that the aesthetic

judgment that individuals make, are made by the prefrontal cortex and the orbitofrontal, which are significantly influenced by the subject's expectations of its probable hedonic value.

Reference [8] stresses that they have conducted diverse investigations about the neuronal structure of the representation of the value of the different options in the human brain, when it comes to choosing between goods that represent an economic outlay [5], [23], [31], [33], [42]. In the present article, the research focuses over if there is an area of the brain that encodes the values of the different options, or if these are represented in different regions of the brain. To do this, they did a fMRI to different subjects while running a process of purchase of goods (food, non-food consumer products and monetary scenarios). In the results they observed that there is activity on an area of the ventromedial prefrontal cortex [30], [42] which the authors believe that this is evidence that the brain encodes the options with a "common currency" that allows a shared assessment, even for different categories of products.

Reference [11] exposed that a key aspect of the current research focuses on how the human brain calculates value. Traditionally, the concept of value had a perception of an absolute measure, but different investigations suggest that value is calculated more often as a change in relation to a reference point, not in isolation form. In this article, the authors present the results of a study designed to decouple the regions of the brain involved in the calculations of separate reference value, and those which are a point of reference. During the fMRI, the subjects participating in the study acted as buyers and sellers during an exchange of lottery tickets. The hypothesis was that the subjects give a greater value to the objects of their property in relation to those that are not theirs, an effect that results from a change of reference point. The results of the experiment showed that the activity in the orbitofrontal cortex and the dorsal striatum were activated in relation to the expected value of the lottery tickets, which indicates the calculation process of independent reference value [4], [13], [32]. In contrast, activity in the ventral striatum occurred in relation to the process in which prices had distorted with respect to a reference point. The results expose the neurobiological underpinnings of the reference unit during the actual calculations of market value.

III. Developing the Technique

Reference [3] considered that there are two main reasons for the significant development occurred in the implementation of neuroimaging techniques in marketing. On the first place, the hope that neuroimages could become less expensive and quicker in the future that other methods of marketing, which they actually believe that it is unlikely to occur, and secondly, the hope that the neuromarketing offers marketing professionals information that is not obtainable through conventional methods. In this regard, there is evidence that this can be achieved in the future. They also suggest that measures such as the willingness to pay (willingness to pay, WTP) have recently been the subject of study through fMRI. In a purchase experiment, they allowed the participants to eat snacks during the process. The result was that the amount that they were willing to pay (a measure of usefulness of decision) was related to the levels of activity in the medial orbitofrontal cortex (OFC) and the prefrontal cortex (PFC) [16], [36]. Curiously, there has been a similar activation in the OFC when subjects anticipate a pleasant taste [32], see beautiful faces [2], listen to pleasant music [56], receive money [23], [33], and also when they experience a social reward [18]. This ratio, usually close, in the regional cerebral activity between the anticipation of a reward for an event, the consumption of pleasant goods and the willingness to pay for them, suggests that the representation of expected utility may depend in part, of the systems that evaluate the quality of consumption experience. The authors propose two different places where one could apply the fMRI in the product development cycle (Fig. 2).

Reference [47] considered that the search for food or a romantic partner are behaviors that we have as animals to ensure our survival. This would indicate that to process different types of rewards, the brain regions can be shared by many species [32], [36]. These rewards would be related with this type of tasks present in great variety of living beings. In contrast there has arisen many new areas of the brain in the course of evolution, and also possible tasks that help ensure the survival of human beings and that formerly did not exist, for example, those related to get enough money to be able to purchase goods in order to subsist. This suggests the specialization potential of the specific regions of the brain in the processing of recent awards, as the money [26]. In this article, the authors conducted an experiment using fMRI in humans, and identified common and distinct brain systems that are used to process the value of erotic stimuli and monetary gains, two stimuli that are considered as brain structures related to survival tasks present in many animals, and another related to brain structures that are relatively new and present in humans. First, they noted that a set of nervous structures, including the ventral striatum, the anterior isle, the anterior cingulate cortex and the midbrain, encoded the subjective value of the rewards without taking into account its type, in accordance with a general hedonic representation. The results also reveal specific reward representations in the orbitofrontal cortex (OFC): while the anterior lateral orbitofrontal cortex, a phylogenetically recent structure, processes monetary gains, the orbitofrontal cortex back side, Phylogenetic and genetically older, process the most basic erotic stimuli. This dissociation suggests an increasing trend in complexity as the representations are more abstract. The results presented in this article support the modular vision of the codification of reward value in the brain. In this article the authors compared the brain responses to two awards: money and erotic pictures. These two awards present important evolutive differences, likely to be reflected in brain level. While money is a secondary reward that recently appeared in human history and whose abstract value has to be learned by association with primary reinforcements, erotic stimuli can be considered as primary rewards, as they have an innate value and meet biological requirements. Therefore, they pose the

hypothesis that monetary gains would trigger the regions mentioned above of the OFC and the erotic images, the posterior regions.

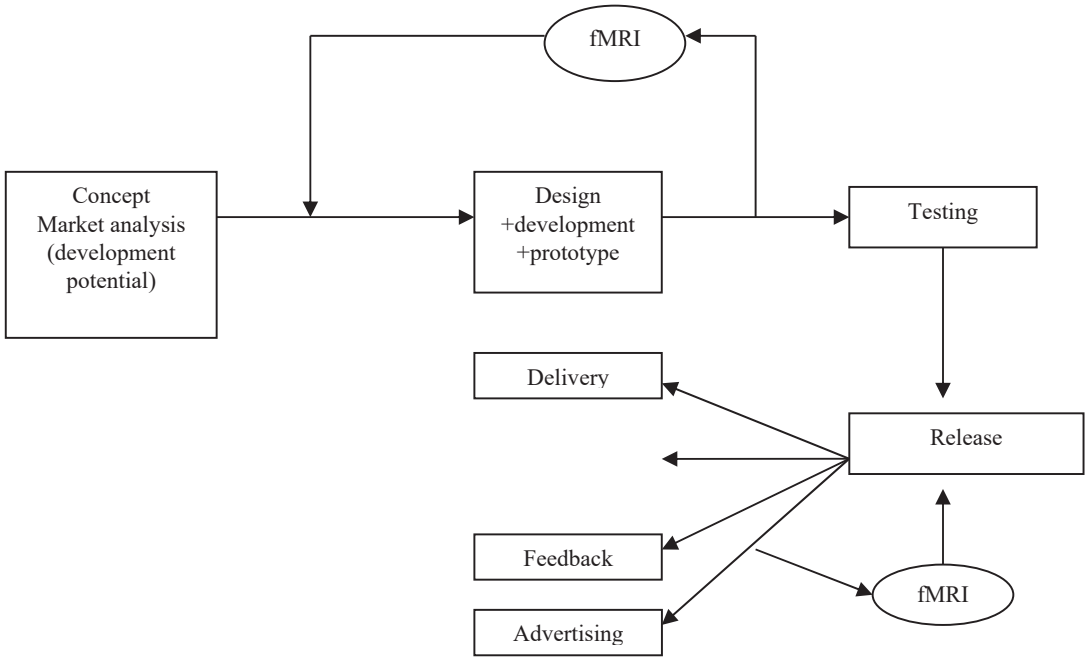

Fig. 2 Product Development Cycle. Applications of fMRI in Neuromarketing. It can potentially enter the product development cycle in two places. In the first it can be used as part of the design process itself. Here the neural responses could be used to refine the product before it is launched. In the second it can be used after the product is fully designed, usually to measure responses of the nervous system in the release of a possible advertising campaign to increase sales [3]

Reference [17] think that when it comes to human behavior at the level of neuroscience and neuroeconomy, individuals make decisions by assigning values to various options [30], [42], [55].

In the present article, they conducted their research, by using fMRI on neuronal networks to calculate the value in human decisions, in particular, at the time of making donations to various charitable entities. The results of the experiment showed that blood oxygenation the ventromedial prefrontal cortex (VMPFC) is related to the subjective value of voluntary donations, suggesting that it could be an assessment system during the decision-making process. In addition, the analysis of functional connectivity indicated that the value of the signal in the ventromedial prefrontal cortex could integrate also processes in the anterior isle and the temporal cortex posterior superior, believed to be involved in social cognition [49].

According to [52], the automatic responses of the brain are involved in evaluation of various commercial options, even though those judgments are not part of the main task to be carried out [33]. The authors researched the influence of product exhibition in the decision-making process of purchase. For this, they made a presentation of articles (cars) to two groups. The first was instructed to pay attention to the information of the different products to take a decision. The second group also got the product presentation but they are purposely distracted, trying to make them pay attention to another completely different stimulus. After this task, each participant is asked to communicate its willingness to buy each of the products. All this while fMRI is done on them. Both in the group of greatest attention as in the minimum, the researchers were able to observe patterns of activation on the isle and in the medial prefrontal cortex. In the results it can be observed that there is no difference in the purchasing decisions of products with great attention and those who got a low attention span. This suggests that the processes of evaluation of the various products do not depend on the attention given to them, highlighting the importance in this task of the implicit and automatic brain processes.

Reference [45] studied that an abstract stimulus can arouse reactions similar to the rewards that are obtained with tangible products. According to the same, the key would be in the feelings of euphoria and anxiety that are aroused, producing brain reactions involving the striated dopaminergic system. The authors carried out various experiments and found endogenous dopamine release in the striatum due to the emotional arousal produced by the music. They also conducted a fMRI study with the same stimuli on the participants, and found that the caudate nucleus is activated more during the anticipation and the nucleus acumens was more involved in the peak experience of emotional responses to music. These results indicate that an intense pleasure in response to music can lead to the release of dopamine in the striatal system. In particular, the anticipation of an abstract reward may result in the release of dopamine in a different anatomical way than the one associated with the peak of

pleasure in it. The results help to explain why music is such a high value in all human societies.

Reference [28] considered that the decision-making process has been generally considered as if it had two phases, the first in which values are assigned to the various options, and another in which it is chosen the option that has the highest relative value of the previous [15]. In previous studies there has been evidence that these subjective values are in the striatum and the medial prefrontal cortex (MPFC). There is also evidence that the activation in these areas represent reward values, even if it is not required to choose, such as in classical conditioning task [24], [32]. The present article investigates, using fMRI, whether if the same neural mechanism is involved in both cases.

Reference [22] observed in a fMRI the activation of the striated area during the process of presentation of products to different subjects and the medial prefrontal cortex during the discovery process of price, which predicted the corresponding decision to purchase or not.

The procedure was performed while subjects watched passively different consumer goods. Once observed the activation of each one of the objects, they were required to choose which one to buy, already outside of the scanner. In the results they observed that the activation of the striated and the medial prefrontal cortex in the processes that didn't require an election, they could predict the possible choices that would make each subject, suggesting that these areas of the brain represent the value.

Reference [40] indicated that the evaluation of the different outcomes is defined by the expected value and by the weight of the decision of each option during the period of decision-making. Various fMRI research studies in humans have studied very simple choices and have found that the neuronal activity in the medial orbitofrontal cortex and in the ventromedial prefrontal cortex is correlated with measures of consumer behavior and its values in the decisions for a range of different products [8], [16], [36], [53].

The authors also considered that other fMRI studies have contributed important discoveries, such as how the orbitofrontal cortex is related with the appetite for food and with the aversion to it [37], that the activity in the medial orbitofrontal cortex in response to a smell depends on whether the subjects considered that the smell of cheddar cheese or body odor were the same or not [10], the perception of price in the tasting of wine [38], existing partnerships with the brand on the consumption of soda [29], or in the consideration of whether a work of art has been created by an expert or by a rookie [21]. All these findings suggest that the evaluation result system is influenced by cognitive processes that determine the expectations and beliefs, a phenomenon also called "placebo effect of marketing" [54] or "expectation bias" [39].

IV. Conclusion

fMRI has become a very important technique to investigate the relationship between emotions and decision making. Since 2001, lots of authors have used it for several experiments all around the world, and the increase of research papers in different journals using the fMRI has been excellent.

There are many other techniques that are frequently found in research about emotions and decision making, such as eye tracking, which consists in measuring eye gaze patterns, the process of analyzing the facial expressions, biometrics or body signal measures about perspiration, respiration, heart rate, electromyography (EMG), facial muscle movement, or electroencephalography (EEG), that can measure brain electrical activity. Despite this wide range of different possibilities, the fMRI is nowadays the most popular one, and many of the most relevant researchers agree with the idea that it is the technique that gets closer to real brain working activity.

The connection between the different stimulus received by the brain and the consumer´s answer is really hard to explain because there are multiple different attributes that must be under consideration.

The widespread use of advanced techniques that combine traditional methods, and others based on technological innovations, has managed to bring researchers to achieve more appropriate and accurate results when it comes to the task of anticipating the outcome of decision-making consumer purchases.

V. References

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