Modern Transformations of Economics: Neuroeconomics

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SUMMARY

Traditionally, economists have not been interested in the neural underpinnings of human behavior. According to the classical decision-making theory, a decision-maker is a perfectly rational cognitive agent ignoring the influence of emotions. However, in recent years this model has been challenged by prospect theory, which identifies heuristics and biases that influence human choice. A recent approach known as neuroeconomics is a transdisciplinary field that tries to shed light on the computational and neurobiological mechanisms underlying the decision-making process, integrating ideas and methods from the fields of psychology, neuroscience, economics and computer science. Neuroeconomics gives researchers an opportunity to look into the "black box" of the human brain, which will give an opportunity to investigate how people make choices, how the brain calculates gains and losses, the roles of emotions and cognition, etc. The aim of this paper is to survey findings from the neuroeconomic literature and investigate the implications of this knowledge for understanding human behavior in various contexts.

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INTRODUCTION

The central concept of neoclassical economic theory is that economic man is a rational decision-making entity who is seeking to maximize his/her own well-being by making consistent choices. Traditionally, economists have not been interested in the neural underpinnings of human choice. They treated human brain as a "black box", believing that details about brain functioning would never be known. Before imaging technology it was impossible to measure subjective feelings directly and economists preferred indirect methods. In his *The Theory of Political Economy* William Jevons wrote: "Far be it from me to say that we ever shall have the means of measuring directly the feelings of the human heart. It is from the quantitative effects of the feelings that we must estimate their comparative amounts" (Jevons 1871, pp. 13, 14).

Since the second half of the 20th century the concepts and methods of psychology have been widely used in economics, since there was an increase in interest in the topic of how people make decisions and what regions of human brain are responsible for the decision-making process. Thus, an idea that there are various factors affecting decisions that are typical for the human nervous system gained huge importance.

In 1990s neuroscientists proved Jevons' fallacy and announced that the investigation of nervous system gave an opportunity to measure human mind and feelings. In turn, these measurements help to understand collaboration between mind and actions and to develop new economic theories. Cognitive neuroscientists, physiologists and psychologists looked towards economic theory as a tool to design new models of choice. As a result, neuroeconomics was born, integrating economics, psychology, neuroscience, behavioral economics, biology, computer science, and mathematics.

NEUROECONOMICS STUDIES

The economics of choice can be broken down into two primary branches, and research in neuroeconomics has a similar split (Zak 2004). The first is solitary choice. Solitary choices are made by individuals without the influence of others. Such problems are mathematically designed as if to maximize an individual "utility function" that is subject to a set of constraints (e.g. an income–expenditure constraint, a time constraint, etc.). Over 300 years ago Daniel Bernoulli puzzled over the idea of "utility function", which is the most fundamental notion in economics. The solitary constrained utility maximization model predicts an individual's behavior in impersonal exchange well, but fails to describe decision-making under risk and uncertainty. Prospect theory proposed a behavioral model of rational choice proving that there were various heuristics biasing rational behavior.

The second branch of neuroeconomic research is strategic choice. Strategic choices are made by interacting subjects, and problems of this kind are mathematically designed using game theory. A game-theoretic model of choice describes people's behavior in the game that can be affected by the information each has or can obtain, by the actions of each player and the outcomes of each strategy. This model is more complex than the solitary utility maximization model and its predictive record is more mixed.

Research topics studied by neuroeconomists are:

(i) identifying the neural processes involved in decisions in which standard economic models predict behavior well;

(ii) understanding "anomalies" where the standard models fail (Zak 2004).

The ultimate goal of neuroeconomics is to reveal the neurobiological mechanisms of the decision-making process for better understanding human behavior in various contexts.

Neuroeconomics makes a huge contribution to human behavior research, providing evidence about neural mechanisms underlying choice behavior and examining factors biasing rational choice, supporting variables, heuristics and biases introduced in behavioral economics, and proposing "new" variables ignored or missing in rational choice theory.

In summary, economics studies human behavior and decision-making – both individual and collective – without studying the processes behind the behavior. Neuroscience, on the other hand, applies a huge arsenal of measurement techniques characterizing various types of behaviors. The expected benefits of neuroeconomics for economics are very high. Neuroeconomics research will allow economists to understand neural substrates of human behavior and answer fundamental questions they are unable to address now, such as: How does the individual make a choice and how is the decision utility calculated? How is the choice affected by emotions? Why do the stated preferences differ from the behavioral ones? Why does the same individual make different choices under the same conditions?

RESEARCH TOOLS OF NEUROECONOMICS

Neuroscientists use a variety of measurement techniques to measure the neural activity of different brain regions, including PET (positron emission topography), fMRI (functional magnetic resonance imaging), EEG/ERP (electroencephalogram/event related potentials), TMS (transcranial magnetic stimulation), single neuron measurement, experiments with humans with brain damage, psychophysical measurement (skin conductance, eye tracking and blood draws) (Zak 2004; Camerer et al. 2005).

PET imaging was first performed on humans in the early 1970s. Experimental subjects are injected with a radioactive isotope that emits positrons (positively charged electrons). Subjects then lie in a ring of crystal detectors and a camera that captures radioactive decay (when a positron meets an electron they annihilate each other and emit gamma rays). When neurons fire they deplete glucose and oxygen and require increased blood flow to resupply these substances. Blood flows to neurons roughly proportionally to their firing rates. PET measures the accumulation of the radioactive tracer in brain regions; regions metabolizing glucose faster receive more blood flow and emit more gamma rays.

fMRI was first used on humans in 1992. fMRI exams the amount of oxygenated to deoxygenated blood. Neural firing increases the demand for oxygenated blood (oxyhaemoglobin). Because deoxyhaemoglobin is paramagnetic, it produces a measurably larger signal relative to oxyhaemoglobin when perturbed by a short radio-frequency pulse. These differences are small and can be measured only in a very powerful magnet (currently fMRI scanners used for humans have magnets from 1 to 8 Tesla; a 1 T magnet is 20,000 times stronger than the magnetic field on the Earth's surface).

A new methodology for the measurement of the neural substrates of human social interaction is "hyperscanning". Hyperscanning allows two or more subjects in fMRI scanners in different locations to interact with each other (through the internet). This allows researchers to see the influence of one person's brain on another person's brain (Montague et al. 2002).

EEGs/ERPs use scalp electrodes to measure the electrical activity of large groups of neurons (more than one million). EEGs are used clinically to help diagnose neurological disordersby examining the synchronicity, frequency and amplitude of EEG "waves" while a patient sits or lies down. ERPs differ from EEGs in thatexperimental subjects are given specific tasks to do that may provoke regional brain activation.

ERPs provide higher temporal resolution than fMRI or PET but lower spatial resolution. The other advantages of ERP over fMRI or PET specified by neuroscientists are its relatively low cost, less demanding statistical analyses (two dimensional), and greater freedom of movement for subjects. The disadvantages of ERPs include low spatial resolution, many trials required per subject, and potential problems with inter-subject comparisons, taking into account bony landmark differences across subjects.

Single neuron measurement requires a microelectrode inserted into the neuron cell body, which can damage or destroy it. For this reason animals are used for this type of measurement. Single neuron measurements offer the highest level of spatial specificity.

Transcranial magnetic stimulation (TMS) is used to "knock out" or activate brain areas, and hence is useful for learning what targeted areas do.

Studies of humans with brain damage are used to study the role of different brain regions in conducting various tasks. If a patient with specific brain region damage cannot perform a specific task, then that region is responsible for doing it.

An old, cheap and easy technique is psychophysical measurement (blood pressure, skin conductance, heart rate and pupil dilation, for example). These measurements are also portable and rapid in time. The disadvantage is that measurements can fluctuate for many reasons (e.g., body movement) and many different combinations of emotions lead to similar psychophysiological output. Eye tracking is also very easy and useful for economists for studying various tasks. Often these measurements are useful in combination with other measurement techniques, which will allow researchers to combinethe results of different measurements within a single experiment.

Using pharmaceuticals in experiments is an important method to induce behavior, i.e. to move from correlation to causation, and its use in neuroeconomics is just beginning.

BRAIN AND MODERN CORPORATION

Neuroeconomists compare the human brain with a corporation, specifying many similarities (Sanfey et al. 2006). From the viewpoint of the authors both brain and a corporation are complex systems transforming inputs into outputs. Both involve the interaction of multiple and highly similar agents (neurons are similar to one another, just as are people) that are specialized to perform particular functions. In corporations, units often take the form of departments performing various activities (e.g. research, marketing). Similarly, the brain consists of different subsystems specialized for different functions. Both are hierarchical structures. Both rely on “executive” systems that make judgments about the relative importance of tasks and decide how to mobilize required resources to perform those tasks. Several neuroimaging studies prove that brain regions that are responsible for executive function are engaged in performing new and effortful tasks; however, when the task becomes less effortful those brain regions demonstrate lower activity. Similar improvements in speed and efficiency are observed in industry. Contemporary high technologies have improved labor productivity in all spheres of life. Presumably, such improvements were accompanied by decreasing the role of the administrative and executive bodies, as is observed in the brain.

MAJOR FINDINGS IN NEUROECONOMICS

In this section major findings in the field of neuroeconomics are introduced such as the neurocomputational model of decision-making, utility for money, cognitive and emotional systems in decision-making process, neural calculation of gains and losses, the role of emotions, intertemporal choice, neural correlates of behavioral preference, simultaneously surveying evidence from the neuroeconomic literature.

A. NEURAL CALCULATIONS OF DECISION UTILITY

According to theclassical economic theory, economic agents are absolutely rational cognitive actors with consistent preferences and decision-making is a choice from a fixed number of alternatives that has the aim to maximize decision utility. In contrast, behavioral economists proved that revealed preference model was far from real-world assumptions and people displayed inconsistent and irrational behavior. In fact, the decision-making process involves three main components: alternatives, evaluation of the utilities of the alternatives, and goal realization (or non-realization). Furthermore, three types of utilities underlie choice behavior: *experienced utility* (the way that the choice makes the decision-maker feel in the moment – either good or bad), *expected utility* (the decision-maker makes choices based upon how he/she expects the experiences to make him/her feel) and *remembered utility* (the decision-maker's future choices are based upon what he/she remembers about his/her past experiences) (Kahneman et al. 1999). To say that we know what we want, therefore, means that expected utility is matched by experienced utility, and experienced utility is reflected in remembered utility. Unfortunately, these three utilities rarely align.

Neuroeconomists have designed a neurocomputational model of decision-making to investigate how expected and experienced utilities are computed in human brain.The keystone of the neurocomputational model of decision-making is the idea that neural system evaluates the comparative pleasantness of all available actions and chooses the one with the highest level (this process is called “the winner takes all”). The neural system “calculates” the level of pleasantness of each attainable alternative. This is a real physical computation that is ended by choosing the most preferred action.

The neurocomputational model is founded on the following key principles (Fehr & Rangel 2011):

- The brain computes a decision value signal for each option at the time of choice;
- The brain computes an experienced utility signal at the time of consumption;
- Choices are made by comparing decision values;
- Decision values are computed by integrating information about the attributes associated with each option and their attractiveness;
- The computation and comparison of decision values is modulated by attention.

The above-mentioned components of the neurocomputational model have the following main characteristics (Fehr & Rangel 2011):

- Decision values are computed from the instant the decision process starts (for example, when a choice pair is displayed to a subject on a computer screen) to the moment the choice is made (for example, when the subject indicates a choice by, say, pressing a button);

- Decision values should be thought of as signals computed at the time of choice that forecast the eventual hedonic impact of taking the different options;
- Because choices are made by computing and comparing decision values, these signals causally drive the choices that are made: options that are assigned a higher decision value will be more likely to be chosen;
- Positive surprises increase experienced utility, and negative surprises decrease it;
- Exogenous increases in the amount of relative attention paid to an preferable item should increase the probability that it is chosen.

NEUROECONOMIC EVIDENCE FOR THE BRAIN COMPUTING DECISION UTILITY

A basic assumption in economics is that each market transaction is a confrontation between buyer's and seller's prices. Buyer's price (WTP – willingness to pay) is the maximum amount of resources that the buyer is ready to give up to obtain the product and seller's price is the minimum amount that the seller is ready to accept to give up the product (WTA – willingness to accept). In order to evaluate whether the decision is beneficial or to decide how much to bid for an item the buyer compares WTP with the price at which the item is being offered. To make good trades, individuals must be able to assign a WTP to an item that is commensurate to the benefits that it will generate. Otherwise they would end up purchasing items for a price that exceeds their worth to them. Despite its importance little is known about how the brain makes these computations.In order to provide evidence for the existence of decision value in the human brainPlassmann and his colleagues carried out the following experiment (Plassmann et al. 2007).Nineteen normal-weight subjects participated in the experiment. Subjects were asked to bid on 50 different sweet and salty types of junk foods (e.g., chips and candy bars). The neural activity of participants' brains was measured with fMRI.

The authors selected the foods based on pilot data to satisfy several characteristics: first, they wanted items to be highly familiar and to be sold in local stores, to remove uncertainty considerations from the WTP computation as much as possible; second, they wanted items to be positive for the subjects (in the sense that their WTP for them is greater than or equal to zero). The foods were presented to the subjects using high-resolution color pictures. Subjects placed bids for the right to eat a snack at the end of the experiment in 100 different bidding trials. In each trial they were allowed to bid $0, $1, $2, or $3 for each food item. At the end of the experiment, one of those trials was randomly selected and only the outcome of that trial was implemented. In addition to a $35 participation fee, each subject received three $1 bills to purchase food during the experiment. Whatever money they did not spend was theirs to keep.

The authors were sure that buyers would bid exactly their WTP for the item since they didn't have any incentive to bid less than the WTP because the price paid was determined randomly. They weren't motivated to increase the bid above the WTP because this might lead to paying a price larger than their WTP.

Neuroimaging results proved that activity in the medial orbitofrontal cortex (mOFC) was correlated with WTP, which provides evidence for the hypothesis that the brain computes decision values at the time of choice. This finding was replicated in multiple studies using distinct choice objects, distinct valuation paradigms (price purchase decisions, binary choices) and distinct choice speeds (from one to several seconds) and the same region of the brain was activated, showing that brain computes decision utility at the time of choice.

According to the neurocomputational model of decision-making, the brain computes experienced utility at the time of consumption. The brain computes the signal of experienced utility, which is the reaction of human organism to the consumption of the chosen alternative. Neuroeconomists emphasize that decision utilities differ from the signals of experienced utility; decision utility is a forecast about the experienced utility.

In opposition to the idea that the experienced pleasantness of a product depends only on its internal properties, there is considerable evidence in marketing literature that change in the external properties of a product (e.g. price or package) has great influenceon the experienced pleasantness of the item. Neuroeconomists rely on the idea that experienced utility depends on both the nature of the item consumed and consumer's expectations from the consumption. Particularly, they are sure that positive surprises increase experienced utility, and negative surprises decrease it.

In order to investigate the extent to which the pleasure derived from drinking a wine depends only on its physiological properties, or whether this pleasure is also modulated by beliefs about the price of the wine, Plassmann and his colleagues conducted an experiment (Plassmann et al. 2008). 20 normal-weight subjects participated in the experiment. Three different wines were tasted by the participants. Two of the three wines were administered twice, once identified by their actual retail price and once by a 900% markup (wine 1: $5 real retail price, $45 fictitious price) or a 900% reduction (wine 2: $90 real retail price, $10 fictitious price). The third wine was used as a distracter and was identified by its retail price (wine 3: $35). The wines were administered in random order, simultaneously with the appearance of the price cue. The participants were asked to evaluate the pleasantness of each wine focusing on the flavor of the wine. Neural activity was measured with fMRI.

The main hypothesis of this study was that an increase in the perceived price of a wine should, through an increase in taste expectations, increase activity in the medial orbitofrontal cortex (mOFC). The results provide evidence consistent with the hypothesis.The authors found increased activation in the left mOFC and the left ventromedial prefrontal cortex (vmPFC). Activity in the mOFC was higher for the high-price ($45) than the low-price condition ($5) in spite of the fact that it was the same wine. Further studies showed that very weak correlation existed between wine taste and its price when subjects had no information about the price of the wine (Goldstein et al. 2008).

Neuroscientific research of decision-making proves that attention has a great impact on consumer choice. In a series of experiments testing this prediction, Armel, Beaumel and Rangel showed that the willingness-to-pay for appetitive items increases significantly with computation time, and that the opposite is true for aversive items (Armel et al. 2008).

The authors conducted the following behavioral experiment: 60 subjects participated in the experiment for choices between appetitive items and 105 for choices between aversive food items. 70 junk foods were represented as appetitive items and 35 as aversive items.The items appeared on the screen at random duration and location. The objective of the experiment was to investigate the influence of attention manipulation and long fixation on consumption decisions.The results of the experiment showed that appetitive items were 6 to 11% more likely to be chosen in the long fixation condition. In contrast, aversive items were 7% less likely to be chosen in the long fixation condition.

So, this model shows that it should be possible to increase the probability for the item to be chosen by changing the relative amount of time that subjects fixate on the item during the decision-making process. Second, it predicts that the effect should be positive for appetitive items, and negative for aversive items.

The results of the experiment have implications for decision-making in real world contexts. Marketers believe that consumers' attention may be manipulated at the point of sale. They apply various tools for biasing consumers' attention, for example, the package of the product, the location of the product on the shelf in supermarkets, the smell of the product, and even the music in the store. All these actions are partly justified because consumers consider only a small number of items in making their choice, but the actions only work on items that consumers consider as appetitive.

B. UTILITY FOR MONEY

The notion of utility for money is of great importance for economists. According to the standard economic model, money has no utility in itself. Its utility is measured indirectly by the value of the goods and services it can buy. This means that the pleasure from cars or books is different from the pleasure from obtaining money.

Neural evidence suggests, however, that the same dopaminergic reward circuitry of the brain in the midbrain (mesolimbic system) is activated for a wide variety of different reinforcers, including attractive faces, funny cartoons, sports cars, drugs, and money. This suggests that money provides direct reinforcement, which means that people value money without taking into account what they are going to buy with it (Camerer et al. 2005).

Neuroeconomists point out that since gaining money provides pleasure, it will be painful parting with it. This phenomenon helps explain why many companies supply their products and services in packages, making it impossible to calculate the price of each attribute in order to present them as “free”. This would reduce the pain of payment and motivate consumers.

C. MULTIPLE PROCESSES IN DECISION MAKING

Neuroscientific research of decision-making supports the idea that either single or dual systems underlie decision-making process. Existing evidence from neuroscience and experimental psychology proves that human behavior is not a product of a unitary process but reflects the interaction of different subsystems that interact and compete, inducing various behaviors. Despite the existing insights in these fields about multiple systems in decision-making, there is still debate about distinguishing sets of processes.

Neuroeconomics has the potential to shed light on the nature of these subsystems by examining dual-process models at a neural level. In general, these models propose the existence of two distinct systems. System 1 has been described as automatic, fast, effortless, unconscious, associative, slow learning, and emotional. System 2 has been described as controlled, slow, effortful, conscious, rule based, fast learning, and affectively neutral (Sanfey & Chang 2008).

The interaction of System 1 and System 2 can be found in the example of driving a car. The novice driver is thought to rely on controlled processing, requiring more cognitive resources for various operations involved in the act of driving. This means that the driver’s behavior is defined by System 2. By contrast, as the level of the driver’s practice increases, the processes become more automatic and efficient, allowing the driver to be engaged in other activities, such as conversing with a passenger, listening to the radio, etc. In this case, the driver’s behavior is defined by -System 1. However, as soon as the experienced driver recognizes a problem that cannot be handled by -System 1, such as an accident, System 2 can override System 1 and devote more cognitive resources to the situation (Sanfey et al. 2006).

The distinction between automatic and controlled processes can be described as rule-based and associative, rational and experimental, reflective and reflexive, cognitive and affective systems, "cool" and "hot" systems, "know" and "go" systems, fast and slow, or Type I and Type II processes. The main characteristics of controlled and automatic processes are described in Table 1.

Table 1
Dual processing of the brain

	Cognitive	***Affective***
Controlled processes • *Serial* • *Effortful* • *Evoked deliberately* • *Good introspective access*	**I**	**II**
Automatic processes • *Parallel* • *Effortless* • *Reflexive* • *No introspective access*	**III**	**IV**

Source: Camerer et al. 2005

Cognitive and affective processes, in combination, define the above mentioned four quadrants. Quadrant I is responsible for the deliberation about purchasing assets, analyzing situation in the stock exchange; Quadrant II is in charge when actors imagine previous emotional experiences so as to actually experience those emotions during a performance; Quadrant III governs the movement of your hand when you take a cup; and Quadrant IV makes you jump when somebody says "Boo!"

Neuroscientists' studies of neural components of automatic and controlled processes show what brain regions are responsible for cognitive and emotional systems. Frontal parts of the brain are responsible for controlled processes. The prefrontal cortex (pFC) is sometimes called the "executive" region, because it draws inputs from almost all other regions, integrates them to form near and long-term goals, and plans actions that take these goals into account (Shallice et al. 1996). Regions that support cognitive automatic activity are concentrated in the back, top and sideparts of the brain.

Distinguishing between cognitive and emotional systems could help to shed light on many fundamental economic patterns, such as asymmetric responses to gains and losses (loss aversion), decisions over time, and fairness vs. unfairness considerations.

D. NEURAL CALCULATIONS OF GAINS AND LOSSES

The question of how the brain calculates gains and losses is perhaps the most hotly debated topic in neuroeconomics. Kahneman and Tversky (1979) formalized the notion of loss aversion, which implies that people are twice more sensitive to losses than to corresponding gains. Their famous dictum explains loss aversion in risky choices and the endowment effect (Thaler 1980) in riskless choices. The endowment effect is a tendency for people to value an item higher when they possess it than they would value the same item if they did not own it. This phenomenon also describes the difference between buying and selling prices or willingness to pay and willingness to accept.

One fundamental question for the study of decision making is whether loss aversion is a product of a single system or reflects the engagement of distinct emotional processes within the brain when potential losses are considered. Some neuroscientists insist that higher sensitivity to losses is driven by negative emotions such as fear or anxiety, which means that loss aversion is explained by a single system that evaluates gains and losses asymmetrically. This notion predicts that higher sensitivity to increasing potential losses should be associated with greater activity in brain regions that are responsible for negative emotions in decision making (such as the amygdala or anterior insula). Alternatively, loss aversion could reflect an asymmetric response to losses versus gains within a single system that codes for the subjective value of the potential gamble, such as ventromedial prefrontal cortex (VMPFC)/orbitofrontal cortex (OFC) and ventral striatum (Tom et al. 2007).

To investigate whether gains and losses are coded by the same brain regions, Tom et al. (2007) conducted an experiment collecting functional magnetic resonance imaging (fMRI) data while participants (16 healthy subjects) decided whether to accept or reject mixed gambles that offered a 50/50 chance of either gaining one amount of money or losing another amount, with gains ranging from $10 to $40 (in increments of $2) and losses ranging from $5 to $20 (in increments of $1). They chose these ranges because Kahneman and Tversky's studies showed that people are twice more sensitive to losses than to corresponding gains (Kahneman & Tversky 1979). The participants were given $30 a week before scanning and one decision from each of three scanning sessions was honored for real money. To encourage participants to reflect on the subjective attractiveness of each gamble rather than to rely on a fixed decision rule, the authors asked them to indicate one of four responses to each gamble (strongly accept, weakly accept, weakly reject, and strongly reject).

The results of the experiment showed that a group of brain regions including the striatum, ventromedial prefrontal cortex, ventral anterior cingulate cortex and medial orbitofrontal cortex, which code for the subjective value of the potential gamble, showed increasing activity for gains and decreasing activity for losses. There were no regions that showed decreasing activation as gains increased. If loss aversion is driven by a negative affective response (e.g., fear, vigilance, discomfort), then one would expect increasing activity in brain regions associated with these emotions as the size of the potential loss increases. Contrary to this prediction, no brain regions showed significantly increasing activation during evaluation of gambles as the size of the potential loss increased (averaging over all levels of gain).

Examination of regions of interest in the striatum and ventromedial prefrontal cortex from the gain/loss conjunction analysis revealed that these regions exhibited a pattern of “neural loss aversion”; that is, the (negative) slope of the decrease in activity for increasing losses was greater than the slope of the increase in activity for increasing gains in a majority of participants. So the authors proved that losses and gains are coded by the same brain regions.

E. THE ROLE OF EMOTIONS

Until recently, economists have ignored the role of emotions in judgment and decision making. Emotion was viewed only as a negative influence deviating human behavior from the rational choice model. However, some researchers stress the importance of environmental, social, and emotional influences on decision making, and recently neuroeconomists have begun to examine the influence of emotions on human behavior using neuroimaging techniques, especially the relative contributions of cognitive and emotional processes to human social decision-making. An example of the latter is behavior in an often-studied decision task known as the Ultimatum Game.

In this game, participants are given the opportunity to divide a sum of money between them. One player is the proposer and the other, the responder. The proposer makes an offer as to how this money should be split between the two. The responder must decide either to accept or reject an offer of money. If the offer is rejected, then neither player receives anything, if it is accepted, the money is split as proposed. According to standard economic models the responder must accept even the smallest sum of money, because some money is better than none. However, behavioral studies indicate that about half of the unfair offers are rejected.

For many years behavioral economists have been seeking to investigate the reasons for turning down monetary rewards in the ultimatum game. They are sure that the game is too simple for participants to fail to understand the rules. This means that something is hidden in the human brain that leads people to punish the partner for an unfair offer.

To shed light on the neural and psychological processes underlying such behavior, and to provide evidence for the emotional processes of economic decision-making in the ultimatum game, Sanfey and his colleagues conducted the following neuroimaging experiment (Sanfey et al. 2003). They scanned 19 participants using functional magnetic resonance imaging (fMRI), each of them in the role of the responder in the ultimatum game. Before scanning, each participant was introduced to 10 people they were told would be partners with them in the games. They played a single game with each partner. The participants were then placed inside the MRI scanner and began playing the ultimatum game with their partners via a computer interface. They completed 30 rounds in all, 10 rounds with a human partner (once with each of the 10 partners), 10 with a computer partner, and a further 10 control rounds in which they simply received money for a button press. The rounds were presented randomly, and all involved splitting $10. Half of these offers were fair ($5:$5), the remaining half were unfair splits (two offers of $9:$1, two offers of $8:$2, and one offer of $7:$3). The 10 offers from the computer partner were identical to those from the human partners (half fair, half unfair). The 10 control trials were designed to control for the response to monetary reinforcement, independent of the social interaction.

Participants accepted all fair offers, with decreasing acceptance rates as the offers became less fair. Unfair offers of $2 and $1 made by human partners were rejected at a significantly higher rate than those offers made by a computer, suggesting that participants had a stronger emotional reaction to unfair offers from humans than to the same offers from a computer. Seeking to investigate neural and behavioral reactions to offers, the authors hypothesized that unfair offers would engage neural structures involved in both emotional and cognitive processing, and that the magnitude of activation in these structures might explain variance in the subsequent decision to accept or reject these offers.

The results of neuroimaging experiment showed that a group of brain regions including the bilateral anterior insula (connected with negative emotional states, particularly anger and disgust), dorsolateral prefrontal cortex (the DLPFC is linked to cognitive processes) and anterior cingulate cortex (the ACC is implicated in detection of cognitive conflict) showed greater activity for unfair offers compared with fair offers. The study found that if the insular activation was greater than the DLPFC activation, participants tended to reject the offer, whereas if the DLPFC activation was greater, they tended to accept the offer. This offers neural evidence for atwo-system account of decision-making in this task.

Regions of bilateral anterior insula demonstrated higher activity for a $9:$1 offer than an $8:$2 offer, in addition, the results of the study showed greater activation of this region for unfair offers than for fair ($5:$5) offers. Indeed, the participants with stronger anterior insula activation to unfair offers rejected a higher proportion of these offers.

The authors concluded that the activation of DLPFC is connected with participants' money maximization goal and did not correlate with the acceptance rates, proving that emotional and cognitive systems compete, inducing accepting or rejecting behavior. The study showed that rejected unfair offers had greater activation in the anterior insula than in the DLPFC, and in the case of unfair offers the DLPFC demonstrated higher activation than the anterior insula. As mentioned above, the experiment showed that unfair offers were also associated with increased activity in the anterior cingulate cortex (ACC), which is responsible for cognitive conflictbetween cognitive and emotional systems.

Their investigation of neural correlates of cognitive and emotional processes helps to explain the basic sense of fair and unfair behaviors, which is a very important aspect in economic, ethical, moral, and social policy, and in other contexts.

F. DECISIONS OVER TIME

Investigations of cognition-emotion interaction help to shed light on the notion of gratification delay. According to the discounted utility theory, people discount all utilities and all types of goods and services at a constant rate. However, research on time discounting shows that gains are discounted more than losses, small amounts are discounted more than large amounts, greater discounting is shown to avoid delay of a good than to expedite its receipt, improving sequences are often preferred to declining sequences, violations of independence are pervasive, and people prefer spreading consumption (Frederick et al. 2002).

One hypothesis that has been advanced to explain this phenomenon is that inter-temporal choice can be viewed as a splice of two processes—an impulsive, affective process and a more far-sighted process guided by the prefrontal cortex (Shefrin & Thaler 1988). Alternatively, an affective system makes individuals display myopic behavior, and a cognitive system makes them take into account long-term consequences of actions. Examination of cognitive and affective processes in the brain will help to better understand inter-temporal choice behavior.

McClure et al. (2004a) carried out an experiment to provide support for this phenomenon. 14 subjects participated in the experiment. Participants made a series of binary choices between smaller/earlier and larger/later money amounts while their brains were scanned using functional magnetic resonance imaging. The specific amounts (ranging from $5 to $40) and times of availability (ranging from the day of the experiment to 6 weeks later) varied across choices. At the end of the experiment, one of the participant's choices was randomly selected to count. The authors found that the options involving immediate rewards activated parts of the limbic system (affective), and regions of the lateral prefrontal cortex and posterior parietal cortex—typically viewed as more cognitive regions—were engaged uniformly by inter-temporalchoices irrespectiveof delay. So, during the competition between cognitive and affective systems comparative advantage of one or the other process will cause the participant to behave less or more impulsively.

G. NEURAL CORRELATES OF BEHAVIORAL PREFERENCE

According to neoclassical theory, people behave consistently and human preferences are constant: once they have revealed that they prefer A to B, people should not subsequently choose B over A. Behavioral economists proved that the revealed preference model did not describe real-world choices because there weremany factors biasing human preferences. Behavioral preferences often deviate from statedones.

It is well-known that chief among the factors affecting people's preferences is brand knowledge. One of the most interesting examples showing the influence of brand knowledge on choice is the “Pepsi challenge”. That is, a taste test run by PepsiCo to show consumers' preferences between Pepsi and Coca-Cola. Neuroeconomic research of neural correlates of behavioral preferences will help to explain this phenomenon.

In order to investigate the influence of brand knowledge on people's preferences McClure et al. (2004b) conducted an experiment with subjects preferring Coke or Pepsi. Authors explain that these two drinks were chosen for three reasons. First, they are culturally familiar to subjects. Second, they are both primarily composed of brown, carbonated sugar water, and sugar water serves as a primary reward in many human and animal experiments. Third, despite their similarities, they generate a large subjective preference difference across human subjects.

A total of 67 subjects participated in the study. For the first, subjects were asked which drink they preferred: Coke, Pepsi or no preference? Their answers were referred to as their stated preferences. Next, while being scanned with fMRI subjects engaged in taste tests: anonymous, semi-anonymous Coke and semi-anonymous Pepsi.

During the anonymous taste test participants chose between two unmarked cups, one of which contained Coke and the other contained Pepsi. During the semi-anonymous Coke taste test participants chose between two cups, one of which was labeled as Coke and the other was unmarked and could contain either Coke or Pepsi. During the semi-anonymous Pepsi taste test participants chose between two cups, one of which contained Pepsi and the other containing either Coke or Pepsi.

Data collected from anonymous taste test supported the idea that stated preferences are not correlated with behavioral preferences. There was no difference between stated and behavioral preferences but there was no significant statistical correlation between these two preferences.

In order to test whether brand knowledge biases consumers' preferences, the authors conducted semi-anonymous tests.During semi-anonymous Coke taste test participants showed a strong bias in favor of the labeled cup. The Coke label had a bigger effect in biasing subjects' preferences than the Pepsi label.During semi-anonymous Pepsi taste test the existence of the Pepsi label did not change the distribution of choices significantly compared to the anonymous test. In the case of the semi-anonymous Coke test the ventromedial prefrontal cortex (VMPFC) showed great activity, which is not true for the Pepsi test. Thus, the authors conclude that brand knowledge has truly different responses both in terms of affecting behavioral preference and in terms of modifying brain responses.

CONCLUSIONS

The question of how we make decisions is a field of interest for philosophers, sociologists, economists, psychologists, and neuroscientists. In classical decision-making theory, an economic agent was viewed as a rational agent who was able to estimate the probabilistic outcomes of uncertain decisions and choose the alternative that maximized his/her utility. However, this model was not able to predict human behavior accurately.

The birth of neuroeconomics as an interdisciplinary field of science, combining theories and methods from neuroscience, economics, psychology and computer science, was a sharp turn in economic thought and fundamentally changed the way economics is done. The methods of neuroscience have allowed neuroeconomists to reveal some of the most important issues in economics, including: Why do people consume and save? How does an individual make choices under risk and uncertainty? How are decision values and decision utilities calculated in the brain? How are gains and losses evaluated? How are individuals preferences defined? How do the emotions affect decision-making process? Neuroeconomics provides the necessary tools to measure neurophysiological activity of the brain during the process of choice and opens a window into human nature. So we may conclude, that the long-term goal of neuroeconomic research is to shed light on the neurobiology of decision-making, which will contribute to the development of a new choice model with higher levels of predictive power.

Neuroeconomics is sometimes criticized as not being able to transform economics, since brain activity is not a field of interest for economics. Besides, critics of laboratory research often reject the ideat hat studies in which participants must remain almost perfectly still inside multi-ton magnets will demonstrate real world situations. Colander (2007) reminds these critics that classical economists were interested in measuring utility directly. He mentions that Edgeworth dreamed of a “hedonimeter” that could measure the utility of each person, while later Ramsey fantasized about a “psychogalvanometer”. This means that the main reason for the classical economists to focus on the utility maximization model of rational choice was not the lack of interest in examining the brain but the lack of brain measurement tools.

However, neuroeconomists are convinced that investigating the activity of different brain regions during various tasks and understanding collaboration and competition between the regions will help to solve economic problems not observed before. They believe that their future is bright.

In this respect Daniel Kahneman says,“It is far easier to argue for mindless economics than for brainless economics” (Datta 2011, p. 305).

REFERENCES

ARMEL, K.C., BEAUMEL, A., & RANGEL, A. (2008). Biasing simple choices by manipulating relative visual attention, Judgment and Decision Making, 3(5), 396-403.

CAMERER, C., LOEWENSTEIN, G., & PRELEC, D. (2005). Neuroeconomics: How neuroscience can inform economics. Journal of Economic Literature, 43(1), 9-64. https://doi.org/10.1257/0022051053737843

COLANDER, D. (2007). Retrospectives: Edgeworth’s hedonimeter and the quest to measure utility. Journal of Economic Perspectives, 21 (2), 215-225. https://doi.org/10.1257/jep.21.2.215

DATTA, S. (ed.) (2011). Economics: Making Sense of the Modern Economy, 3rd Edition. London: Profile Books Ltd.

FEHR, E. & RANGEL, A. (2011). Neuroeconomic foundations of economic choice—Recent advances. Journal of Economic Perspectives, 25(4), 3-30. https://doi.org/10.1257/jep.25.4.3

FREDERICK, S., LOEWENSTEIN, G., & O’DONOGHUE, T. (2002). Time discounting and time preference: A critical review. Journal of Economic Literature, 40(2), 351-401. https://doi.org/10.1257/002205102320161311

GOLDSTEIN, R., ALMENBERG, J., DREBER, A., EMERSON, J., HERSCHKOWITSCH, A., & KATZ, J. (2008). Do more expensive wines taste better? Evidence from a large sample of blindtastings. Journal of Wine Economics, 3(1), 1-9. https://doi.org/10.1017/s1931436100000523

JEVONS, W. (1871). The Theory of Political Economy. London and New York: Macmillan and Co.

KAHNEMAN, D., & TVERSKY, A. (1979). Prospect theory: An analysis of decision under risk. Econometrica, 47(2), 263-292. https://doi.org/10.2307/1914185

KAHNEMAN, D., DIENER, E., & SCHWARZ, N. (eds.). (1999). Well-being: The foundations of hedonic psychology. New York: Russell Sage Foundation. https://doi.org/10.1017/s0953820806231972

MCCLURE, S. M., LAIBSON, D. I., LOEWENSTEIN, G., & COHEN, J. D. (2004a). Separate neural systems value immediate and delayed monetary rewards. Science, 306(5695), 503-507. https://doi.org/10.1126/science.1100907

MCCLURE, S.M., JIAN, L., TOMLIN, D., CYPERT, K. S., MONTAGUE, L. M., & MONTAGUE, P.R. (2004b). Neural correlates of behavioral preference for culturally familiar drinks, Neuron, 44(2), 379–387. https://doi.org/10.1016/j.neuron.2004.09.019

MONTAGUE, P. R., BERNS, G.S., COHEN J.D., McCLURE, S.M., PAGNONI, G., DHAMALA, M., WIEST, M.C., KARPOV, I., KING, R.D., APPLE, N., & FISHER, R.E. (2002). Hyperscanning: simultaneous fMRI during linked social interactions. Neuroimage, 16(4), 1159–1164. https://doi.org/10.1006/nimg.2002.1150

PLASSMANN, H., O'DOHERTY, J., & RANGEL, A. (2007). Orbitofrontal cortex encodes willingness to pay in everyday economic transactions. Journal of Neuroscience, 27(37), 9984-9988. https://doi.org/10.1523/jneurosci.2131-07.2007

PLASSMANN, H., O'DOHERTY, J., SHIV, B., & RANGEL, A. (2008). Marketing actions can modulate neural representations of experienced pleasantness. Proceedings of the National Academy of Sciences, 105(3), 1050-1054. https://doi.org/10.1073/pnas.0706929105

SANFEY, A.G., & CHANG, L.J. (2008).Multiple systems in decision making. Annals of the New York Academy of Sciences, 1128(1), 53-62. https://doi.org/10.1196/annals.1399.007

SANFEY, A. G., RILLING, J. K., ARONSON, J. A., NYSTROM, L. E., & COHEN, J. D. (2003). The neural basis of economic decision-making in the ultimatum game. Science, 300(5626), 1755–1758. https://doi.org/10.1126/science.1082976

SANFEY, A., LOEWENSTEIN, G., MCCLURE, S., & COHEN, J. (2006) Neuroeconomics: cross-currents in research on decision-making. Trends in Cognitive Sciences, 10(3), 108-116. https://doi.org/10.1016/j.tics.2006.01.009

SHALLICE, T., BURGESS, P., & ROBERTSON, I. (1996).The domain of supervisory processes and temporal organization of behavior.Philosophical Transactions of the Royal Society B: Biological Sciences, 351(1346), 1405–1412. https://doi.org/10.1098/rstb.1996.0124

SHEFRIN, H.M. & THALER, R.H. (1988).The behavioral life-cycle hypothesis. Economic Inquiry, 26(4), 609–643. https://doi.org/10.1111/j.1465-7295.1988.tb01520.x

THALER, R. H. (1980).Toward a positive theory of consumer choice. Journal of Economic Behavior and Organization, 1(1), 39-60. https://doi.org/10.1016/0167-2681(80)90051-7

TOM, S. M., FOX, C.R., TREPEL C., & POLDRACK R.A. (2007). The neural basis of loss aversion in decision-making under risk. Science, 315(5811), 515-518. https://doi.org/10.1126/science.1134239

ZAK, P. J. (2004). Neuroeconomics. Philosophical Transactions of the Royal Society B: Biological Sciences, 359(1451), 1737-1748. https://doi.org/10.1098/rstb.2004.1544