NeuroEconomics

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Abstract:

Over the last two years a research field has developed under the banner of "neuroeconomics" in which recent neuroscientific methods are deploid to analyze economically relevant processes. This paper aims to provide an overview of the methodology and current state of neuroeconomic research by giving a brief definition of the concept of neuroeconomics, outlining relevant methodologies, and describing studies undertaken in the current research areas to date. Finally, some future prospects are considered.

1 Concept and background

For quite some time now, under the banner of "neuroeconomics", the scientific community has offered first approaches to apply modern neuroscientific methods to questions that are relevant to economic and business research (Camerer, Loewenstein, & Prelec (2003)). This debate primarily draws upon theories and problems related to behavioral economics (Sanfey, Rilling, Aronson, Nystrom, & Cohen (2003), Smith (2002)) as well as marketing research (McClure et al. (2004b), Kenning, Plaßmann, Deppe, Kugel, & Schindt (2002)). Research has been motivated by the lack of empirically-based statements on intrapersonal decision-making processes. A good example is the still unresolved series of questions as to how emotions, feelings and moods influence decision making. Put more precisely: when and how, but most of all, why such influences prevail is a matter of particular interest (Zizzo (2003), Weinberg & Salzmann (2004)).

Such lack of clarity can be explained by the fact that intrapersonal decision-making processes cannot be observed. Although it is certainly possible to vary stimuli and observe reactions in experimental research the underlying thought processes have to be reconstructed theoretically. As neuroscientific methods and findings improve, researchers hope to support these theoretical constructs empirically in the near future, thereby contributing to a further development in economic theory. Therefore one can define neuroeconomics as the attempt to investigate economic-related behavior by using neuroscientific methods.

2 Overview of neuroscientific techniques

In order to extend the concept, neuroscientific methods which can be used in this research area need to be specified. Because the syllable "neuro" indicates that these methods deal with an analysis of the nervous system, all methods which relate to activities of the nervous system, are initially taken into consideration. Accordingly, also procedures which provide "peripheral indicators" (Kroeber-Riel & Weinberg (2003), S. 67) and electrodermal reactions (Groeppel-Klein & Germelmann (2003), S. 56ff.) would be seen as part of neuroeconomic research. However, the latter methods are not central to neuroeconomic research. Rather, in the relevant literature the five techniques outlined in Table 1 are used, which are relating to activities in the brain as part of the central nervous system. These can be grouped into two categories according to the underlying mechanisms: procedures for measuring electrical activity of the brain and those for measuring neural metabolism processes (for an introduction seePosner & Raichle (1997)).

Changes in electric currents	**Changes in metabolism**
Elektroencephalography (EEG) Magnetencephalography (MEG)	Positron-Emissions-Tomography (PET) Functional transcranial Doppler-Sonography (FTCD) Functional Magnetic Resonance Imaging (fMRI)

Table 1: Overview of neuroscientific techniques and their bases

2.1 Methods of measuring electrical activity

Electroencephalography is the oldest of the methods listed. With the aid of the EEG, the researcher acquires information about electronic activity of the brain. Through electrodes placed on the skin of respondents, variations in tension can be measured on the surface of the brain. The temporal resolution capabilities of EEG are measured in milliseconds. This facilitates a precise determination of the sequence of brain activities. However, this temporal precision is obtained at the cost of spatial depiction as only activity at the surface of the brain can be measured.

This problem is partly resolved by the use of Magnetencephalography (MEG). This procedure captures magnetic currents running along individual nerve fibers. In comparison to the EEG, this has the advantage of being able to depict also deeper cortical brain structures (see Braeutigam, Stins, Rose, Swithenby, & Ambler (2001), Braeutigam, Rose, Swithenby, & Ambler (2004)) Furthermore, this technology provides an excellent overview of the temporal structure of decision-making processes as clarified by the following quotation from a brand study by Bräutigam et al. (2001, p. 241):

"*Choosing among different brands of closely related products activated a robust sequence of signals within the first seconds after the presentation of the choice images. This sequence engaged first the visual cortex (80-100 ms), then as the images were analyzed, predominantly the left temporal regions (310-340 ms). At longer latency, characteristic neural activation was found in motor speech areas (500-520 ms) for images requiring low salience choices with respect to previous (brand) memory, and in right parietal cortex for high salience choices (850-920 ms).*"

2.2 Methods of measuring metabolic processes

Positron emissions tomography (PET) is a nuclear medicine technology through which metabolic processes in the body can be investigated (Aine (1995)). A weakly radioactive substance is added to the bloodstream of a test person by way of injection or inhalation. With the aid of detectors, regions of the brain in which there is a higher level of activity in the form of increased metabolic activity, can be captured. This data is processed into maps in which activation differences can be depicted. Despite excellent spatial resolution the application to healthy test persons is controversial, because of the use of radioactive contrast substances,

With the procedure of **functional transcranial Doppler sonography** (FTCD), by means of ultrasound, averaged and event-related blood flow velocities are measured simultaneously within in two cerebral arteries (for an overview see Deppe, Ringelstein, & Knecht (2004)). If, in one artery, the activity rises relative to the other in executing a particular function, conclusions can be drawn as to differences in blood flow velocity. The advantage of this procedure is that the results are easily reproducible, are not limited to large pieces of equipment and are relatively cost-effective and flexible. For example, they can be used at the point of sale. However, a disadvantage of the procedure is that the emphasis can only be on certain areas of the brain (so-called "regions of interest"). In the preliminary stages, therefore, the researcher must have an idea as to which areas are to be observed.

Functional magnetic resonance tomography (fMRI) is currently the most popular technology. This procedure uses magnetic fields and radio waves in order to depict different kinds of body tissue. The strength of transmitted MR signals varies according to the density of the different kinds of body tissue and the strength of the magnetic field. The MR signals are captured by detectors and, by means of a computer, converted through mathematical and statistical procedures into colored maps. Activations in specific regions can be isolated with the help of mathematical transformations and statistical inference.

3 A short introduction to the most important regions of the brain

The human brain is the most complex structure that we know. On average, the female brain weighs 1245 grams and the male brain, 1375 grams. From the neuropsychological perspective, it forms the centre of all psychological processes. Even though this statement is currently generally accepted, manifestation of psychic phenomena within the brain structure has been controversial for some time. The phrenologists of the 18th century were still convinced that a particular area of the brain was responsible for specific functions. At present, referring to higher cognitive brain functions, this "strict localization theory" is obsolete. Scientists now recognize that, for many neural processes, several centers work together (Miyashita (2004), p. 435). Only through this "co-operative" work does perception of reality as we regard it take place. If one initially considers the brain in a superficial manner, one can immediately recognize that the cerebral cortex consists of two halves, the so-called "hemispheres". Considered anatomically, the left half comprises primarily a number of short neural connections. On the other hand, the right half comprises mainly long connections linked to brain areas which are far apart from one another. Furthermore, the left half of the brain is generally somewhat larger than the right half. The assumption that both halves of the brain perform different functions was (apparently) confirmed by the experiments of ROGER SPERRY. In order to treat certain forms of epilepsy, he severed the connection between the two halves, the *corpus callosum,* in order to restrict the epileptic attacks to one half only. In the case of these so-called "split-brain" patients, Sperry discovered a series of distinctive processes which he attributed to the different functions of the two halves of the brain. Accordingly, these patients could, for example, read something that was located on the left side of their face with the aid of the right half of the brain and write this with the left hand, which was similarly controlled by this side, but not say what they had read and written, provided the words not been "seen" by the left half of the brain. If one then assumes that the left half is responsible primarily for the spoken and written language as well as mathematical capabilities, the right half handles spatial perceptions and recognition of patterns. This assumption forms the basis for the so-called hemisphere theory which is often presented in marketing theory in a very much abridged form.

Apart from this rough and superficial differentiation, two distinct procedures are used to describe spatial neural activity. Firstly, there is the approach developed by Brodman. He established that cell structures in the brain differ. Based on this observation, he suggested a means of dividing the brain into 52 areas (Albright, Jessell, Kandel, & Posner (2000)). As before, a customary approach towards identifying and naming the most important areas of the brain is the division into the so-called Brodman areas (BA). With respect to economic research, in particular the middle front cortex (BA 8 and BA 6) seems to be of particular significance. Accordingly, a meta-analysis of the medial frontal cortex by Ridderinkhoff et al. (2004) reveals that the primary activation differences in decision-making activities related to uncertainty, are to be found in an area with an edge length of 30 mm x 30 mm (Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis (2004)).The following figure provides an overview of the brain divided into the various Brodman areas.

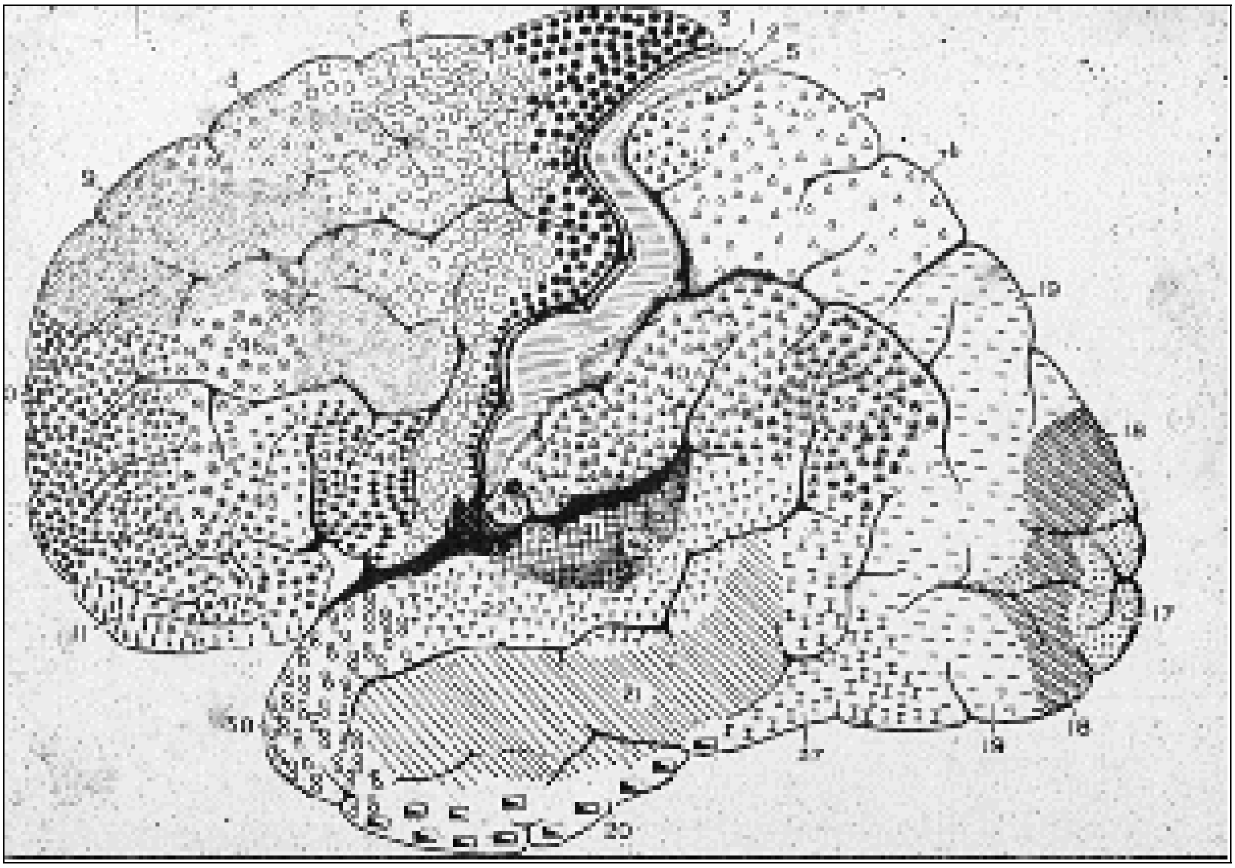

Figure 1: The cytoarchitechtonic brain map of Brodman (1906).

However, the division suggested by Brodman has, in the meantime, proven too approximate and imprecise. Accordingly, different brain atlases have been developed in order to map different brain areas with the help of a three dimensional coordinate system. The first and most prominent one was published by Talairach and Tournoux in 1980 (Talairach & Tournoux (1988)) for the purpose of stereotaxis. Today, the different data analyzing software packages use enhanced reference brains which are based on Talairach and Tournoux’s work such as the reference brain from the Monteral Neurological Institute (MNI). Thus, each activity can be allocated on the x,y-level and in z-direction (for orientation see figure 2).

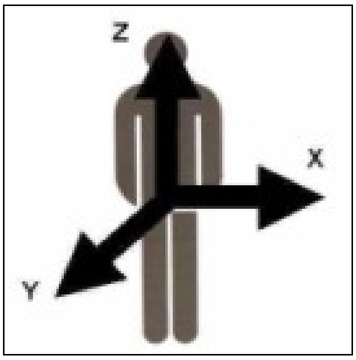

Figure 2: Orientation of axes with reference to Talairach and Tournoux (1988).

A typical neuroeconomic study regularly comprises information about the currently active Brodman area and the exact allocation of Talaraich or MNI coordinates.

4 Overview of the first applications in economic research

The number of neuroeconomic studies is still sufficiently low that one can maintain a reasonable perspective and understanding of its full range. Worldwide, barely more than fifty research groups deal explicitly with the subject of "Neuroeconomics".[1] Similarly, several commercial suppliers have already been able to establish themselves in the market.[2] However, their work is both ethically and methodologically controversial (Blakeslee (2004)). Table 2 provides an overview of the scientific application of the various techniques as well as the scientific studies, the basic issues with which they deal, and the results obtained.

Author	Theoretical Background	Problem	Method	Results
Breiter, Aharon, Kahneman, Dale, & Shizgal (2001)	Prospect theory	neural reactions to anticipation and experience of monetary gains and losses	fMRI	Partly differing brain areas for expectations and factual counting of monetary incentives involved as well as partly identical areas of the brain. The latter overlap with regions that respond actively to tasting stimuli and drugs that creates euphoria.
Lo/Repin Lo & Repin (2001)	Decisions in financial markets	role of emotions in live decision-making processes of stockbrokers	EEG/EDR	differing activation states depending on degree of market volatility and experience of the dealer
McCabe, Houser, Ryan, Smith, & Trouard (2001)	Game theory, particularly trust and willingness to cooperate	Determination of neural correlates of cooperative behavior	fMRI	Relationships between cooperation as well as willingness to trust and brain activity in areas responsible for emotional processes as well as their integration in decision-making
Erk, Spitzer, Wunderlich, Galley, & Walter (2002)	Choice decisions between different cultural objects or products (automobile) -	investigation of neural representations of social incentives	fMRI	Products which symbolize wealth and status lead to increased activity in areas of the brain that are responsible for perceptions of rewards
Kenning et al. (2002)	Preference decisions of consumers with respect to markets	Neural correlates of brands in decision-making processes	fMRI	Subjectively strong brands relieve pressure on areas responsible for rational processes and lead to increase activity in those areas responsible for emotional decisions
Smith, Dickhaut, McCabe, & Pardo (2002)	Game theory, in particular decision-making subject to ambiguity, risk, gains and losses	Neural carriers of attitudes about monetary payments (gains or losses) and assumptions about possible outcomes (risk or ambiguity)	PET	Independence between attitudes about payments and assumptions about the probability of outcomes in the form of different neural systems
Sanfey et al. (2003)	Game theory, in particular Ultimatum Game	Investigation of neural carriers of cognitive and emotional decision-making processes during the	fMRI	Interrelationships between fair and unfair behavior and areas of the brain which are responsible for Processing positive and negative emotional states as well as between decisions to accept or

		Ultimatum Game		reject
Ambler, Braeutigam, Stins, Rose, & Swithenby (2004)	Purchasing behavior	Comparison of reaction times to complicated (diverse brand) and simple (identical products, but different package sizes) purchasing decisions	MEG	Negative interrelationship between brand familiarity and time required for decision-making, negative interrelationship between simple purchasing decision and reaction time
Knutson & Peterson (in press)	Decision-making subject to uncertainty, in particular investor behavior	Determination of neural correlates of expectations benefit theory	fMRI	Significant role of emotions in anticipating stimuli with respect to neurological reconstruction of expected benefit
de Quervain et al. (2004)	Altruism, cooperation	Investigation of neural bases of "altruistic punishment"	PET	Sanctions against defectors activate reward centers in the brain (reward related brain regions)
McClure et al. (2004b)	Neural impact of visual stimuli (brand)	Neural bases for evaluating a soft drink	fMRI	Depending on whether and, if yes, what brand information given to subjects will activate the enjoyment of a soft drink with respect to various different regions of the brain
McClure, Laibson, Loewenstein, & Cohen (2004a)	Temporal preferences for monetary stimuli	Neural bases for discounting alternative premiums	fMRI	Short-term premiums activate limbic regions, long-term premiums are processed in the prefrontal cortex

Table 2: overview of first neuroeconomics research projects (chronological order)

An initial and common result of these studies is that, depending on the stimulus, context and emotional state of the decision-making object, highly varied decision-making processes can be observed (McClure et al. (2004a)). In the following section, the academic rationale for analyzing decision-making processes in a differentiated manner will be considered. Two significant attributes of these decision-making processes are already evident: non-linearity (Bechara, Damasio, Tranel, & Damasio (1997)) and a networked construction of the decision process

(Paulus & Frank (2003)) - the prefrontal cortex thus seems to assume the role of an important hub. The available time also exerts a substantial influence on the prevailing network configuration. Decisions which require a rapid reaction are processed differently to those which can be made over longer periods of time. This also explains why the so-called Stroop Task (for an application see Kerns Kerns et al. (2004)) implies that with a shortening of the decision-making interval, there is a correspondingly drastic increase in the rate of errors.[3] Against this background, it is surprising that only a few neuroeconomists work with the MEG, because it provides a sound temporal resolution. Finally, the results obtained in this manner can be used to develop a typology of various different decision-making subjects (for example effective or rational decision makers).

5 Current topics in neuroeconomic research

5.1 Preferences and benefits

Preferences play a substantial role in economic theory (Slovic (1995), pp 364).[4] An important reason for this is its influence on decision-making behavior. In traditional studies, preferences are often reconstructed. As a supplement to this, neuroeconomic research can capture preferences in the process that can be observed through neural activity which correlates with the behavior in question. By so doing, it is possible to associate different preferences with different activity patterns and thus to draw conclusions, for example, as to the elasticity of demand (Camerer et al. (2003)).

An advantage of neuroeconomics is that preferences can be spatially and temporally differentiated according to their development. The statement is based on a supposition that differing preferences - Kahneman differentiated between four types (Kahneman (1994b)) - are "produced" in different places in the brain. If this supposition is confirmed, it would, for example, be possible to determine whether a cigarette smoker would select a particular brand because, for him, it represents a particular demonstrative function or because he is addicted to the smoke from that brand (see Camerer et al. (2003), pp. 12).

The neural bases of the benefit construct constitute a further facet of neuroeconomic research (for a delineation of the concept of benefit and preference see Drakopoulos (1990)). In general, it is extremely difficult to measure the benefits from a good objectively and validly, because it always seems subjective and situation-dependent (see, for example, the criterion of Pareto Optimality which is based on this assumption). However, neuroeconomic methodologies can overcome these difficulties, because, in general, for many decisions, activation can be observed in the so-called "reward areas" of the brain (Erk et al. (2002)). If it were possible to develop a category for measuring this activation, this could then be used as an instrument for measuring subjective benefit. The "benefits balance" of a measure which could affect two or more people, would then be objectively measurable.

The influence that neuroeconomics has already exerted on researching the benefit construct, becomes evident when considering the utility of money. In classical economic theory, the utility of money is always derived. One can neither eat nor drink it and money cannot satisfy needs. Money is only useful, because a certain amount facilitates the acquisition of goods. However, this can only explain in part, why certain people still attempt to maximize their income even when this may lead them to ruin (addiction to gambling, for example). Neuroeconomic studies prove that money income activates so-called "reward areas" in the brain. Accordingly, the utility of money is not, as previously assumed, only derived, but also intrinsic.

The research of hedonistic behavior aims in a similar direction. People who reveal such behavior often derive utility not from the use of a particular good, but from the purchasing experience itself. It is well known that compulsive buyers often barely use the goods they purchase, but proceed directly to buy new ones. It can be assumed that such behavior is similarly accompanied by an activation of reward areas in the brain. The following section will demonstrate that hedonistic behavior can invalidate a significant premise of decision theory, namely the transitivity axiom. This axiom requires that when the following applies:

(x') > (x), it is not possible for

(x) > (x') to occur.

(x) and (x') represent two bundles of goods. The validity of this mathematically extremely important premise has been contentiously debated in the literature ({Humphrey, 2001 #8596). There are many studies in which it has been broken. The most well-known phenomena are the money pump problem and the problem of reverse preferences. From the neuroeconomic perspective, a possible explanation is that the exchange of a good in itself can create utility which exceeds the negative utility of sacrificing the necessary monetary outlay[5]

Finally, the first studies on the subject of "temporal preferences“ prove that guaranteed short-term premium payments are subject to a different decision-making process than long-term payments ({McClure, 2004 #8604}). This has already led to a modification of the previous model.

5.2 Fairness, trust, altruism

In classical theoretical approaches, the ideal image of the "Bayesian maximizer" is suggested. This image is characterized by behavior which maximizes one's own subjective (expected) utility. If these premises are confronted with the data acquired from experiments, various theoretical problems arise (see e. g. Kahneman (1994a), Frey (1990)). Accordingly, in the context of the Ultimatum Game, it becomes evident that people often behave fairly, rather than purely to maximize their own benefit. With the aid of the fMRI, Sanfey et al. were able to prove that **fairness** is typically associated with activations in particular regions of the brain, more precisely, the anterior insula and the dorsolateral, prefrontal cortex (Sanfey et al. (2003)). These areas probably play an important role in integrating emotions into neural decision-making processes. Their role presumably derives from evolutionary processes. In an analogous manner, the economists Bolton and Ockenfels believe that fair behavior is ultimately associated with evolution (Bolton & Ockenfels (2000), p. 189). More recent evolution-theory studies support this supposition and demonstrate that both fairness and defection inevitably occur in groups (Doebeli, Hauert, & Killingback (2004)).

The Certainty Effect constitutes an additional, significant object of investigation (see e. g. Conlisk (1989), p. 392). From the work of Tversky and Kahnemann, we know that a more certain alternative will be preferred even when its expected value lies substantially below that of another, more risky alternative. From a neuroeconomic perspective, this supposition seems credible, that more certain decisions will lead to an immediate activation of reward centers in the brain. This then implies that the uncertain alternative will not be considered. Thus far, there are no empirical results to support this proposition. The following table provides an overview of the generally known cognitive anomalies in decision theory which can be regarded as potential neuroeconomic objects of investigation (Eisenführ & Weber (2003), pp. 366).

Characteristic/Attribute	Observation
Memory and Recall	
Reconstructed Memory	Imperfect memories are rebuilt using contemporary cues and historical exemplars
Primacy/Recency	Initial and recent experiences are remembered selectively
Selective Memory	Coincidences are remembered, non-coincidences are not
Telescoping	Compression of history
Perception and Beliefs	
Anchoring	Judgments are influenced by quantitative cue contained in the decision task
Availability	Responses rely too heavily on readily retrieved information, and too little on background information
Context/Framing	History and framing of the decision task influence perception and motivation
Prominence/Order	The format of the decision task or order of task, influences the weight given to different aspects
Prospect	Inconsistent probability calculus, asymmetry in gains and losses
Regression	Idiosyncratic causes attached to fluctuations, regression to the mean underestimated
Representativeness	High conditional probabilities induce overestimates of unconditional probabilities
Task Definitions and Decision Process	
Constructual	Cognitive Task misconstructed, preferences constructed endogenously
Prevarication/Projection	Misrepresentation for real or perceived strategic advantages or to reinforce and project self-image.
Reference Point	Choices are evaluated in terms of changes from a status quo point.
Rule-Driven	Choice guided by principles, analogies and exemplars rather than utilitarian calculus; rules induce pro forma, focal responses.
Saliency	Inconsistency in selecting and weighting information judged relevant to decision task
Status Quo/Endowment	Current Status and history are favored relative to alternatives not experienced
Superstition/Credulity	Causal explanations for coincidences are accepted too readily
Suspicion	Subjects mistrust offers and question motives of others in unfamiliar situations
Temporal	Time discounting is temporally inconsistent, instant gratification

Table 2: Cognitive Anomalies (see McFadden (2004))

Similar roots such as fairness presumably lie at the basis of the construct of trust.[6] This would seem to be the case, because the emergence of cooperative relationships is often associated with initial and risky activities of one form or another. **Trust** is generally defined formally as a **rational calculation**. Accordingly, Coleman presents a model of trust-related decisions that comprises three variables: 1) p, the likelihood of making a profit (a gain). This equals the probability that the recipient of trust actually behaves in a trustworthy manner; 2) L (for Losses), the potential loss that occurs if trust is breached and 3) G (gain), the potential gain if the recipient of trust in fact proves to be trustworthy. The normative hypothesis of this model is that an actor will always be accorded trust when the following assumption applies:

$$p*G > (1-p)*L$$

This model seems convincing, but leaves a number of open questions: how would the giver of trust determine the exact value of p in a new situation, for example at the beginning of a new business relationship? Where would an individual who is capable of learning, acquire the courage to initiate regular cooperative ventures by means of a risky initial transaction or activity, if all actors behave opportunistically by definition?[7] And why would there be co-operation between individuals in biological systems where the individuals are not fully aware of or able to undertake probability calculations (Axelrod (2000), pp. 80). It seems far more realistic that confidence is given on the basis of simple and often emotionally characterized heuristics and then reciprocated within certain limits.

The existence of altruistic behavior is also theoretically questionable. For example this manifests itself in that Person A accepts monetary disadvantages in order to constrain asocial behavior from another Person B even though Person A is not directly affected by the negative behavior. What point would such behavior have for A? By using PET, a research group led by Ernst Fehr was able to prove that altruistic behavior leads to an activation of reward regions in the brain and can thus create certain benefits and utility (de Quervain et al. (2004)). Obviously, the abovementioned Person A behaved altruistically, because for him personally, the cost of such behavior is rewarded (by his brain!).

5.3 Memory, learning and knowledge

The economic relevance of the subject of **memory**[8] can be depicted very clearly in the context of business communications policy. Brand and company recall and recognition are essential psychographic goals of communication strategies. In order to achieve this objective, knowledge about the fundamental manner in which people absorb, process, and store information is necessary. This issue simultaneously forms an essential research area in the cognitive neurosciences.

Against this background, if one considers that in Germany, approximately €20 billion each year are spent on advertising investment (Homburg & Krohmer (2003), p. 621) of which, according to general opinion, a large proportion has no effect at all, it is evident that substantial inefficiency can be assumed to prevail. A successful and practical application of neuroeconomics in this area is likely, therefore, to have substantial economic implications. At present, two general trends can be determined. Firstly, memory is organized in phases or stages. Secondly, memory content is frequently located at different areas within the brain (e. g. Jokeit, Heger, Ebner, & Markowitsch (1998) and for an overview see Rösler, Lüer, & Kluwe (2002)).

The issue of exactly which neural processes influence learning, for example, by customers, employees and investors, is closely associated with the subject of neuroeconomics. It is well known that explicit knowledge is learnt more quickly than implicit. Furthermore, from the work of Eric C. Kandel, we know that for learning purposes, a fundamental conditioning often occurs if the particular stimulus (a noise, for example) is preceded with a specific time lag (see Kandel & Hawkins (1992)). Thirdly, it has been proven that long-term memory is based on a synthesis of more recent proteins and the formation and extension of new synaptic connections and can therefore be observed. By so doing, new approaches to economic research are recognizable in this important area.

If one regards **knowledge** as "individual problem-solving capabilities", it is evident that memory and learning are the fundamental bases of knowledge. Consequently, if one wishes to be successful over time in the area of knowledge management, it seems essential to develop a neurologically-based theory of the development of knowledge, the basis of which has already been discussed and in which the concepts of learning and memory play a central role.

5.4 Dual-Process -Theory debate

There is a historically grown and to date non-consensual debate about the mechanisms human emotion, cognition, memory, information processing, and behavior are based on (see e. g. Zajonc (1980), Lazarus (1982), and for a review on dual process models see Smith & DeCoster (2000)). By localizing brain activity during specific cognitive tasks and relating these functions neuroanatomically, methods of functional brain imaging are able to visualize different dissociated neural networks which are assumed to be responsible for memory, behavior, cognition and integrating emotion into decision making (Bechara et al. (1997)). Thus, neuroeconomic studies seem to be a promising approach to gain new insights for dual-process theories.

6 Discussion and future prospects

The potential of building on an inductive process to develop new theories of economically relevant patterns of behavior is generally considered a fundamental advantage of combining economics with neurology (Glimcher & Rustichini (2004)).

At present, there is a particular emphasis on investigating decision-making processes which have already been conducted isolated for decades in both disciplines. The interdisciplinary exchange is likely to provide new impulses. Nonetheless, the potential offered by neuroeconomic research is limited.

For one thing, neuroeconomic projects are very personnel cost and time intensive. Few economic research institutes are likely in future to have access to the necessary and very substantial resources required to purchase an fMRI scanner, for example. The development of synergistic research projects may provide a solution to the problem. In this context, both clinical and economic issues can be investigated. An example of a possible application would be the investigation of different forms of addictive behavior.

On the other hand, the application of neurological methods is associated with diverse legal and moral considerations, such as a lack of problematic ethical issues and the agreement of respondents. There is no end to these ethical and legal discussions in sight, and indeed they have not really even begun.

Nonetheless, the neuroeconomic approach seems fundamentally suited to a further development of economic theory. In particular, a contribution to a better explanation of economically relevant behavior can be expected. This could then be used to increase the predictive power of economic models and to base them on more realistic assumptions. The initial characteristics of these new models are:

1. **Non-linearity**: decision-making processes do not proceed according to the pattern "the more, the better", but rather according to the pattern "yes/no". They have a discreet character at the individual level.

2. **Problem-solving orientation**: over the last few years, the notion of the Bayesian maximizer has become progressively discredited. It has been replaced by the notion that people do not attempt to maximize a particular goal category, but to solve problems (see Slovic, 1995, p. 369). The analysis of various methods of resolving real economic problems should, therefore,

become a more important element of economic research.

3. **Network structure**: There is no such thing like one single decision-making region in the human brain which is responsible for decision-making processes. Rather, the brain can be considered allegorically as an orchestra comprising several instruments which serve different functions in producing a variety of musical pieces.

4. **Asymmetry between positive and negative stimuli**. Positive stimuli are often processed in so-called "reward regions", while negative stimuli such as fear and anxiety are processed in the limbic system, for example in the amygdala (LeDoux (2000), Seidenbecher, Laxmi, Stork, & Pape (2003)).The extent to which both regions interrelate with respect, for example, to simultaneous gains and losses and whether there are compensatory relationships, remains unclear.

5. **Irrelevance of probabilities**: diverse paradoxes in game and decision-theory experiments can be attributed to the fact that the human brain has not mastered the relatively new concept of probability accounting.[9] Consequently, there is the danger of capturing epiphenomena. Rather, decision-making strategies tend to have a heuristic character which can be influenced emotionally (Slovic (2002)).This may apply particularly to those decisions which are primarily intuitive or impulsive.

6. **Taking time into account**: the temporal execution of a decision-making process seems to exert a substantial influence on the quality of the decision. In experimental terms, this is evident from the several investigations (e. g. McClure et al. (2004a)).

7. **The cognition/emotion debate**: Despite the seemingly relevance of emotion in human existence and human behavior, scientist concerned with human nature have not yet been able to reach a consensus about the role of emotion in a theory of mind and behavior.

8. **The role of the mind/body debate**: in the business administration and economic literature there is often a clear distinction between the neurobiological and psychic processes. If

one considers the more recent developments in neurology, this distinction is becoming increasingly obsolete (Damasio (1994)). Damasio suggests that neurobiological processes seem to be the basis of psychic processes.

Despite these initial results, neuroeconomics has so far not been able to make substantial progress in terms of concepts. The researchers limit themselves primarily to familiar phenomena which they investigate with the aid of neuroscientific methods and describe in the language of this discipline. Certainly, diverse studies present neuroeconomic correlates, but they do not attempt to provide a theoretical foundation. New phenomena which would imply the development of an innovative and theory-specific set of concepts are barely discernible to date, yet. A reason for this may be that, at present, most neuroeconomists need to work through the familiar anomalies discussed earlier in this text, before they turn their attention to developing new questions and concepts. Although this process is legitimate, it may entail foregoing the opportunity to provide a radical new start to descriptive decision-making theory.

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[1] An overview can be found at http://www.richard.peterson.net/Neuroeconomics.htm.

[2] The following firms are examples: Market Psychology Consulting. (Finance) San Francisco, CA, USA; Neurosense

Limited. Oxford, UK; Brighthouse Neurostrategies Group. Atlanta, GA, USA; SalesBrain, LLC. San Francisco, CA, USA and Paris, France; Shop Consult. Amstetten, Austria.END

[3] The "Mouse Lab" experiments of Schkade and Johnson (1989) provide the economic equivalent.

[4] If one currently looks up the concept of "preferences" in the EBSCO data bank, there are 15,000 contributions in academic publications.

[5] Accordingly, the contravention of this premise does not reduce the grave associated mathematical consequences

[6] Vgl. http://fac.cgu.edu/~zakp/CNS/projects.htm

[7] The familiar "tit-for-tat" strategy is characterised precisely by the fact that the first move is one of trust. See Axelrod, 2000, S. 12.

[8] Memory should be regarded here as closely associated with the work of Markowitsch (2002:100), and thus, in general, as the storage of new information which can be recalled as memory.

[9] “When it comes to quantifying probability evaluations precisely, people are not used to doing this and in fact rail against it", Eisenführ/Weber, 2003, p. 151.