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FOUNDATIONS OF NEUROECONOMICS AS AN ACADEMIC FIELD IN BULGARIA

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Abstract

The pioneering and innovative research in Bulgaria in the field of neuroeconomics uses fMRI (functional magnetic resonance imaging) and the BOLD method (Blood Oxygenation Level Dependent). We will explain the methods and scientific base of neuroeconomics with real experiments in that new scientific field. The experiments are made in a lab situated in university hospital UMBAL "St. Ivan Rilski" using GE Signa HDxt 1.5T scanner and specialized equipment of the Nordic Neuro Lab for audio-video psychological paradigms and brain stimulation. This unique and original research for the Bulgarian scientific community employs an interdisciplinary field of neuroeconomics to explain human behaviour and decision making and might be perceived as a foundation of the neuroeconomics as an academic field in Bulgaria.

Key words: neuroeconomics in Bulgaria, fMRI experiments

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Introduction

The economic paradigm of the rational choice of the *homo economicus* and utility maximization does not succeed in adopting the complexity of decision-making by the individuals and does not take into account the complexity of the neuronal activity of the brain, its biochemistry, the cognitive psychological biases and the human emotions. The advances in decision making under risk and uncertainties i.e. in economics, naturally led to the fact that the behavioral economics become a mainstream school in the economic science (Kahneman & Tversky, 1979; Kahneman, Slovic & Tversky, 1982; Gilovich, Griffin, Kahneman, 2002; Pompian, 2006; Thaler, Sunstein, 2012; Kahneman, 2013). This school in economics has its famous Nobel laureates – Daniel Kahneman (2002), Robert Schiller (2013) and Richard Thaler (2017) – and offers a descriptive explanation of the human behavior and decision making by using lab experiments and big data analyses of the financial markets. Thus, the irrationality of the humans and the reasons for the systematic diverting from the rational choice paradigm are now scientifically explained by behavioral economics. The growing understanding of

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the psychic and neurobiological processes originating from the central human nervous system led to an expansion of interdisciplinarity in science. At the same time the rapidly growing development of the computer and neuro-cognitive sciences additionally accelerated the introduction of the interdisciplinarity in almost all scientific schools in the 21st c. The neuro-cognitive sciences study the higher cognitive functions of the human brain and the related neuronal activity of the brain. This science is a complex and integrated approach, which includes cognitive science, psychology, neuroscience, and neurolinguistics. The two basic schools in the neuro-cognitive science are: experimental-behavioral and computational modeling. The aim of both schools is to understand the nature, the essence of the cognitive abilities of the humans by the neuronal activity in the brain and the complex nature of brain activation. Because of the rapid development of these scientific and technological processes, neuroeconomics, as a science, has emerged. This newest economic science (Dorris and Glimcher, 2004; Camerer et al., 2005; Caplin and Dean, 2008; Glimcher, 2011) is an enhanced continuation of behavioral economics and behavioral finance, combining them both with the neuro-cognitive sciences. Neuroeconomics is described by Colin Camerer as *"...a specialization of behavioral economics that plans to use neural data to create a mathematical and neurally disciplined approach to the microfoundation of economics"* (Camerer, 2008, p. 44). Neuroeconomics is a highly experimental science and since the beginning of the 21 c. *"Neuroscientists have run thousands of such experiments, and they have learned to expect particular regions of the brain to "light up" – indicating increased flow of oxygen, which suggests heightened neural activity – depending on the nature of the task. Different regions are active when the individual attends to a visual object, imagines kicking a ball, recognizes a face, or thinks of a house. Other regions light up when the individual is emotionally aroused, is in conflict, or concentrates on solving a problem"* (Kahneman, 2011: p. 366). Based on the academic advances in the field of neuroeconomics and for the purposes of this study we will use a definition of neuroeconomics as a scientific field given by the Society for Neuroeconomics – *"Neuroeconomics combines the rigorous modeling from economics with psychological studies of social and emotional influences on decision making, and utilizes tools from neuroscience that permit the observation of otherwise latent valuation and decision-making computations that take place in the brain"*. Neuroeconomics uses scientific advances and the emerging possibility to employ functional magnetic resonance imaging (fMRI) to study in real time the neuronal activity of the brain areas to understand human decision making and the reasons for their economic choices. The fMRI along with the additional equipment for psychological paradigms (psychological tasks) and supply of audio-video images (static and dynamic) provides an opportunity for volunteers

to be tested by the Blood Oxygenation Level Dependent (BOLD) method and to observe in real time brain activation. BOLD imaging is the standard technique used to generate images in fMRI studies and relies on regional differences in cerebral blood flow to delineate regional activity of the brain. This technology and scientific method are non-invasive and safe for human health. By the changes in the cerebral blood flow of the brain regions, we do understand which area of the central nervous system is activated and when. Thus, we may produce a cartography of the activated brain areas like the hand motor cortex responsible for relatively simple actions like lifting a pencil, but also of extremely complex cognitive activities such as understanding a spoken foreign language. Thus, the method gives us also a possibility to observe real time brain activation during representation of stimuli and psychological paradigms. Our experiment *(The Heads and Tails)* and psychological paradigm research brain activation when betting money i.e. making a choice under risk and uncertainties. Our aim is to research and to confirm different brain activation in the case of betting of hypothetical and real money. The grounds of this method is imaging the increased neuronal activity which emerges because of the blood flow in the brain areas and the increased level of oxygen and glucose (contained in the blood), which is precisely reflected in the images from the scanner. The research method brain magnetic resonance imaging with contrast dependent on blood oxygenation was introduced for medical purposes in the beginning of the 1990s by the Japanese biophysicist Ogawa (Ogawa et al., 1990). Wider accessibility of the fMRI and quality improvement of collected data, their higher resolution, the space-temporal synchronization and the increased possibility for their quantitative and qualitative processing by specialized software, lead to the wider dissemination of the approach, and not only. As a result, fMRI audio-video stimuli, games, tasks, etc. psychological paradigms (psychological experiments and tasks) to confirm or reject a certain scientific hypothesis become very popular. Psychological paradigms nowadays not only aim to image neuronal activity, but also to make a comprehensive study of the interconnected brain activations and their complex understanding and analysis. The latest applications of the fMRI are in the field of the neuro-cognitive sciences, neuroeconomics and neuromarketing (Lindstrom, 2008). Currently, the BOLD method and the fMRI are leading methods in imaging diagnostics and are a preferred medical standard. The greatest advantages of the method are its safety – noninvasive with no ionizing radiation, gamma radiation and application of radiopharmaceuticals. The experiments and data collecting are fast and precise, and the received resolution of the images is with precision of up to 1 mm in diameter. So the above mentioned essential advantages of the fMRI and BOLD methods for neuroeconomics research make a real difference with the alternative methods: the positron emission tomography (PET), the X-ray

examination (computer tomography, CT), the Intracarotid Amobarbital Test (IAT), electroencephalography, and the magnetic encephalography.

Neuroeconomics in Bulgaria

The establishment of neuroeconomics in the Republic of Bulgaria begins in 2012, when Doctor Boyan Ivantchev and Doctor Marin Penkov began a discussion and a theoretic development of the new for the country research and diagnostic methods in the field of the functional research of the brain by magnetic resonance imaging. On 17.07.2014, Ivantchev and Penkov began practical experiments in the field of the functional research of the central nervous system (CNS) with the use of fMRI "GE Signa HDxt" 1,5 T magnet strength on the territory of UMBAL "St. Ivan Rilski" EAD, Sofia. Such a specialized and unique equipment in the city of Sofia exists only on the territory of UMBAL "St. Ivan Rilski" EAD. In parallel with this scientific work, one of the researchers published several related research and experiments in the field of behavioural economics and behavioural finance (Иванчев, 2013, 2017; Ivanchev, 2015, 2018). As a result of the scientific experiments and the gained scientific experience of the researchers under a set by them specification, several innovative practices [1] and equipment were introduced in the department of radiology in UMBAL "St. Ivan Rilski" EAD:

a) Post-processing of images received during the functional testing of the brain;

b) Post-processing giving an opportunity for the merging of images received in the functional testing of the brain with treatise images, as well as a review and processing of the received set of data;

c) Decrease of the artefacts from movement in the diagnostics of the head, spine, body and muscle-skeleton system; Non-contrast imaging of the tissue perfusion and quantitative assessment of the brain blood flow;

d) Post-processing of brain images – ASL (quantitative and qualitative assessment and diagnostics of the blood flow in the arterial vessels of the brain); Installation of an updated software platform Scan Tools 23.0 for diagnostics;

e) Upgrade of the basic computer of the magnetic resonance system to 16 transmission channels;

f) A possibility for the reconstruction of minimum 13 000 FFT/S (in a matrix 256x256 and full FOV).

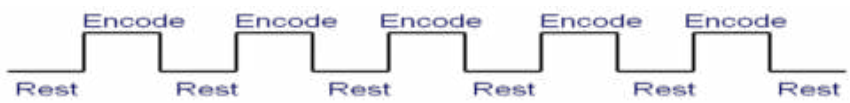
The Heads and Tails Experiment

For the first time in the scientific and medical practice in Bulgaria, a cognitive psychological paradigm was created for the research and diagnostics of the

reactions of the CNS in decision-making under risk and uncertainty, and in particular, diagnostics of the brain reactions in decision-making on the basis of hypothetical and real money choice. Our scientific hypothesis was that betting real and hypothetical money will be perceived differently and will cause a different activation of the central nervous system. The psychological paradigm is based on the highest achievements in cognitive psychology (De Mey, 1992) and behavioral science and its highest technical application in modern economics – neuroeconomics.

Design of the Paradigm

The design of the psychological paradigm was developed by Doctor Boyan Ivantchev, while the experiment was performed in collaboration with Doctor Marin Penkov at UMBAL "St. Ivan Rilski"EAD by using General Electric Signa HDxt 1,5T scanner and specialized devices and equipment of Nordic Neuro Lab [2] – the nordicActiva Software (paradigm machine) and the Nordic Visual System. It is of great importance to clarify that to apply and use the "Head and Tails" paradigm the team had to recode part of the software (stimuli presentation) of the NordicActiva Software by using computer language – Extensible Markup Language (XML). That was necessary because there is no standard equipment for a neuroeconomic research and the software must be adapted to the needs of the scientific experiments and goals. The experiment employs the fMRI BOLD Method and the illustrated below scheme of Block Experimental Design:



Source: Bulgarian Neurocognitive Lab Ltd.

Figure 1: Block Experimental Design ((Stimuli 30sec. + Resting State 30sec.) x (5 repetition)).

The experiment uses a series of five stimuli "question – choice" during the block of stimulation of 30 seconds. Each one of the stimuli is sent to the experiment participant by the audio system (Audio System HP), which is especially adapted for scanner 1,5T magnet strength. The scientific audio stimuli standards for brain activation are based on a minimum of 3 seconds and due to that the selected series and time stimulation are scientifically correct.

Working Hypothesis

The working hypothesis of the psychological paradigm: We hypothesized that during the experiment we will see "lighting up" i.e. activation of the prefrontal cortex (PFC) areas of the brain (this brain region has been implicated in planning complex cognitive behavior, personality expression, decision making, and moderating social behaviour.). Respectively we hypothesized that we will have differences and deviations according to a different stimuli – real or hypothetical money – delivered to the participants of the experiment.

Stimuli

Stimulus 1 – A series of five questions and choices with the result of a loss or a profit of hypothetical money.

Stimulus 2 – A series of five questions and choices with the result of a loss or a profit of real money.

The aim is to establish the neurobiological processes flowing in the brain, and as a result of the paradigm they should be three dimensionally and accurately illustrated. It is proved that the focal increase of the brain blood flow may be referred directly to the neuronal activity. Because the brain metabolism of the glucose (CMRglu) and the brain blood flow are related, this dependency leads to the conclusion that the brain metabolite levels of oxygen (CMRO2) are connected with the brain blood flow. As fMRI measures the vascular hemodynamic response inducted by neurologic activity, it is necessary to know the chain sequence of the activated area. An action or an audio-video stimulation and presentation of psychological task (paradigm) of the volunteer tested leads to an increase in the axonal or electrical activity in a certain brain area. Which, for its part, starts an increase in the blood flow and the blood volume as well as an increased glucose and oxygen metabolism.

Participants

Eleven (six male and five female) physically and psychiatrically healthy volunteers participated in the study and the "Heads and Tails experiment". One of the male volunteers was eliminated, because of the artifacts during the experiment.

Informed agreement and additional requirements

Before entering, the scanner volunteers were comprehensively informed about the safety and fMRI experiment and were asked to sign informed agreement for participation in the experiment, as follows: a medical form of UMBAL "St. Ivan Rilski"; a form prepared particularly for the study objective and a psychological paradigm of the testing. All the participants were with dominant left hemisphere (they used their right hand) and free of narcotic substances and relaxants, which might compromise the testing results.

Technical Parameters of the Research

All the participants were scanned on the 1.5 T MRI scanner Signa HD xt General Electric and with 8HR BRAIN head antenna.

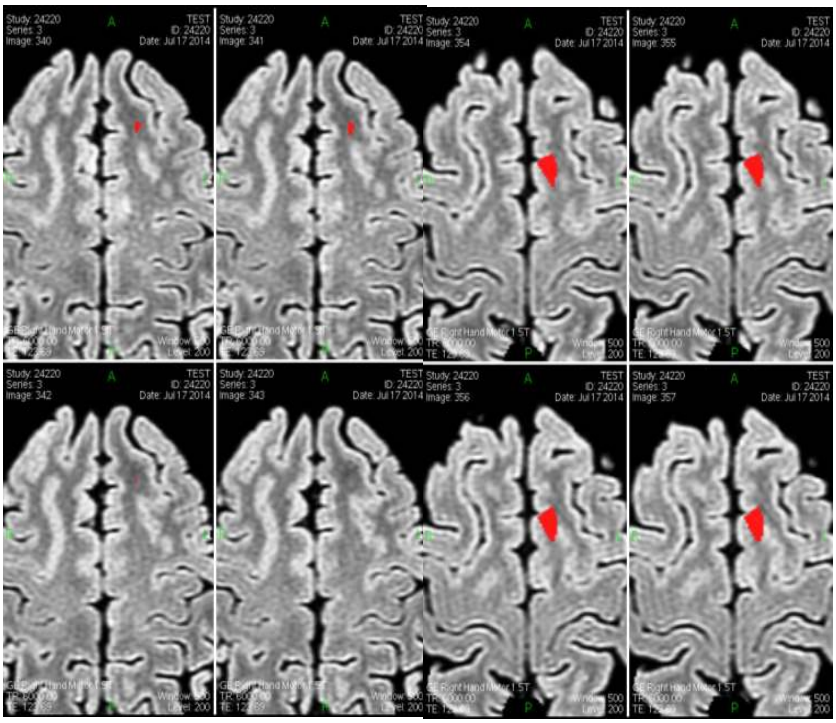
Sequences

Anatomic: SAG T2 FLAIR CUBE (TE 140ms; TR 6000 ms; Flip Angle FOV 22.4 Matrix 256/256 thickness of the cut 1.8 mm step 0).

Functional: T2* BOLD 2D Gradient Echo; EPI, Asset, FMRI (TE 40 ms; TR 3000ms Flip Angle 90; FOV 24 cm; thickness of the cut 4mm; step 0.

Results

The activation of the brain areas was presented in visual color scales superimposed on a calibrated in advance 3D card of the brain folds. A FLAIR CUBE sequence was used for the anatomic brain mapping. On it, an image was fused from the fMRI BOLD methods in a color scale, giving a visual idea of the level of activation of the cerebral cortex, where the most saturated color corresponds to the highest activation. Based on the experiments conducted with the individual participants, a different level of activation of the brain parenchyma was reported, which is related to the conscious emotions. These were the areas of the prefrontal cortex of the dominant hemisphere. Thus, brain areas are related to an initially low emotional level, as the presence of activation of the brain parenchyma in the field of the Amygdala in the left and the left hippocampus and the ventrolateral hypothalamus. The difference of the activation level is clearly expressed in the experiment with hypothetical money (Image A) and the experiment with real money (Image B), while in the latter there is a distinct increase of the activation area, not only in volume but also in saturation of the signal:



Source: Bulgarian Neurocognitive Lab Ltd.

Figure 2: Image A (Left) and Image B (Wright)

Analysis of the Results

On the basis of the experiment conducted, a distinct difference is observed of the activations of the CNS in decision-making with hypothetical and real money. When the participants make decisions during the game "Heads and Tails" with real money, there is a significantly greater activity in the brain area of the medial prefrontal cortex and the Front Gyrus Cinguli. This finding scientifically confirms our hypothesis and conclusion that during the real money decision-making process, the cognitive functions of the human brain are more intense and are not comparable with the case when the decision-making is based on a hypothetical money choice.

Conclusion

The above mentioned results and conclusions are of crucial importance for the real benefit of demo trading accounts on the forex and capital markets. Thus our firm conclusion is that there is no benefit of demo trading accounts for traders

who are trying to obtain a practical understanding and experience on the financial markets. This is so due to the low activation of the brain in decision-making with hypothetical money, i.e. in trading with a demo account and hypothetical money. While we explain this difference and the phenomenon of the real money, we may prevent those wishing to trade on the forex and capital markets from holding the fallacy that the results, achieved by demo trading account are comparable or that they are a guarantee for the results that will be achieved in trading with real money. The results of this research may protect a multitude of people all over the world from great losses on the financial markets and deterioration of their financial position and loss of family savings and wealth. The "Heads and Tails" experiment as such marks the beginning and fundament of the neuroeconomics research in the Republic of Bulgaria. This experiment is part of the theoretical and practical research and experiments made by Dr Ivantchev and Dr Penkov under the "Innovation and Competitiveness" Operational Program 2014 – 2020 – Project: BG16RFOP002 – 1.002 – 0044 "Developing innovative methodology for researches in the field of the neuro and cognitive science and theoretical and practical foundations of Neuroeconomics and Neuromarketing". The above mentioned innovative methodology was successfully concluded and verified by the Operational Program in the year 2019. Therefore we would be able to say that the innovative methodology for research in the field of neuro and cognitive science and the theoretical and practical foundations of Neuroeconomics and Neuromarketing were established successfully in Bulgaria. Now we have a fully operational experimental base for neuroeconomic and neuromarketing research and experiments. The laboratory is situated in UMBAL "St. Ivan Rilski" EAD and is fully operational. The introduction of the innovative methods, techniques and analyses allows reaching beyond the localization of the neuronal activity and beyond the simple mapping of the brain areas, associated with certain stimuli, tasks and paradigms. The established set of methods proves the different activation of the central nervous system in decision-making with hypothetical and real money, while there are not many similar scientific experiments (Miyapuram, Tobler, Gregorios-Pippas & Schultz, 2012) and conclusions in the academic literature. We believe the research contributes to the international level in the field of neuroeconomics, arguing that demo account trading is useless for the future decision making and so is real money trading, because of different brain mechanisms activated during decision making process. Hence, we are arguing, that the results from the demo trading on financial markets, based on hypothetical money decision making process, are misleading and might destroy the trader's wealth and cause multiple damage in the asset management industry. Our innovative research methodology will continue in the future in the field of neuroeconomics, neuromarketing and neurosciences. The achieved knowledge and skills may be applied – on the level of individuals – to the Bulgarian society –

to train and improve their financial literacy, savings and investments and to avoid irrational economic choices as well as on the level of institutional investors, asset managers, insurance and bank institutions and mutual funds.

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Notes

[1] There is a Reference letter (2016) signed by the director of the UMBAL "St. Ivan Rilski" EAD about the innovative practices introduced by Ivantchev and Penkov

[2] The Nordic Neuro Lab equipment is bought by the Bulgarian Neurocognitive Lab Ltd. and is funded by Operational Program "Innovation and Competitiveness" 2014 – 2020 by a total value of 434 148,40BGN.

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