Chapter 5
Neuroeconomics: Genesis and Essence

Danuta Miłaszewicz

Abstract Making choices and decisions is one of the most important issues in the theory of economics. Neuroeconomics is a subfield of behavioral economics which uses empirical evidence of limits on computation, willpower and greed to inspire new theories of economics. The aim of chapter is to present the milestone on the development path of neuroeconomics, the essence of this science and areas of its researches. The literature analysis method and the induction and deduction method are applied here.

Keywords Neuroeconomics • Definition • Creation • Research areas

5.1 Introduction

Neurosciences which, "analyze the nervous system, including the brain, to understand the biological basis for behavior" (Bloom 2008: 3) have the capacity for the scientific examination what processes occur in the human brain during thinking, feeling, wishing, learning, or entering interactions with the surrounding environment. Undertaking the attempt to clarify thought processes, feelings, emotions, decision-making processes (choice or lack of choice) allows us to explain and anticipate conducts and attitudes of people. The dynamic development of this science has become on the other hand the basis to deepen searches conducted within the scope of other disciplines, going far beyond medicine. Thanks to the above mentioned, such disciplines of knowledge as neuropsychiatry, neuroinformatics, neuropsychology, neurocognitive science, neurophilosophy, neurodidactics (neuroeducation), neurosociology, neuromarketing, neuromanagement, neuroleadership, neuroaccounting or neuroeconomics have been developed. The latter one in general may be determined as the field developing slightly beyond the main stream of economics. The interdisciplinary approach implementing the

D. Miłaszewicz (✉)
Department of Macroeconomics, Faculty of Economics and Management,
Institute of Economics, University of Szczecin, Mickiewicza 64, Szczecin 71-101, Poland
e-mail: dmilasz@wneiz.pl

K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_5

possibilities of the brain imaging and cognitive neuroscience to deepen the knowledge in the field of economics. Neuroeconomics has emerged on the canvas of the neoclassical economy, or rather criticism of its assumptions with regard to microfoundations for individual's decisions. Utilizing new research methods and techniques, it criticizes assumptions and creates new possibilities with regard to the clarification of economic decisions undertaking processes.

The main goal of the study refers to the presentation of the genesis of neuroeconomics, its essence, research areas with the specification what possibilities have occurred in the field of economic decisions studying in relation to the implementation of advanced technologies of the brain imaging. The execution of that purpose requires the implementation of the method for the subject matter literature analysis and tits synthesis.

5.2 Milestones Toward the Creation of Neuroscience

One of the most important issues in the theory of neoclassical economics refers to the manner of undertaking economic decisions by individuals. According to its assumptions, it takes place in a rational manner—the individual operates in compliance with its own function of utility, undertaking economic decisions on the basis of full information (the assumption on the absolute knowledge[1]), with the unlimited possibilities, the individual acts in its own interest, in such a manner so as to maximize the expected utility and the individual follows preferences which meet determined requirements—axioms.

The theory of the expected utility has been often criticized, pointing out that in reality the individual does not undertake decisions according to the manner highlighted by the theory. The need for modification occurred first of all when it started to be perceived also as the descriptive theory, that is, the theory describing how a rational individual behaves and how to use it in that role for other economic models. Very often, researchers have formulated rules governing the expected utility hypothesis on the basis of conducted experiments, based on the game theory. The purpose of such experiments referred to the examination of individual preferences and choices as well as the presentation of the individual's decision-making processes occurring in reality. Such experiments may be considered as the first milestone on the development path of neuroeconomics. Their results created the foundation to formulate examples which did not confirm the postulate of the expected utility (so called paradoxes of rationality, that is, the discrepancy between the theory and reality, e.g. Allias in 1953, Ellsberg in 1961). Moreover, such

[1]The hypothesis regarding the absolute knowledge means that the researcher assumes that people undertake economic decisions in such a manner as if they knew all the facts which in reality could exert influence on their decisions.

experiments highlighted a series of inconsistencies between actual conducts of persons examined (players) and theoretical optimal conducts models (axioms).

The second milestone leading to the neuroeconomics development shall refer to the works of Herbert A. Simon, who has elaborated a limited rationality concept. As one of the first, he criticized and negated the paradigm adopted in economic sciences, and in particular the assumption on ideal rationality with undertaking economic decisions as unrealistic ones due to a limited cognitive capacity of the decision maker. The decision maker, in his/her opinion, focuses rather on a satisfactory choice, satisfying certain adopted by him/her requirements with the implementation of a limited rationality (Simon 1972, 2000). In spite of the fact that the decision maker attempts to be rational, such rationality has certain visible limits with a dual nature—internal (mental) and external (environmental) limits. The decision maker is limited by intrinsic values, reflexes, skills, social standards and habits, incomplete information on alternative choices, as well as his/her own computational capabilities. Being aware of his/her limited possibilities, the decision maker knowingly ignores information or knowledge, the acquisition of which would outdo benefits that could be brought by such information or knowledge (Simon 1990).

For the purpose of enhancing the current theory and the creation of the more realistic model for making a choice, Simon postulated to refer to the literature in the field of psychology and so called procedural rationality, named by him the psychological theory of rationality. According to Simon, the transition from rationality which denominated the classical economy (instrumental rationality), to procedural rationality requires a change in the manner of approaching the science "from an emphasis on deductive reasoning from a tight system of axioms to an emphasis on detailed empirical exploration of complex algorithms of thought" (Simon 1976: 147).

Simon, recognized as the "behavioral economy prophet" (Barros 2010), believed that one of the tools useful with regard to studies concerning the rational choice hypothesis refers to the creation of a simplified laboratory simulation in order to observe human conducts. Thus, he supported conducted experiments which were not perceived by the traditional economy as reflecting proper research methods (Miłaszewicz 2016: 16–17). On the other hand, the behavioral economy resorts to experiments, in particular, the experimental economy, while their implementation and development shall be considered as a subsequent milestone toward the development of neuroeconomics. The fact that Simon was awarded in 1978 with Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel for his pioneering research into the decision-making process within economic organizations came as a confirmation of the necessity to take into consideration numerous factors within the scope of the economic analysis.

Simon's works supporting the consideration of numerous psychological factors in studying decision-making processes constitute an important step toward the development of the psychological trend of the economy as well as the basis for the so-called "old" behavioral economy (Sent 2005: 230; Altman 2000, s. XVII; Frantz 2013: 13–14). On the other hand, achievements of two psychologists, Daniel

Kahneman and Amos Tversky, referred to by Simon in his Noble Speech (Simon 1978: 361) are directly associated with the "new" behavioral economy.

The reason for differentiating between the "old" and the "new" behavioral economy refers to differences in perceptions of the human brain functioning and normative suggestions regarding rationality. Adopting such approach, the achievements of Simon demonstrate a limited influence on the development of the "new" behavioral economy (Angner and Loewenstein 2012: 659), as the works of Kahneman and Tversky, focusing initially on decision-making mechanisms in conditions of hazards, "started from the rationality assumption that has characterized mainstream economics and next analyzed departures from this yardstick, rather than developing an alternative one" (Sent 2005: 230) and "capture human cognitive biases within a framework of utility maximization" (Bossaerts and Murawski 2015). The basic discriminant of the "new" behavioral economy refers in fact to attempts of the implementation of a bigger dose of reality into the analysis of decision-making processes, however, on the other hand, it is less critical with regard to the neoclassical economy, recognizing instrumental rationality as the model and observing from that perspective actual mechanisms of human conducts as subjected to errors. It introduces the notion of heuristics and the theory of two systems of thinking (quick, automatic, based on associations, emotional thinking *versus* free, rational, conscious thinking) into the studies over decision-making processes (Kahneman 2002: 1451; Kahneman 2012: 31 and others). A. Tversky and D. Kahneman related the notion of heuristics to their conception of cognitive deviations featuring human thinking and decision-making processes. In their understanding, heuristics refer to the strategy of reasoning handled by people in an unconscious manner, ignoring some information and more complex methods of reasoning so that the decision-making process is quick and absorbs less energy (Tversky and Kahneman 1974: 1124; Tversky and Kahneman 1992: 317). Human brain implements heuristics due to cognitive limitations, and heuristics themselves lead to decisions less favorable than optimal ones or they violate axioms of rational decisions.

The fact that D. Kahenem was awarded in 2002 with Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel "for having integrated insights from psychological research into economic science, especially concerning human judgment and decision-making under uncertainty" (The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2002) shall be perceived as a subsequent mile step in the process of neuroeconomics development and recognition of changes of the paradigm in economic sciences. Kaheman obtained the prize together with V. Smith, who was honored "for having established laboratory experiments as a tool in empirical economic analysis, especially in the study of alternative market mechanisms" (The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2002). Those awards strengthened the position of such sub-fields of the economic knowledge as the economic psychology, behavioral economy and experimental economy.

However, V. Smith's perception of rationality presented within the scope of so-called ecological rationality theory, was competitive toward the one presented

by Kaheman. On the canvas of the psychology itself it was developed by G. Gigerenzer and A. Kruglanski. Their point of view was presented in the form of so–called Neurosciences:adaptation rationality adaptation rationality and it is equivalent to the view presented by Smith, as they share not only a critical approach to the realism of neoclassical economy assumptions, but also negation of instrumental rationality as the normative conception. They may be also distinguished by the approach to heuristics themselves. V. Smith is of the opinion that the immanent feature of the human brain and its limited calculation resources (Smith 2005). In the light of adaptation rationality, heuristics are decision-making strategies, rules adopted to solve a given decision-making problem (Evans 2010: 98). They demonstrate a normative and descriptive character, they are based on the compromise between the precision of the forecast and efforts undertaken to assess it. The adaptation decision maker implements heuristics in a conscious manner and strategically modifies them accordingly to the changing surrounding (Sloman 2002: 382; Frederick 2002: 668). Heuristics related to a constant decision-making compromise maintained by the decision maker between the precision of the decision and the cost of its undertaking. Effective decision-making strategies on purpose ignore a part of information. People undertaking decisions in such a manner achieve satisfactory, however, not optimal results (Gigerenzer 2008: 9).

Authors of adaptation rationality highlight that it is not possible to assess decisions exclusively from the perspective of axioms of economic rationality. One shall take into consideration first of all the role of the decision-making environment in which the decision is undertaken, as it determines a better or worse effectiveness of the decision. On the other hand, predispositions and the personality of the decision maker which influence his/her decisions play a role. The above mentioned aspect is more precisely expressed by Gigeranzer himself (2015: vii) highlighting that the basic principle of his research program refers to the claim that "behavior is funcion of mind and enviroment".

Studies maintained within the scope of behavioral economy led to the discovery of the set of mechanisms confirming that the assumed so far by economists rationality of *homo oeconomicus,* exists in principle, however, it demonstrates deviations from the model rationality which in a significant manner decide about the conducts of individuals. Thus, rationality shall be perceived rather as a personal entity and not a subpersonal one (Stanovich 2011: 5).

Numerous regularities in conducts of individuals, confirmed by experiments, highlight the existence of a series of mechanisms, biologically in-built into the human body causing that the choices made by individuals considerably deviate from models stemming from the expected utility. Additionally, such studies have revealed a tremendous complexity of the decision-making aspect. They would have been, however, impossible without the development of medical techniques allowing for a more precise *in vivo* examination of the nervous system and the human brain at the moment of the decision-taking. Such techniques allowed to take a closer look at the brain during its operation and to look for relations between its conditions and states of mind. They allowed to look at the whole spectrum of

aspects in an entirely new manner, empathizing the significant role of unaware and uncontrolled processes in undertaking every day decisions.

First non-invasive methods of examining the living brain were applied in the second half of 20th century. They included: electroencephalography (EEG), computed tomography (CT) and computerized axial *tomography* (CAT), techniques implementing positron emission as positron emission tomography (PET) and single-photon emission computed tomography (SPECT). Other devices applied for that purpose refer to magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI). The most recent methods include: magnetoencephalography (MEG), transcranial magnetic stimulation (TMS) and single neuron imagining (SNI)[2].

Examining the living brain with various methods of neuroimaging created new possibilities with regard to discovering secrets of that organ and it constitutes a subsequent milestone leading to the development of neuroeconomics. Those methods allow to image the activity of various centers of the brain exactly to the millimeter and the millisecond as well as to examine reactions of individual neurons. They enable direct inhibition or activation of such areas with the magnetic field and pharmaceuticals. Their effects are supplemented by techniques of examining various peripheral systems in the human body as well as the study referring to the psychological role of hormones and neurotransmitters. Thanks to such methods and techniques we obtain answers to questions in economy referring to motives of the individual in the decision-making process.

5.3 The Essence of Neuroeconomics

Neuroeconomics refer to a relatively new field of knowledge commenced in 1990s of 20th century. The moment of its birth is associated with the article by M. L. Platt and P. W. Glimcher published in 1999 *Neural correlates of decision variables in parietal cortex,* which formalized for the first time an economic-mathematical approach for the physiological study of decision making, which pointed to potential neurobiological constraints on the algorithmic processes involved in decision making (Sharp et al. 2012).

According to T. Zaleśkiewicz (2013: 446) neuroeconomics refers "to the field of science which examines neuronal correlates of decisions and economic assessments". In the opinion of et al. neuroeconomics is the study of the biological microfoundations of economic cognition (includes memory, preferences, emotions, mental representations, expectations, anticipation, learning, perception, information

[2]The description of methods and devices used for neuro-imaging, that is for examining the structure and functions of the living brain, may be found in: (Kosslyn and Rosenberg 2006: 133–138; Camerer 2007; Jaśkowski 2009: 42–77; Fritz 2011: 18–27; Kable 2011).

processing, inference, simulation, valuation, and the subjective experience of reward) and economic behavior (Camerer et al. 2015: 153).

However, most often neuroeconomics may be defined as an interdisciplinary field that brings together psychology, economics, neuroscience, and computational science to carry out in vivo investigations of the brain processes involved when individuals make economically relevant decisions (Mohr et al. 2010; Sharp et al. 2012).

According to some researchers, neuroeconomics has its root in behavioral economics (Mohr et al. 2010) or behavioral economics is the first set of shoulders that neuroeconomics stands on (Sharp et al. 2012). Other researchers emphasize that neuroeconomics is a subfield of behavioral economics which uses empirical evidence of limits on computation, willpower and greed to inspire new theories. It is also a subfield of experimental economics because requires mastery of difficult experimental tools which are new to economists And to many neuroscientists supply theories and experimental designs for neuroscience (Camerer 2007).

The combination of the traditional economy based on the hypothetical and deductive method as well as behavioral economy taking into consideration psychological aspects of human conducts, and simultaneously, the implementation of experimental economy tools and methods applied by cognitive neuroscience allowed for better examination of economic entities with regard to decision-making. Representatives of such fields dealing so far with the examination of the decision-making process from their own perspective, have undertaken, within the scope of neuroeconomics, the cooperation allowing for multi-aspect analysis of complex phenomena. The implementation of neuroscience tools has effected the opportunity of combining economic experiments with a simultaneous observation of the activity of the nervous system of the human being and the human brain. The development of technologies implemented in neuroscience has additionally created the platform for cooperation between representatives of natural and social sciences, in particular biology. Its role should be extended to providing some of the foundations of theories of human behavior. The contribution of biology to research on choice should not be limited to providing a mechanistic account of human decision-making. "Biological variation may be used to identify potential behavioral variation that would be missed (or absorbed by the error term) if one were to follow economic theory alone. Biologists observe phenomena relevant to choice that traditional models do not capture, and they have research methods to manipulate these phenomena (e.g., pharmacological interventions) that behavioral scientists do not have" (Bossaerts and Murawski 2015).

Interdisciplinary aspect of neuroeconomics constitutes a tremendous challenge for researchers and conducted by them studies. Neuroeconomics is becoming skilled in the sheer diversity of methods used by the different parent fields. Thus, a neuroeconomist shall be equipped with "...some working knowledge of the analytical tools used by choice theorists, the analytical tools used by computational modelers, experimental design in psychology and economics, statistical techniques ranging from those used in neuroimaging to those used in the analysis of behavior, and the full suite of neuroscience methods available for investigating cognition"

(Kable 2011). For that reason, wide-ranging studies in the field of neuroeconomics referring to actual decision-making processes are conducted in principle by interdisciplinary research teams, where knowledge, skills and competences of individual participants complement each other.

5.4 Areas of Neuroeconomics Research

The subject of neuroeconomics focuses on the explanation of the decision-making process. As a relatively new field of knowledge it has not developed so far a common theory explaining neurobiological mechanisms of decision making, and within its scope various concepts are developed and tested. Areas of interest and research topics in the field of neuroscience have been developing along with the development of the field and the number of conducted experiments conducted. In 2003, in which "a group of economists, psychologists and neurobiologists began to identify themselves as neuroeconomists and to explicitly shape the convergence between the fields" (Glimcher et al. 2009: 8). Camerer et al. (2003) highlighted that neuroeconomics should provoke thought, and suggest interesting, fresh perspectives on old problems. Considerations conducted within its scope might affect the way that two traditional topics in economics (1) intertemporal choice and self-control, (2) decision making under risk and uncertainty.

Since that time the number of research conducted in the field of neuroeconomics has been increasing rapidly. Five principal motivations for pursuing neuroeconomic research include (Camerer et al. 2015: 153):

- some researchers, including economists, are willing to study neuroscience for its own sake,
- neuroeconomic research will likely provide a new way of (imperfectly) measuring human well-being, neural activity has been shown to correlate with reports of subjective well-being, receipts of reward, and revealed preferences,
- neuroeconomics will serve as a catalyst for model development. Neuroscientific data and neuroscientific models have inspired economists to develop many new economic models,
- neuroeconomics will provide a new, powerful way to test economic models which ambitiously specify both how choices depend on observables, and what computational mechanism leads to those choices,
- neuroeconomics will improve our ability to predict behavior and to design interventions that influence the behavior of others and manage our own appetites and drives.

Camerer emphasized in one of his articles of 2007 that neuroeconomics is likely to provides three types of evidence about economic behavior (Camerer 2007):

- evidence which shows mechanisms that implement rational choice (utilitymaximisation and Bayesian integration of information), typically in

tasks that are highly-sculpted to make decisions that are useful for survival across species (vision, food, sex and danger),
- evidence which supports the kinds of variables and parameters introduced in behavioral economics,
- evidence which suggests the influence of "new" variables that are implicit, underweighted, or missing in rational-choice theory.

Moreover, the same year three major research (topics) fields in which the neuroeconomic can make important contributions to economic theories were distinguished by R. Yu and X. Zhou. They included (Yu and Zhou 2007):

- utility computation in decision making—one important area where neuroeconomics can contribute is in identifying neural substrates associated with economic concepts and in understanding their psychological functions. Neuroeconomic studies also support previously discovered economic rules concerning utility computation. Another important phenomenon concerning utility computation in economic decision is the time discounting of utility,
- the role of emotions in decision making—emotions influence people decisions, but traditional economic studies usually ignore such influence and leave emotion outside the scope of decision-making research. And the ability to experience and anticipate emotions is crucial to advantageous decision making. This field of interest included also moral decisions which play an important role in our daily economic decisions. Moral decisions, the evaluation of actions of other people or of our own actions made with respect to social norms and values, are not the main topic in economics,
- economic decisions in social context—the people always make decisions in social situations. Neuroeconomic studies have found evidence to support that people make decisions based on the prediction of others'possible actions and the associated outcomes.

Recently, active work in neuroeconomics is taking place in every choice domain, but the most important are the four topics of neuroeconomic research (Camerer et al. 2015: 172–191):

- risky choice—with three main topics in that field: statistical moments and evaluation of risky choice; prospect theory; causal experiments and their implications for economics,
- intertemporal choice and self-regulation—intertemporal preferences are one of the most active research topics in the field of neuroeconomics, researchers have identified a large group of empirical regularities, many of which are related to neural mechanisms,
- social preferences—in this area "the neuroeconomic approach aims to provide a micro-foundation of social preferences in terms of the underlying neural networks, which will eventually be achieved with the development of formal models of the underlying brain circuitry showing how the assumptions and parameters of behavioral models of social preferences relate to the empirically verified assumptions and parameters of the brain model. This will lead to a better

understanding of the nature of social preferences, and the sources of individual differences in other-regarding behaviors, including pathologies" (Camerer et al. 2015: 183),

- strategic thinking—in that field of research, neuroscience could contribute to game theory by identifying strategic algorithms that are being implemented in the brain. In addition, game theory could be of special use in neuroeconomics by parsing how general reward and learning structures combine with specialized social inference mechanisms (such as "theory of mind") to determine strategic choice. Conducted studies refer to four aspects of strategic thinking: strategic awareness that outcomes are affected by actions of other players; beliefs, iterated beliefs and strategic choice; learning about the value of strategies; strategic teaching and influence value.

According to G. Urbanik-Papp (2014) neuroeconomics deals with four groups of decisions in areas challenged with various research questions:

- in case of decisions undertaken within the conditions of risk and uncertainty:
  - how does the brain interpret and code financial profits and losses?
  - what are the brain's foundations for the operation in conditions of uncertainty?
  - what structures of the brain are related to undertaking decisions in the context of profits and what structures of the brain are related to undertaking decisions in the context of losses?
- in case of moral decisions:
  - are moral assessments formulated under the influence of strong emotions or as a result of rational analysis?
  - is the observation of moral standards of the absolute character (deontological) or is it based on considering consequences of decisions (consequentional)?
- in case of decisions with deferred effects:
  - what influences the decision of immediate consumption or deferred gratification?
  - what is the role of emotions and rational analysis in deferring gratification?
  - what part of the brain is responsible for comparing possible options?
- in case of decisions referring to the social context:
  - how does the brain shape the utility of own profits and the utility of disbursements for other persons?
  - what parts of the brain account for choices made by participants of economic games?
  - what are the neuronal correlations of decisions on sharing money with other persons?

The results of studies in the field of neuroeconomics in those areas allowed to create so called "economic mind map" being the evidence for a certain universal type of stimulating brain areas activated during making economic decision (Zaleśkiewicz 2013: 422–423).

5.5 Conclusions

With the increasing popularity of studies in the field of behavioral and experimental economy, at the end of 20th century, deviations from rigid rules of rationality started to be accepted. A considerable contribution to the above mentioned situation includes the development of science as well as, a more frequent associating with each other, interdisciplinary contents and tools within the scope of neuroeconomics which may be perceived as the interdisciplinary debate devoted to a new, holistic manner of perceiving the human with the comprehensive approach—treating the human as bodily, mental and social being.

Neuroeconomics focusses on testing the existing economic and it enhances settling the issue which of the competitive theories demonstrates corresponding to it neuronal correlations being more reliable. Knowledge provided by neuroeconomics may direct posed hypotheses, and methods applied within its scope enable the measurement of variables which in spite of their importance for the decision-making process so far have been difficult to be depicted (Gęsiarz 2011: 51). The importance of that field stems from the fact it is used within the scope of economic metaphors are used to study how neurons and neural networks make decisions. Therefore the excitement generated by neuroeconomics is because the metaphor of utility and value can be used across the different levels of explanation from cells to society, making this a rather unique field (Sharp et al. 2012).

Observed as a result of studies in the field of neuroeconomics reactions of the nervous system may become in the future the foundation for elaborating theories which subsequently will be tested on economic grounds (Gęsiarz 2011: 52). Camerer et al. (2015: 200) are of the opinion that neuroscience methods continue to rapidly advance it is likely that neuroscientific insights will significantly improve our economic vision. Glimcher et al. (2009) on the other hand expresses the opinion that developing at a fast rate neuroeconomics will be able in the future to execute tasks posed for the classical economy. M. Noga (2017) forecasts the development of neuroeconomics being able to build macroeconomic models explaining various general economic phenomena and thanks to its achievements economic laws will approximate, with their character, to deterministic natural laws (Noga 2017: 107–121).

Irrespective of the fact how the fate of neuroeconomics will run, whether or not it will elaborate its own paradigm and the whole research program, its current achievements and perspectives on decision-making processes are undertaken by a real man and the economy itself.

References

Altman M (ed) (2000) Handbook of contemporary behavioral economics: foundations and developments. Armonk, New York

Angner E, Loewenstein G (2012) Behavioral economics. In: Gabbay DM, Thagard P, Woods J (eds) Handbook of philosophy of science. Philosophy of economics. Elsevier, Oxford-Amsterdam

Barros G (2010) Herbert A. Simon and the concept of rationality: boundaries and procedures. Braz J Polit Econ 30(3):455–472

Bloom F (2008) Fundamentals of neuroscience. In: Squire L, Berg D, Bloom FE, du Lac S, Ghosh A, Spitzer N (eds) Fundamentals of neuroscience, 3rd edn. Elsevier, San Diego, pp 3–13. https://www.hse.ru/data/2013/10/09/1280379806/Fundamental%20Neuroscience%20(3rd%20edition)%202008.pdf. Accessed 3 May 2017

Bossaerts P, Murawski C (2015) From behavioural economics to neuroeconomics to decision neuroscience: the ascent of biology in research on human decision making. Curr Opin Behav Sci 5:37–42

Camerer CF (2007) Neuroeconomics: using neuroscience to make economic predictions. Econ J 117(519):C26–C42

Camerer C, Loewenstein G, Prelec D (2003) Neuroeconomics: how neuroscience can inform economics. http://www.nyu.edu/econ/user/bisina/camerer_loewenstein_prelec.pdf. Accessed 28 Apr 2017

Camerer C, Cohen J, Fehr E, Glimcher P, Laibson D (2015) Neuroeconomics. In: Kagel J, Roth R (eds) Handbook of experimental economics, vol 2. Princeton University Press, Princenton and Oxfort, pp 153–216

Evans JSBT (2010) Thinking twice: two minds in one brain. Oxford University Press, Oxford

Frantz R (2013) Frederick Hayek's behavioral economics in historical context. In: Frantz R, Leeson R (eds) Behavioral economics and hayek. Palgrave Macmillan, New York

Frederick S (2002) Automated choice heurisitcs. In: Gilovich T, Griffin D, Kahneman D (eds) Heuristics and biases: the psychology of intuitive judgment. Cambridge University Press, Cambridge, pp 666–677

Fritz C (2011) Od mózgu do umysłu. Jak powstaje nasz wewnętrzny świat. Wydawnictwa Uniwersytetu Warszawskiego, Warszawa

Gęsiarz F (2011) Po co ekonomom mózg, czyli o pożytkach z neuroekonomii. Rocznik Kognitywistyczny V:49–55. doi:10.4467/20843895RK.12.006.0410

Gigerenzer G (2008) Rationality for mortals. Oxford University Press, New York. http://www.thedivineconspiracy.org/Z5274K.pdf. Accessed 30 Apr 2017

Gigerenzer G (2015) Simply rational: decision making in the real world. Oxfort University Press, New York

Glimcher PW, Camerer CF, Fehr E, Poldrack RA (2009) Introduction: a brief history of neuroeconomics. In: Glimcher PW et al (eds) Neuroeconomics: decision making and the brain. Elsevier, London

Jaśkowski P (2009) Neuronauka poznawcza: Jak mózg tworzy umysł. Vizja Press&It, Warszawa

Kable JW (2011) The cognitive neuroscience toolkit for the neuroeconomist: a functional overview. J Neurosci Psychol Econ 4(2):63–84

Kahneman D (2002) Maps of bounded rationality: a perspective on intuitive judgment and choice. Prize Lecture. http://www.nobelprize.org/nobel_prizes/economics/laureates/2002/kahnemann-lecture.pdf. Accessed 14 Apr 2017

Kahneman D (2012) Pułapki myślenia. O myśleniu szybkim i wolnym. Media Rodzina, Poznań

Kosslyn SM, Rosenberg RS (2006) Psychologia: Mózg. człowiek. Świat. Wydawnictwo, Znak, Kraków

Miłaszewicz D (2016) Origins of experimental economics. In: Nermend K, Łatuszyńska M (eds) Selected issues in experimental economics. Springer proceedings in business and economics. Springer, Cham, pp 15–26

Mohr PNC, Li SC, Heekeren HR (2010) Neuroeconomics and aging: neuromodulation of economic decision making in old age. Neurosci Biobehav Rev 34:678–688
Noga M (2017) Neuroekonomia a ekonomia głównego nurtu. CeDeWu, Warszawa
Sent EM (2005) Simplifying Herbert Simon. History Polit Econ 37(2):227–232
Sharp C, Monterosso J, Montague PR (2012) Neuroeconomics: a bridge for translational research. Biol Psychiatry 72:87–92
Simon HA (1972) Theories of bounded rationality. In: CB MG, Radner R (eds) Decision and organization. Nord Holand, pp 161–173. http://innovbfa.viabloga.com/files/Herbert_Simon___theories_of_bounded_rationality___1972.pdf. Accessed 20 Apr 2017
Simon HA (1976) From substantive to procedural rationality. In: Latsis SJ (ed) Methods and appraisal in economics. Cambridge University Press, Cambridge, pp 129–148
Simon HA (1978) Rational decision-making in business organizations. Nobel Memorial Lecture, 8 December. http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/1978/simon-lecture.pdf. Accessed 20 Apr 2017
Simon HA (1990) Invariants of human behavior. Ann Rev Psychol 41:1–19. http://www.annualreviews.org/doi/pdf/10.1146/annurev.ps.41.020190.000245. Accessed 21 Apr 2017
Simon HA (2000) Bounded rationality in social science: today and tomorrow. Mind Soc 1 (1):25–39
Sloman SA (2002) Two systems of reasoning. In: Gilovich T, Griffin D, Kahneman D (eds) Heuristics and biases: the psychology of intuitive judgment. Cambridge University Press, Cambridge, pp 379–397
Smith VL (2005) Behavioral economics research and the foundations of economics. J Soc Econ 34:135–150
Stanovich KE (2011) Rationality and the reflective mind. Oxford University Press, New York
The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel (2002) http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2002/index.html (Accessed 16 Aug 2015). Accessed 27 Apr 2017
Tversky A, Kahneman D (1974) Judgment under uncertainty: heuristics and biases. Science 185 (4157):1124–1131
Tversky A, Kahneman D (1992) Advances in prospect theory: cumulative representation of un-certainty. J Risk Uncertain 5:297–323. doi:10.1007/BF00122574
Urbanik-Papp G (2014) Neuroekonomia jako interdyscyplinarne podejście do badania decyzji ekonomicznych. Kultura Polityka 15:158–172
Yu R, Zhou X (2007) Neuroeconomics: opening the “black box” behind the economic behaviour. Chin Sci Bull 52(9):1153–1161
Zaleśkiewicz T (2013) Psychologia ekonomiczna. Wydawnictwo Naukowe PWN, Warszawa