Everant Journals/AFMJ

Research Article

Account and Financial Management Journal ISSN: 2456-3374
Impact Factor: 4.614

The Proces of Multidimensional Decisin-Making Research with Emphasis on the Mediodorsal Thalamus and Prefrontal Cortex

Ana Njegovanović

Voćarska 38,10000 Zagreb

ARTICLE INFO

Corresponding Author:
Ana Njegovanović,
Voćarska 38,10000 Zagreb

ABSTRACT

The scope of this paper is based on the existing literature which discusses the various decision-making processes in terms of scientific theories including economics, neuroscience, mathematics, quantum physics, while reflecting on the on the role mediodorsal thalamus and prefrontal cortex in working memory. Using the multidisciplinary approach to investigating how the brain works in terms of obtaining new knowledge, of continuous sophisticated global information, the importance of interaction between mediodorsal thalamus and prefrontal cortex during decision-making. How strong are the links between information on mediodorsal thalamus (MD) and prefrontal cortex (mPFC) in making investment decisions. Magnocellular division into medio dorsal thalamus (MDmc) is important for learning new information. The Medio dorsal thalamus (MD) contributes to adaptability in decision making. Prerequisites indicate that cognitive processes are managed by prefrontal cortex (PFC) and median temporal limbs, indicating their importance in cognitive processes.

KEYWORDS: ***neural correlation of decision making / investment decisions, mediodorsal thalamus, prefrontal cortex***

1. INTRODUCTION

Decision making is explored from multiple Perspectives including computer modeling, economics, epidemiology, neurobiology /neuroscience, psychology, mathematics, quantum physics. Through scientific disciplines we investigate the economic framework , which is formalized with the theory of utility (Friedman and Savage, 1948) and prospective theory (Kahneman and Tversky, 1979; Kahneman and Tversky, 1992), economic risk. While the signal framework is finalized with the signal detection theory (Green and S wets, 1996), which emphasizes the reaction of people to the variability or to the perceptual uncertainty or risk of signals (Lynn et al., 2005; Lynn, 2010). To a large extent, the economic signaling frames remain isolated from each other, the result of these frames are probably orthogonal focal points on the economic signal, the risk. The economic framework focuses on the variability of costs and benefits resulting from the decision. However decisions usually do not include perceptual uncertainty about the possibilities - various options perceptively are different and clearly defined. We emphasize research within the economic framework including variation effects and valueout comes on choice (Verplanken

DOI: 10.18535/afmj/v2i11.05
Page no.1046-1056

and Holland, 2002; McClure e et al., 2004), the effect of context or forming sensitivity to the variability and value of the outcomes (Kahneman and Tversky, 1979 Kühberger, 1998, Widmann et al., 2006) and neuroanatomic and functional correlates of economic decision-making (Knutson et al., 2005; Kable and Glimcher, 2007). In the real world of decision-making are important economic and signal risk, therefore both.

The analysis of decision-making in economic theory shows that the decision-making process is based on the goal, accurate investment analyzes, and its possible outcomes and calculated returns, as well as on the subjective perspectives of the investor. Investments have a greater or lesser risk. However modern investment theories are intertwined with other branches of science and their involvement (neuroscience, quantum physics, math, artificial intelligence) can expand our knowledge and understanding of a complex investment system.

Modern investment theory has incorporated various aspects of Keynes and Fischer. The net present value investment rule becomes the standard component of corporate finance. Jorgenson's (1963) neoclassical investment theory basically formalizes ideas by giving Fisher. Keynes's work on subjective probability foreshadowed the modern probabilistic approaches, such as Markowitz (1952) that led to the establishment to the selection of the portfolio. Undoubtedly, Keynes influenced the investor accelerator theory known as the business cycle application by Samuelsson (1939 and b). Keynes was also inspired by Tobins and Brainar development of Tobins IQ (Brainard and Tobin, 1968, and Tobin, 1969) in the incorporation of expectations. The methodology of measuring the marginal q has been developed by Mueller and Reardon (1993), which also belongs to this line of thought.

every investment activity in society is accompanied by risk and uncertainty. Investment is defined as general investment as the current cost to achieve future earnings (Avram et al., 2009).

Computerized memory and process capacities reach unmatched proportions, and they will affect new financial functions. For example: finance, risk management, trading and positioning, consulting and data processing. Although the financial functions will be the same as in the 20th century, still with accelerated development of new sophisticated tools they are observed through desire for wealth or financial claims (instead of today's credit, loan or securities). Artificial Intelligence is defined as the ability of the model to make either optimal or satisfactory decisions. Deciding is therefore the process that culminates by selecting a specific action course between several alternatives. Computer decoding is automated by computer techniques such as neural networks and decision trees. Computer finance (as well as finance) also relate to intelligent decision making, portfolio optimization (how to allocate your portfolio), algorithmic trading (should I buy these actions), prices (how much I have to pay for that security). The development of the financial market, many areas of academic research that continuously identify new methods and algorithms for computer-making. The performance of these models depends on the types of problems and requirements of that model.

Making decisions shapes our lives. Mathematics rationalizes information checking and balances the alternative inherent in any decision. Mathematical models are based on computer programs that support decision making by bringing order and understanding of the huge flow of data. Mathematics serves to evaluate and improve the quality of information, present and resolve options, model alternatives available and their consequences, and even control the minor decisions needed to achieve a larger goal. Mathematics is at the center of decision-making, including those that generate electricity,

Volume 2 Issue 11 November 2017
DOI: 10.18535/afmj/v2i11.05
Page no.1046-1056

generate profits on financial markets, evaluate legal evidence, and choose a new business strategy. Mathematics is used as the main tool for transferring investment science principles and their use in order to calculate investments for a good decision.

The importance of financial theory is reflected through portfolio theory, property theory price, option price theory, and market efficiency theory. Scientific theory improves our understanding and understanding of risk management. Market science, however, is in the period of classical finance, the Newton phase, which means that we look at finance as financial instruments: stocks, bonds and loans, therefore, in statistically highly aggregated conditions, while models analyze securities risk and assume that volatility securities are constant over time and can be estimated using historical data on a past-price-based world where there is no progress, no structural change, no evolution. However, in reality, volatility of security is based on a highly aggregated set of many risks and have mutual interaction. Classical finances are based on the assumption that people are rational financial decision makers as well as most of the Bankers Trust dealing with beta stocks with respect to volatility in the market. But these models have problems in addressing a multitude of key beta-risk factors such as changes in financial market volatility, changes in global product, volume of transaction processing. Critical factors are described as "financial attributes", whereby "beta" ignores or neglects to resemble them as homogeneous white noise packets. It should be emphasized, however, that theorists do not neglect, but are looking for a "finance particle theory" that will help in understanding property financial attributes. In the search for particle finance theory, there is a shift that reflects on the strengthening of financial discipline.

Potential applications of quantum physics to finance, can be seen through the inclusion of stochastic variables such as volatility and interest to the rate in the quantum system cost by creating models that would be more realistic which is a mathematical challenge. There are also sociological barriers to overcome. Development and discussion of integrals and quantum markets with hardcore brokers whose bottom line simply makes profits; not always easy. The risk of financial volatility and its relation with the intrinsic time is related to the business cycle addressed through multiple evolutionary equilibrium quantum games leading to turbulence and multifractal signature and dynamic risk (BB Mandelbort, 1997; BB Mandelbort and RL Hudson, 1997, 2004).

The prefrontal cortex has two main divisions that are important for decision making. Dorsal lateral prefrontal cortex (dlPFC) that acts as the cognitive function with executive functions, work memory, including thinking and acting regulation and ventromedial prefrontal cortex (VMPFC) associated with emotion, motivation, and decision making. Thalamus can quickly assemble circuits that enable successful decision making. This new feature is the result of research researchers at NYU Langone Medical Center and published in the May 3, 2017 in the journal Nature. The research was focused on the part of the thalamus, which is associated with the prefrontal cortex PFC, which is traditionally associated with executive functions such as working memory, attention and focus to decide the selection. The conducted experiments (mice and computer simulation neural circuits) revealed that medio dorsal thalamus strengthens links within the prefrontal cortex instead of strictly transmitting to the cortex as previously thought. The experiment indicated that the medio dorsal thalamus MD can be a conductor connection between circuits because the brain follows the previously learned rules and make decisions in real time (Michael Halassa, MD, PhD, assistant professor at NYU

Volume 2 Issue 11 November 2017
DOI: 10.18535/afmj/v2i11.05
Page no.1046-1056

Langone Neuorscience Institute, New York, 2017).

The medial prefrontal cortex (mPFC) is implicit in cognitive processes including decision-making (Kennerley and Walton, 2011), attention, work memory (Bissonette et al., 2013), emotional control (Sotres-Bayon and Quirk, 2010), and social interactions (Li et al., 2014). Median prefrontal cortex (mPFC) is defined by reciprocal connections with medullary thalamus (MD) (Rose and Woolsey, 1948; Heidbreder and Groenewege, 2003). Different from sensory or motor nucleus of the thalamus, the medio dorsal thalamus integrates information from the median prefrontal cortex (mPFC), limbic structures and to the basal ganglia to the flexible management of behavior. medio dorsal lesions or chemogenetic inhibition of the medio dorsal neurons weak oscillator relationship between the medio dorsal and prefrontal cortex creating deficits in the flexible behavior of the working memory (Floresco et al., 1999; Romanides et al., 1999; Parnaudea et al., 2013, 2015) that resemble the deficits caused by lesions of the prefrontal cortex (Hunt and Aggleton, 1998; Mitchel you Chakraborty, 2013). However, anatomical and behavioral meta data linking the medio dorsal thalamus and cortex medial prefrontal cortex, and how data is transmitted, still unclear.

2. SCIENTIFIC BASE IN THE PROCESS OF MAKING MEDIDODORSAL THALAMUS AND PREFRONTAL CORTEX

Decision making in an uncertain global environment with continuous changes in theoretical and applicative terms requires adaptation and availability of options by determining their associated values. It is necessary to emphasize that the identity of the selected options during the selection of the corresponding election search is maintained. Without this, the outcomes of such excerpts are questionable knowledge of decision making, whether it will continue to take other alternatives or end the search and instead persist with the chosen option (Quilodran et al., 2008). Convergent evidence points to the integrity of the orbital and medial parts of the prefrontal cortex, supporting the ability to use feedback to enable rapid regulation of choice behavior and switch from research to the existence of response patterns (Hayden et al., 2011: Khamassi et al., 2013: Morrison et al ., 2011: Walton et al., 2004: 2011). However, it is not clear enough how all relevant information is integrated in cortical networks. A correlated subcortical structure with neuronal nets of the medio dorsal thalamus helps to align the rapid integration of choice and outcome associated with prefrontal cortex, but also receives inflows from amygdala and ventral striatum (Agleaton and Mishkin, 1984; Goldman-Rakic and Porino, 1985; McFarland and Haber, 2002; Ray and Price, 1993; Russche et al., 1987; Timbie and Barbas, 2015; Xiao et al., 2009).

Prefrontal cortex integrates and interprets inputs from cortical and subcortical structures and uses information to develop meaningful responses that maintain present and future circumstances, including action-oriented sequences involved in receiving rewards and inhibition of behavior that pose excessive risk and harm to the individual. The core of the medio dorsal thalamus (MD) is anatomically linked to the median prefrontal cortex (mPFC) (Leonard, CM, 1969). Electrophysiological studies confirm this link by showing that electrical stimulation of the medullary thalamus activates neurons in the medial prefrontal cortex (Ferron et al., 1984; Mantz et al., 1988). Recent researches have described two main types of prefrontal exciting responses following the stimulation of mediodorsal thalamus: responses of short and long latencies (Gioanni et al., 1999; Pirot et al., 1994). Both types of responses are mediated by the exocytic glutamate of amino acids (Gigg et al.,

Volume 2 Issue 11 November 2017
DOI: 10.18535/afmj/v2i11.05
Page no.1046-1056

1992 Pirot et al., 1994). Short latency responses result from the activation of the medio dorsal thalamus and the medial prefrontal cortex pathways, while long-lasting latency reflects responses by activating the return of collateral antidromic properties (Pirott et al., 1994).

3. EFFECT SUNK COST EFFECT AND TRANSCRANIAL DESIGN (noninvasive method)

Rationally making financial / economic decisions about the objects of expected future value, investment, or experience relevant to choose is the basis of traditional economic theory (Edvards, 1954, Frank and Bernanke, 2006, Gabantous and Gond, 2011). However, choices are not always rational and intelligent (Tversky and Kahneman, 1974; Samuelson and Zeckhauser, 1988; Kahneman et al., 1991; Shafir et al., 1993). Specifically, when people invest in investment, they hardly give up, though the expected value is no longer favorable. Consideration of past cost tendencies called cost effect (Arkes and Blumer, 1985). One of the most consistent biases in human decision-making is the effect of so-called sunk costs (Garland, 1990; Arkes and Hutzel 2000; van Puten et al., 2010). This can explain why people cannot leave an unsatisfactory task (Arkes and Blumer, 1985) and can raise prices in auctions (Murnighan, 2002). Understanding decision-making is supported by neuroscience tools, the involvement of neuroscience in decision-making processes, as these processes are implemented in the brain (Blakemore and Robbins, 2012, Grabenhorst and Rolls, 2011, Kable and Glimcher, 2009, Rangel et al., 2008). Neurophysiological brain imaging studies have identified a network of brain regions that are relevant to decision making, including ventricular stratum, amygdala, front Cingular cortex, and parietal cortex (de Martino et al., 2006; Hare et al., 2008; Hunt et al., 2012 Plat and Glimcher, 1999). However, the orbital frontal cortex and ventromedical prefrontal cortex integrate options of different dimensions and calculate expected values or usefulness (Grabenhorst and Rolls, 2011; Kable and Glimcher, 2009; Padoa- Schioppa and Assad, 2006; Schwabe et al., 2012; Valentin et al. 2007), which is a nucleus in the theories of decision making in economics and psychology (Kahneman and Teversky, 1979; von Nneumann and Morgenstern, 1944). Neural signatures of the effects of sunk costs (Haller and Schwabe, 2014) have shown that previous investments reduce vmPFC activity during subsequent decisions and reduced vmPFC activity correlates with sunk costs. While social norms are represented in (DLPFC) the dorsolateral prefrontal cortex (Sanfey et al., 2003; Baumgartner et al., 2011), these are aspects of the data were consistent with this. So, summarily, the norm does not lose the resources associated with the activity of the right dlPFC, the right dlPFC shows greater association with vmPFC when the participants invested in comparisons when they did not. Namely, the data showed that the dlPFC cost model is a norm that does not lose resources, activates after the investment and overcomes vmPFC, hindering rational choices based on expected values. But it should be stressed that this model has its disadvantages, brain imaging with functional magnetic resonance fMRI is correlative, but it is necessary to test the causal relationship between brain activity and behavior. In order to test the causal relationship between brain activity and behavior, transcranial equilibrium stimulation (tDSC), a method for non-invasive human brain stimulation using weak electrical current (Nitsche and Paulus, 2000) was used.

The protocol for experiments of transcranial balance simultaneous stimulation was conducted on sixty participants (men and women aged between 18 and 32 years) with previously off (before the test) current diseases, medication, history of neurological disorders and any contraindications for transcranial balance contemporaneous stimulation TDSC with the written consent of the participants in the experiment for a fee of 12 € and plus what they have won in the investment mission (Https://doi.org/10.1093/cercor/bhv/298) . The conducted surveys included a questionnaire. Effect of "sunk costs". The study was conducted by a modified version with a newly developed investment task (Haller and Schwabe, 2014), which is adapted to time constraints linking with a safety application TDSC times (transcranial balance simultaneous stimulation) The data show that the dorsolateral prefrontal cortex (DLPFC) plays an important role in the effect of so-called sunk costs by supporting a model in which the dzPFC dorsolateral prefrontal cortex is implementing the norm, neutralizing decision-making based solely on expected values (Bogdanov, Ruff and Schwabe, Oxford University Press, 2015, Transcranial Stimulation Over the Dorselateral Prefrontal Cortex Increase the Impact of Past Expenses on Decision Making).

4. THE ROLE OF MEDIODORAL TALAMUS AND PREFRONTAL CORRESPONDENCE IN WORK MEMORY

Work memory and decision making are basic cognitive functions that include a distributed interactive network of human brain regions with back wall and prefrontal cortexes in the nucleus. Common and different roles as well as the nature of their coordination in cognitive function are still poorly known.

Thalamus is a small region located in the center of our brain and is presumed to emit signals from the eyes, ears, tongues and skin to other parts of the brain to process. New researches indicate the role of the thalamus not only in the forwarding of information, but has a significant role in cognitive behavior, decision-making and focus. Although the medial prefrontal cortex (mPFC) is defined by reciprocal connections with the mediodorsal core of the thalamus (MD), the nature of the information transfer between MD and mPFC is poorly known. Median prefrontal cortex is implicated in many cognitive processes including decision making (Kennerley and Walton, 2011), attention, work memory (Bissonette et al., 2013), emotional control (Sotres-Bayon and Quirk, 2010) and social interaction al., 2014). The working memory as a dynamic neural system for temporal maintenance and information processing is significant in the cognitive functions of thinking, decision making and understanding of languages. It is known that prefrontal cortex plays an important role in the work memory, however research suggests that the core of the medullary thalamus also plays an important role in the working memory.

Investigating the role of the work memory reveals an important role for the thalamus. Most of the research on work memory focused on prefrontal cortex (Xiao- Jing Wang, 2017). Decades of research link work memory with continuous activity in the subset of cortical neurons, neurons begin to shoot when we need to remember something, like a phone number, and stop firing when we type a number.

The role of the prefrontal cortex PFC in the working memory shows that it encodes relevant data (Goldman-Rakic, 1987; Miller and Cohen, 2001; Baddeley, 2003). Ten cures studies have shown a strong neural activity in the prefrontal cortex during the period of delay, the task of working memory (Fuster and Alexander, 1971; Funahashi et al., 1993; Wilson et al., 1993; Levy and Goldman-Rakic, 2000). The key features of decompensation of the work memory are: a memory stimulus that contains information about the contents of the memory and it encodes the stimuli that are important to this task: it is deterrent to attention (Miller et al., 1996; Sakai et al., 2002) tasks that are not relevant are not coded in the working memory (Rainer et al.,

Volume 2 Issue 11 November 2017
DOI: 10.18535/afmj/v2i11.05
Page no.1046-1056

1998). Studies have shown increased activity periods delays in the prefrontal cortex (so for example continuous activation measured bifunctional magnetic resonance imaging (fMRI) in the lateral prefrontal cortex while subjects held their spatial location in the working memory during the delay of a few seconds, Courtney et al., 1998). Longer delays show a higher error rate that is consistent with the failure of the work memory to retain the information on the stimulus. This information were the basis that the prefrontal cortex where the information about the stimuli to remember is stored in random access memory (examination papers: D'Esposito and Postle, 2015), however, an increasing number of work calls into question the theory (Druzgal and D'Esposito 2001; Curtis and D'Esposito,2003; Postle et al., 2003; Ranganath et al., 2004; Srenivasan et al., 2014 b; Postle, 2015). Therefore, if the prefrontal cortex is not responsible for the work memory then it is necessary to identify the brain regions responsible for the process. Strong evidence suggests a sensory cortex that plays an important role (Pasternek and Greenlee, 2005) A large number of electrophysiological investigations point to individual neuronal activity in most sensory cortexes including visual (Miller et al., 1993; Motter, 1994), listening (Gottlieb et al., 1989), and thus the taste cortex (Lara et al., 2009). Extensive work using electroencephalogram EEG, ECoG electrocorticography, and magnetic-encephalopathy MEG revealed increased oscillatory activity during the work memory task in both frontal and backward areas (Roux and Uhlhaas, 2014). All experimental studies and analyzes show that prefrontal cortex is not included in data storage but reflects control processes such as monitoring and control. The work (Ester et al., 2015) reflects highly accurate presentation-oriented grids and work memory and showed that orientation information can be decoded from BOLD signal in localized frontal-partial sub regions. Interpretation of such results suggests that data can be decoded even when neurons do not present this information. It is also possible that orientation data can be decoded from the preoperative cortex activity pattern responsible for activating the correct representation in the back sensory cortex, although some prefrontal cortex neurons are not adapted to that information in their cutoff rate. If prefrontal cortex neurons are responsible for precise sensory images localized in small sub regions, it is possible that these representations are omitted by standard methods used in a single unit of neurophysiology. This possibility can be ruled out by recording neural activity on multiple scales, such as combining ECoG and individual methods (Lewis et al., 2015).

5. CONCLUSION

The universe in our head is bigger than we can imagine, extending far beyond the reach of our conscious mind. Neuroscientific research gains first insights into the vastness of our inner space. In every moment of our lives, networks in our brain buzzing activity of billions of electrical signals that run along the cells induces it warmer chemical impulses in billions matter connections between neurons. Our life shapes and shadows what is happening below the surface, how we behave, what matters to us, how we make decisions. Our experience is the ultimate product of these hidden networks.

The first decision theory, assumed that human beings are rational and decision makers, who proc j will become complementary advantages and disadvantages of its capabilities in order to make an optimal decision. However, scientific research has led to the opposite results. Many decisions in real life do not seem to follow pure logical behavior and often choices are not optimal. Sometimes we choose selfishly, sometimes generously, sometimes impulsive, but sometimes long term. Professor experimental neuroscience funding and decision-making Peter Bossaerts indicates that economists and financial intuitions do not take into account the emotional inputs that enter into financial decision making when designing models and financial products.

Financial institutions and banks rely on prospect theories that turn around the reference point in order to make purchasing decisions. The theory can help individuals to reach a risk aversion when deciding. So, banks and financial institutions use the reference point and the prospectus for the theory of the market selling complex investment vehicles such as structured products. Many studies of the brain that have been conducted during the process of making financial / investment decisions are not sufficiently utilized by the financial industry.

The aim of the presentation is intertwined and different scientific branches of the economy over mathematics, quantum physics, artificial intelligence to neuroscience to get a broader picture insight about deciding who becomes imperative in the 21st century. This century implies the adoption of new knowledge based on scientific contributions, principles of education of the upcoming generation using new tools and technologies, a shift away from Newtonian physics will therefore move away from the classic to the theory of finance modeling quantum model assisted mathematics, neuroscience contributions, traveling the paths to artificial intelligence to improved financial systems by improving and creating new frameworks of financial systems and banks through sophisticated decision making.

Review of mediodorsal thalamus and prefrontal cortex and their role in working memory and decision-making are fundamental cognitive functions including distributed interactive network of regions of the human brain with the rear parietal and prefrontal cortex in the core. Their common as well as a variety of roles and the nature of their co-ordination in cognitive function, although we know little known, allows us to glimpse in the unknown, expecting the further development of neuroscientific contributions in this and other areas.

References

1. Arkes H, Hutzel L. 2000. The role of probability of success estimates in the sunk cost effect. J Behav Decis Mak. 13: 295-306.
2. Arkes HR, Blumer C. 1985. The psychology of sunk cost. Organ Behav Hum Decis Process. 35: 124-140.
3. Baddeley, A. (2003). Working memory: Looking back and looking forward. *Nat. Rev. Neurosci.* 4, 829-839. doi: 10.1038 / nrn1201.
4. Brainard, W. C and Tobin, J., (1968), "Pitfalls in Financial Model Building", American Economic Review, vol. 58, no. 2, 99-122.
5. BB Mandelbrot, A. Fisher and L. Calvet, A Multifractal Model of Asset Returns, Cowles Foundation Discussion Papers: 1164, 1997.
6. BB Mandelbrot, Fractals and Scaling in Finance, Springer, USA, 1997.
7. BB Mandelbrot and RL Hudson, The (Mis) Behavior of Markets: A Fractal View of Risk, Ruin and Reward, Basic Books, USA, 2004.
8. Blakemore, S.-J., Robbins, TW, 2012. Decision-making in adolescent brain. Nat. Neurosci. 15, 1184-1191.
9. de Martino, B., Kumaran, D., Seymour, B., Dolan, RJ, 2006. Frames, biases, and rational decision-making in the human brain. Science 313, 684-687
10. D'Esposito, M., and Postle, BR (1999). The dependence of span and delayed-response performance on prefrontal cortex. *Neuropsychologia* 37,

Everant

1303-1315. doi: 10.1016 / s0028-3932 (99) 00021-4
11. Ester EF, Sprague TC, Serences JT (2015). Parietal and frontal cortex encode stimulus-specific mnemonic representations during visual working memory. neuron 87, 893-905. 10.1016 / j.neuron.2015.07.013.
12. Druzgal, TJ, and D'Esposito, M. (2001). Neural network reflecting decisions about human faces. *neuron* 32, 947-955. doi: 10.1016 / s0896-6273 (01) 00519-0
13. Fisher, I., (1930), TheTheory of Interest, Macmillan, New York.
14. Fuster, JM, and Alexander, GE (1971). Neuron activity related to short-term memory. *Science* 173, 652-654. doi: 10.1126 / science.173.3997.652
15. Friedman M., Savage LJ (1948). The utility analysis of choices involing risks. J. Polit. Econ. 56, 279-304. 10.1086 / 256692
16. GIGG, J., TAN, AM, AND FINCH, DM Glutamatergic excitatory responses of anterior cingulate neurons to stimulation of mediodorsal thalamus and their regulation by GABA: an in vivo iontophoretic study. Cerebelo.Cortex 2: 477-484, 1992.
17. Gigg, J., Tan, AM, and Finch, DM Glutamatergic excitatory responses of anterior cingulate neurons to stimulation of mediodorsal thalamus and their regulation by GABA: an in vivo iontophoretic study. Cerebelo. Cortex 2: 477-484, 1992.
18. Gioanni, Y., Rougeot, C., Clarke, PBS, Lepouse´, C., Thiery, AM, and Vdal, C. Nicotinic receptors in the rat prefrontal cortex: increase in glutamate release and facilitation of mediodorsal thalamo-cortical transmission. Eur. J. Neurosci. 11: 18–30, 1999.
19. Goldman-Rakic, P. (1987). "Circuitry of the prefrontal cortex and the regulation of behavior by representational memory," in *Handbook of Physiology, Section 1. The Nervous System* , (Vol. 5) eds F. Plum and V. Mountcastle (Bethesda, MD: Wiley), 373–417.
20. Gottlieb, Y., Vaadia, E., and Abeles, M. (1989). Single unit activity in the auditory cortex of a monkey performing a short term memory task. *Exp. Brain Res.* 74, 139–148. doi: 10.1007/bf00248287
21. Grabenhorst, F., Rolls, ET, 2011. Value, pleasure and choice in the ventral prefrontal cortex. Trends Cogn. Sci. 15, 56–67
22. Green DM, Swets JA (1966). Signal Detection Theory and Psychophysics. New York, NY: Wiley.
23. Guillery RW. 1995 Anatomical evidence concernig the role of thalamus in corticocortical communication: a brief review. J. Anat. 187: 583-
24. Jones EG. 2007. The talamus 2 Volume Set. Cambridge, UK : Cambridge University Press.
25. Kable, JW, Glimcher, PW, 2009. The neurobiology of decision: consensus and controversy. Neuron 63, 733–745.
26. Kahneman D., Tversky A. (1979). Prospect theory: an analysis of decision under risk . Econometrica 47 , 263–291. 10.2307/1914185
27. Knutson B., Taylor J., Kaufman M., Peterson R., Glover G. (2005). Distributed neural representation of expected value . J. Neurosci . 25 , 4806–4812. 10.1523/JNEUROSCI.0642-05.2005
28. Kühberger A. (1998). The influence of framing on risky decisions: a meta-analysis . Organ. Behav. Hum. Decis. Process . 75 , 23–55. 10.1006/obhd.1998.2781

29. Lara AH, Kennerley SW, Wallis JD (2009). Encoding of gustatory working memory by orbitofrontal neurons . J. Neurosci. 29 , 765–774. 10.1523/JNEUROSCI.4637-08.2009
30. Lara, AH, and Wallis, JD (2014). Executive control processes underlying multi-item working memory. *Nat. Neurosci.* 17, 876–883. doi: 10.1038/nn.3702
31. Lynn SK, Cnaani J., Papaj DR (2005). Peak shift discrimination learning as a mechanism of signal evolution . Evolution 59 , 1300–1305. 10.1111/j.0014-3820.2005.tb01780.
32. Lynn SK, Zhang X., Barrett LF (2012). Affective state influences perception by affecting decision parameters underlying bias and sensitivity . Emotion 12 , 726–736. 10.1037/a0026765
33. Lynn SK, Barrett LF (2014). "Utilizing" signal detection theory . Psychol. Sci . 25 , 1663–1673. 10.1177/0956797614541991
34. Miller, EK, and Cohen, JD (2001). An integrative theory of prefrontal cortex function. *Annu. Rev. Neurosci.* 24, 167–202. doi: 10.1146/annurev.neuro.24.1.167
35. Miller, EK, Erickson, CA, and Desimone, R. (1996). Neural mechanisms of visual working memory in prefrontal cortex of the macaque. *J. Neurosci.* 16, 5154–5167.
36. Miller, EK, Freedman, DJ, and Wallis, JD (2002). The prefrontal cortex: categories, concepts and cognition. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 357, 1123–1136. doi: 10.1098/rstb.2002.1099
37. Miller, EK, Li, L., and Desimone, R. (1993). Activity of neurons in anterior inferior temporal cortex during a short-term memory task. *J. Neurosci.* 13, 1460-1478.
38. Mcclure SM, Laibson DI, Loewenstein G., Cohen JD (2004). Separate neural systems value immediate and delayed monetary rewards . Science 306 , 503–507. 10.1126/science.1100907
39. Mitchell AS, Sherman SM, Sommer MA, Mair RG, Vertes RP, Chudasama Y. 2014. Advances in understanding mechanisms of thalamic relays in cognition and behavior . J Neurosci . 34 (46) :15340–6.
40. Leonard, CM The prefrontal cortex of the rat. I. Cortical projections of the mediodorsal nucleus. II. Efferent connections. Brain Res. 12: 321–343, 1969
41. Keynes, JM, (1936), The General Theory of Employment, Interest and Money, Macmillan.
42. Markowitz, HM, (1952), „ Portfolio Selection „ , Journal of Finance, vol. 7, no. 1, 77-91.
43. Motter, BC (1994). Neural correlates of feature selective memory and pop-out in extrastriate area V4. *J. Neurosci.* 14, 2190–2199.
44. Mueller, DC i Reaardon, E., (1993), „ Rates of Return on Corporate Investment „ , Sothern Economic Journal, vol. 60, no. 2, 430-453.
45. Murray JD, Jaramillo J, Wang XJ, (2017) „ Working memory and decision making in a fronto parietal circuit model „.
46. Nitsche MA, Cohen LG, Wasermann EM, Prior A, Lang N, Antal A, Paulus W, Hummel F, Boggio PS, Fregni F, 2008. Transcranial direct stimulation: state of the art 2008. Brain stimul. 1: 206- 223.
47. Pasternak, T., and Greenlee, MW (2005). Working memory in primate sensory systems. *Nat. Rev. Neurosci.* 6, 97–107. doi: 10.1038/nrn1637

48. Pasternak, T., Lui, LL, and Spinelli, PM (2015). Unilateral prefrontal lesions impair memory-guided comparisons of contralateral visual motion. *J. Neurosci.* 35, 7095–7105. doi: 10.1523/JNEUROSCI.5265-14.2015
49. Rainer, G., Asaad, WF, and Miller, EK (1998). Selective representation of relevant information by neurons in the primate prefrontal cortex. *Nature* 393, 577–579. doi: 10.1038/31235
50. Sakai, K., Rowe, JB, and Passingham, RE (2002). Active maintenance in prefrontal area 46 creates distractor-resistant memory. *Nat. Neurosci.* 5, 479–484. doi: 10.1038/nn846
51. Roux, F., and Uhlhaas, PJ (2014). Working memory and neural oscillations: α-γ versus θ-γ codes for distinct WM information? *Trends Cogn. Sci.* 18, 16–25. doi: 10.1016/j.tics.2013.10.010
52. Roux, F., Wibral, M., Mohr, HM, Singer, W., and Uhlhaas, PJ (2012). Gamma-band activity in human prefrontal cortex codes for the number of relevant items maintained in working memory. *J. Neurosci.* 32, 12411–12420. doi: 10.1523/jneurosci.0421-12.2012
53. Samuelson, P., (1939b), „ A Snthesis of the Principle of Acceleration and the Multiplier“ , Journal of Political Economy, vol. 47, no. 6, 786-797.
54. Schwabe, L., Tegenthoff, M., Höffken, O., Wolf, OT, 2012. Simultaneous glucocorticoid and noradrenergic activity disrupts the neural basis of goal-directed action in the human brain. J. Neurosci. 32, 10146–10155
55. Tobin, J., (1984), „ On the Efficency of the Financial System“ , Lloyds Bank Review, vol. 153, 1-15
56. Verplanken B., Holland RW (2002). Motivated decision making: effects of activation and self-centrality of values on choices and behavior . J. Pers. Soc. Psychol . 82 , 434–447. 10.1037/0022-3514.82.3.434
57. van Putten M, Zeelenberg M, van Dijk E. 2010. Who throws good money after bed? Action vs. state orientation moderates the sunk cost fallacy. Judgm Decis Mak. 5: 33-36.
58. von Neumann, J., Morgenstern, O., 1944. The Theory of Games and Economic Behavior. Princeton University Press, Princeton, NJ.
59. Wurtz RH, McAlonan K, Cavanaugh J, Berman RA. 2011. Thalamic pathways for active vision. Trends Cogn Sci. 15(4): 177- 184.