NEUROFINANCE – GETTING AN INSIGHT INTO THE TRADER'S MIND

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Much of the academic finance theory is based on the assumption that individuals act rationally and behavioral finances treats investors' choice based by behavioral biases. In contrast, neuro-finance (as a blending of psychology, neurology and finance) attempts to understand behavior by examining the physiological processes in the human brain when exposed to financial risk. Scientists map the mind to learn how fear and greed drive the financial markets. The paper, will briefly present why neurofinance is important and how will be able to provide in the near future a number of effective tools for improved financial decision making.

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Much of the ***academic finance*** is based on the assumption that individuals act rationally, consider all available information in the decision-making process and the expected utility theory represents the model for choice under certainty. In fact, when it comes to financial decisions, investors may not always be as rational as we think.

A new field of finance, called ***behavioral finance*** examines why some traders achieve phenomenal success while others gamble away fortunes. Behavioral finance that is, finance from a broader science perspective including sociology and psychology, represents a new approach to financial markets, in response to the difficulties faced by the academic finance. Behavioral finance attempts to understand and explain how emotions influence investing decisions. Humans differ very much with respect to concepts such as risk aversion, time preference and tastes. "Limits to arbitrage", form one of the two buildings blocks of behavioral finance. Psychology (behavioral biases) is the second building block of behavioral finance (people's beliefs and people's preferences). "Extraordinary Popular Delusions and the Madness of Crowds," written by ***Charles Mackay*** in ***1841***, remains a Wall Street classic to this day. He shows how otherwise intelligent people sometimes succumb to mass idiocy. Mackay examined the history of alchemy, witch hunts, fortunetelling and speculative frenzies such as the ***mania over tulips*** that gripped Holland in the early 17th century, when the flower bulbs *traded at a higher price than gold*. Keynes coined a colorful term for one of the vital ingredients of economic prosperity, the naive optimism that prompts people to cast aside their fears despite all experience: "animal spirits."[453]

The explanation that human beings are irrational about money lies in the human brain and its multi-billion neuronal connections. Recently, behavioral economists have leveraged the findings from psychology and neurology developing new fields like ***neuroeconomics***[454] and ***neurofinance***, in order to understand how people make economic decisions. By looking inside the brain, we may have a more realistic model of decision-making, and we'll be able to explain in a better way (compared to the standard model) a wide range of individual economic behaviors

[453] **Levy, Adam**, "*Mapping the trader's brain*" – Bloomberg Markets, Feb. 01. 2006 – source: http://www-psych.stanford.edu/~span/Press/bk0206press.html

[454] Neuroeconomics is an emerging transdisciplinary field that uses neurostientific measurement techniques to identify the neural substrates associated with economic decisions" – **Zak, J. Paul** "*Philosophical Transactions: Biological Sciences*, Vol. 359, No. 1451, Law and the Brain (Nov. 29, 2004), pp. 1737-1748

and their effects translated into aggregate market phenomena. Neurofinance is a new science that analyzes financial markets by applying neurotechnology to trading behaviors[455]. The main objectives are: improving trading results and a better understanding of financial markets, by identifying which physiological traits affect trading behavior, correlating these traits (that occur in our brain and hormonal activity) with trading success or failure and developing tools, technology and training methods to improve trading performance. The main difference between neurofinance and neuroeconomics, though they use many similar techniques, is that neurofinance focuses more narrowly on trading and financial markets.

Decision-making process is fundamentally integrative, melding the complex cognitive processes through which causal relations between actions and consequences are encoded, retrieved and maintained in working memory, with the motivational processes that determine the value, or utility, of actions or sequences of actions. It is important to recognize the interaction of the cognitive, motivational and behavioral processes engaged during the course of specific decisions that cannot be reified to a single specialized circuit, cell type or intracellular process[456]. They are better understood at a systemic level. Brian Knutson was wondering ***why some of the traders get rich while others walk away losers***. The answer may lie somewhere in the approximately 60000 miles of neural wiring inside our brains. What lies behind a successful trader? There has to be something more than simply guts, self confidence to take a loss and move on, or understanding risk and reward at a simply and intuitive level. May neurofinance be able to understand the brain's electrochemistry of a successful trader? Why some of them gamble away fortunes on losing investments, averaging down or doubling when logic tells them to stay out, or letting winning positions ride when rational persons would cash out? Why smart guys like Paul Tudor Jones, Richard Dennis, Victor Sperandeo, Stanley Druckenmiller, Ed Seykota, Jesse Livermore, Bernard Baruch, Warren Buffett and so many others made multimillion and even billion-fortunes in trading securities? How come George Soros became known as "the Man Who Broke the Bank of England" after he made $US 1 billion profit during the 1992 Black Wednesday UK currency crisis? What is that makes them so special?

It's not enough to be smart or highly educated. There are a lot of outstanding people, some of them geniuses, scientists who were honored with Nobel Prize in Economics, but nobody knows that some of them might have become rich (some of them never made a dime on the market) exclusively because of their discovered financial models or theories, except for conferences and interviews fees, selling books and teaching other people how to make money. It might be frustrating to see that others who dropped college have made multi-million fortunes on the market, and very well known scholars in the finance field, NOT. "*If all it took to beat the markets was a Ph.D. in mathematics, there'd be a hell of a lot of rich mathematicians out there"* - Bill Dries. "*No matter what kind of math you use, you wind up measuring volatility with your gut."* Ed Seykota

Probably, the preeminent example that fundamentals are not everything is the collapse of the famous hedge fund founded by John Meriwether in 1994 – ***Long Term Capital Management (LTCM)***. John Meriwether was one of the first traders to bring quantitative finance to Wall-Street and gained a measure of fame in Michael Lewis' book Liar's Poker, where he is described by Lewis as a Salomon Brothers Uber-trader and master of Liar's Poker[457]. The failure of LTCM is a cautionary tale about hubris, arrogance, overconfidence and the limits of modern financial theory. With *an outstanding team* of quant finance traders and scientists, including two *Nobel Prize winners: Robert C. Merton* and *Myron Scholes*, LTCM used complex mathematical models to take advantage of fixed income arbitrage deals (termed convergence trades) usually with U.S.,

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[455] **Edwards, David** – "*What is Neurofinance*" – Brainwaves, Corante Weblog Columns, August 9, 2004 – source: - http://brainwaves.corante.com/archives/2004/08/09/what_is_neurofinance.php

[456] **Balleine W. Bernard** – "*The Neural Basis of Choice and Decision Making"*, The Journal of Neuroscience, August, 1. 2007, 27(31):8159-8160

[457] Book Review of "*When Genius Failed: The Rise and Fall of Long-Term Capital Management* by **Roger Lowenstein**" , Random House, September 2000 - http://www.bearcave.com/bookrev/genius_fails.html

Japanese, and European government bonds. Although from 1994-1996 LTCM returned more than 30% a year, and their funds swelled to more than US$ 7 billion, in 1998, they crashed and burned, endangering the US financial system (Federal Reserve Bank of New York organized a bailout of $3.625 billion by the major creditors to avoid a wider collapse in the financial markets[458]). Because of the small differences in value of the assets arbitrage, LTCM had to take highly leveraged positions to make a significant profit. "*But the system wasn't designed so that most people could beat it"*. They ignored two underlying assumptions behind the market models they used: markets are always liquid and markets tend toward equilibrium where "mispricing" are corrected. True, but the assumptions failed to be true during a market panic. The panic caused by the Asian and Russian Financial Crisis (1997 and 1998), made LTCM to liquidate many positions causing large losses, including the arbitrage positions between Royal Dutch and Shell shares. Because of the liquidity dry-up of the panic and high-leveraged positions, LTCM had nothing else to do but crash and burn. They didn't expect panic to happen. According to Nassim Taleb: "*Rare events are always unexpected, otherwise they would not occur"*.

Meriwether was so confident about his market opinions and his quantitative financial analysis, that even if the market would go against him, he would not change his opinion. Often he would increase the size of his position, despite of the market opinions. If his mathematical models showed a mispricing, he remained confident that fair value would return, over time, so he kept his positions and even added to it. He believed in nothing but fundamentals. Meriwether ignored completely an old trading adage: *"Ninety percent of what we do is based on perception. It doesn't matter if that perception is right or wrong or real. It only matters that other people in the market believe it. I may know it's crazy, I may think it's wrong. But I lose my shirt by ignoring it"*[459]. As Keynes used to say: *"Markets can remain irrational longer than you can remain solvent"*

The collapse of LTCM gave markets a tuff lesson about pride, arrogance, defiance, greed and hubris, making some market players say memorable words, like the one of Kaufman and Lenzner : "*Meriwether and his sidekicks had a bad case of hubris. As Kaufman puts it: „There are two kinds of people who lose money: those who know nothing and those who know everything." With two Nobel prize winners in the house, Long-Term Capital clearly fits the second case"*[460]. *„It seems LTCM could have survived one Nobel prize – winner, but with two, they were doomed"* – Frederic Townsend. As a conclusion, we might consider the Ed Seykota's joke: *"Some people seem to like to lose, so the win by losing money"*.

Some recent examples of other astonishing loses are[461]: Societe Generale (2008 – USD 7.2 bn – European Index Futures – Jerome Kerviel), Aracruz Celulose Brazil (2008 – USD 2.5 bn – FX Options), Sadia Brazil (2008 – USD 1.09 bn - FX and Credit Options), CITIC Pacific China (2008 – USD 1.89 bn – FX Trading), Amaranth Advisers (2006 – USD 4.6 Bn – Nat Gas Futures – Brian Hunter) and the list may go on. The collapse of Britain's Barings Bank in Feb. 1995, is perhaps the most popularized financial collapse. Barings Bank was sold for 1 sterling pound to ING, because of the rogue trader, called Nick Leeson – a derivative trader on SIMEX.

Now, it is easily understandable why mapping a trader's mind, why neurofinance is very important. Because of one single person, thousands of employees, several hundred thousands of customers and other collateral parties may go broke if the trader in charge does not perform well. And in most cases, the problem was not "outside" but "inside". If Leeson lost, someone else won. Definitely won. Trading derivatives it's a zero sum game. Will neurofinance be able to help us understand what was in Leeson's mind? And in his counterpart's mind? What made Leeson lose and what made the other one win? And how can we replicate the winner's succes?

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[458] http://en.wikipedia.org/wiki/Long-Term_Capital_Management

[459] "*Making Book on the Buck*" – Wall Street Journal, Sept 23, 1988, pg 17.

[460] **Lenzner, Robert,** Forbes Magazine, Oct. 19, 1998 – source: www.streetstories.com/jm_forbes98.html

[461] http://en.wikipedia.org/wiki/List_of_trading_losses

Jack Schwager, wrote in one of his books: *„Time and Time again, those whom I interviewed for this book and its predecessor stressed the absolutely critical role of psychological elements in trading succes!"* When asked to explained what was important to success, Jack says: *„The Market Wizards NEVER talked about indicators or techniques, but rather about such things as discipline, emotional control, patience and mental attitude toward losing"*. The message is CLEAR: ***The key to winning in the market is internal, NOT external"***[462]**.**

Neuroscience and neurofinance help us understand whether there is a mismatch between brain and financial markets, when trading. Although, in the decision theory and equilibrium theory, all risks are the same, the brain distinguishes at least two kinds of risk: risk generated by an unintentional source (a random generator, "nature", a financial market without insiders) and the risk generated by an intentional source (a strategic opponent, a financial market with insiders). The difference between them, manifests in the engagement of different functional regions of the brain and attitudes toward the source.

Decision neuroscience has made important progress over the past ten years, following the discovery of the role of dopamine neurons in prediction under uncertainty. Some treat with skepticism this subfield of finance, because it cannot be considered science. Neurofinance is based mainly in laboratory experiments. Lack of external validity is perhaps the most important reservation that people can have about laboratory experimentation.

Tools available to neurofinance, allow for understanding how people make financial and economic decisions, by analyzing how the brain works when these choices are made. By looking inside the brain, we may create a more realistic model of decision making and able to explain a much wide range of individual economic behaviors compared to the standard finance models. Some of **the neurofinance tools** are: ERP that record electrical activity of the scalp („event-related potentials" that measure brain response that is directly the result of a thought or perception – measured with EEG - electroencephalographic), ERF („event-related field" – that measure brain response that is directly the result of an event – measured with MEG - magnetoecepephalographic), TMS - Transcranial Magnetic Simulation, PET scans - Position Emision Topography, MRI – Magnetic Resonance Imaging, ***fMRI***[463] - Functional Magnetic Resonance Imaging and other lesion brain studies. Neurofinance has progressed dramatically over the past years, following the discovery of the role of ***dopamine***[464] neurons in prediction choice under uncertainty**.**

Decision making by traders is highly emotional (Lo & Repin 2002), and it activates hormones such as estosterone and cortisol that have a direct influence on the very brain regions. Hsu et al[465] (2005) has shown that dopamine projection in the ventral striatum is less activated under ambiguity than when probabilities of risk are known. Behavioral finance also confirms that

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[462] **Schwager, D. Jack,** "*The new market wizards: conversations with America's top traders"*. John Wiley & Sons, 1992 books.google.ro/books?id=LjivAz8xd3UC&printsec=frontcover#v=onepage&q&f=false

[463] **Functional MRI or functional Magnetic Resonance Imaging (fMRI)** is a type of specialized MRI scan. It measures the hemodynamic response (change in blood flow) related to neural activity in the brain or spinal cord of humans or other animals. It is one of the most recently developed forms of neuroimaging. Since the early 1990s, fMRI has come to dominate the brain mapping field due to its relatively low invasiveness, absence of radiation exposure, and relatively wide availability. Source: http://wikipedia.org

[464] ***Dopamine*** represents one type of neurotransmitter formed in the brain by the decarboxilation of dopa and essential to the normal functioning of the central nervous system. A reduction in it's concentration within the brain is associated with Parkinson's desease. Dopamine is the primary neurotransmitter involved in the reward pathways in the brain. Dopamine is released by naturrally rewarding experiences such as food, sex, use of certain drugs and neutral stimuli that become associated with them. Thus, drugs that increase dopamine signaling may produce euphoric effects. Many recreational drugs, such as cocaine and amphetamines, alter the functionality of the dopamine transporter (DAT), the protein responsible for removing dopamine from the neural synapse. Source: www.wikipedia.org

[465] Hsu M, Bhatt M, Adolphs R, Tranel D, Camerer CF. 2005. Neural systems responding to degrees of uncertainty in human decision making. Science 310:1680–83

humans treat pure risk and ambiguity differently. According to him, another activation emerges, namely, in the amygdala, that forms part of a circuit that has been associated with goal directed learning, a signal of a need to start learning. Amygdala has been for long time, viewed as the „fear center" of the brain. Fear may be the emotional expression of estimation uncertainty, just like arousal accompanies positive reward prediction errors (and relates to activation of the dopamine system). That is, fear may act as a dual signal, relaying both a caution not to bet on things unknown and a directive to find out more (Hsu et al. 2005)[466]. All these regions (amygdala, insula and the dopamine system) have in comon perhaps the most important feature of the human condition: emotions. Studies have showed that subjects who fail to express emotional anticipation when making risky decisions (because of specific brain lesions) consistently opt for inferior financial choices.

Neurofinance literature analyses the role of affect in financial decisions. Lo & Repin[467] (2002) found that profesional securities traders experience emotional states characterized by hugh arousal market events such as high price volatility, using peripheral measures of arousal, like skin conductance and blood volume pulse. Lo, Repin and Steenbarger (2005) found that subjects whose emotional reaction to monetary gains and loses was more intense on both the positive and negative side, exhibited significantly worse trading performance[468]. ***Kuhnen and Knutson***[469] (2005) found that Nucleus accumbens activation preceded risky choices as well as risk-seeking mistakes, while anterior insula activation preceded riskless choices as well as risk-aversion mistakes. These findings suggest that distinct neural circuits linked to anticipatory affect promote different types of financial choices, and indicate that excessive activation of these circuits may lead to investing mistakes. So in another study of them in 2007[470] they can predict what goods people purchase by measuring activation in the same areas of the limbic or emotional system. The manner a person likes a product, is correlated with activation in the nucleus accumbens, while charging excessive prices for the product, activated the insula. This is the main reason why companies have started to conduct ***neuromarketing*** and measure brain activation in order to see whether their products will be a success. In 2008[471] another study of them, affirmed that nucleus accumbens (NAcc) activation spontaneously increases prior to financial risk taking. Using event-related fMRI, they predicted and found that anticipation of viewing rewarding stimuli, cues influence financial risk taking by altering anticipatory affect, and so identify a neuropsychological mechanism that may underlie effective emotional appeals in financial, marketing, and political domains.

Behavioral and neural studies of ***temporal discounting***, (Zak, 2004), states that one of the major behavioral differences that exists between human and other animals is the ability to postpone immediate gratification for a future (possibly larger) reward. It is interesting to see the main types of discounting: exponential discounting that implies a constant preference between rewards should exist over time, and the hyperbolic discounting, that show a clear tendency to discount expected outcomes proportionate to their delays exists and often there is a preference reversal

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[466] Bossaerts, P. *"What Decision Neuroscience Teaches Us About Financial Decision Making"*, The Annual Review of Financial Economics,. Pg 391, 2009

[467] **Lo, Andrew W. and Repin, Dmitry V**., *The Psychophysiology of Real-Time Financial Risk Processing"* (October 2001). MIT Sloan School of Management Working Paper No. 4223-01; MIT Laboratory for Financial Engineering Working Paper No. LFE-1039-01.

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between the immediate and the delayed reward in the period of time just before the reward is due. Knutson et al (2009) tested a „future self-continuity" hypothesis that individual differences in the perception of one's present self as continuous with a future self would be associated with measures of saving in the laboratory and everyday life. Higher ***future self continuity*** predicted reduced discounting of future rewards and greater lifetime of accumulation of financial assets, promoting saving for the future[472].Shiv[473] et. al. (2005) tested the "***Myopic loss aversion***" hypothesis and showed that the lesion patients would be less risk averse and would be more profitable, since their brain lesions mitigated the affect associated with fear of money loss. McClure[474] et al (2004), used fMRI to show that decisions based on instant reward activated parts of the limbic system associated with the dopamine pathways. They found that tradeoffs involving delayed monetary rewards largely activated regions of the lateral prefrontal cortex, the brain region associated with cognitive introspection, illustrating the important of the limbic system in the human decision making. Bossaerts (2009) suggests that emotions play a crucial supporting role in the mathematical computations needed for reasoned choice, rather than interfering with it, even if emotions may not always be balanced appropriately. Tom et al (2007) analyzed whether loss aversion were predicted by a measure of neural loss aversion in several regions, including the ventral striatum and prefrontal cortex[475].

Should computers replace humans in financial markets? Bossaerts (2009) says no, because humans with all the limitations and maladapted brains to certain situations, they are better are certain tasks. Neurofinance should identify these limitations and help people replicate success. Computers should overcome only when humans cannot adapt. (It is very well known that most of the banks that play their money on FX have impressive robots that trade under certain algorithms). Neurofinance is bound to impact all of finance, with impact on household, consumer finance, college and retirement plans, corporate finance, microfinance, most of the market professionals and many other subfields of finance. As Kuhnen (2007) concludes, findings from neuroeconomics and neurofinance may also be used by policy makers, in order to increase social welfare. If government wants to encourage workers to save more for retirement, it may design financial policies that trigger the right part of the limbic system to induce the desired behavior. Or if they want to discourage some activities, they should institute incentives that trigger people risk-averse part of the brain, knowing how brain works when faced with uncertainty.

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