TRADERS' DECISION-MAKING PROCESSES: RESULTS FROM AN INVESTMENT SIMULATION MONITORED WITH AN EEG

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***Abstract*— The objective of this article is to identify, with the aid of an electroencephalogram (EEG), whether traders use different areas of the brain (and therefore different levels of neuronal activity) in their decision-making process when it comes to making a financial investment. A sample of forty (40) experienced traders was used, divided equally into 50% male and 50% female. Some findings through brain mapping indicate that these operators in the financial market tend to make decisions using an associative based rule process (anchored to historical or intuitive data); rather than any form of analytical based rule, as the classical financial literature on this issue suggests. From an economic standpoint, this work is distinct from the classical theories of Finance - Efficient Markets Theory and Modern Portfolio Theory - to the extent that it not only employs assumptions of behavioural finance, but also encompasses studies of neurocognitive processes.**

Keywords— Neuroeconomics, Rationality, EEG, Cognitive Science

I. INTRODUCTION

The objective of this article is to identify, with the aid of an electroencephalogram (EEG), whether traders use different areas of the brain (and therefore different levels of neuronal activity) in their decision-making process when it comes to making a financial investment.

From an economic standpoint, this work is distinct from the classical theories of Finance - Efficient Markets Theory and Modern Portfolio Theory - to the extent that it not only employs assumptions based on behavioral finance, but also encompasses studies of neurocognitive processes. The aim of this contribution is to strengthen the methodological link between neuroscience and economics / finance by using an EEG (electroencephalogram).

It is widely accepted that within neuroscience people use prices as anchors, as observed in some seminal work by Miller (1956), Parducci (1965), which suggests that this is no difference within the financial market. In behavioral finance, anchoring is seen as a behavioral bias, since it uses a number to draw up an estimate, even when there is no logical connection or even a relationship. In other words, there is a heuristic process to formulate any kind of judgment, as already envisaged in the work of Tversky & Kahneman (1981).

The evaluation of the acceptance of a certain decision - financial or not - is strongly linked to a risk-benefit analysis calculated by these agents, underpinned by the neuropsychological aspects related to the emotional space of a decision (ED).

From the experimental point of view, functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) have been recently used to study the brain activity correlated with this type of decision-making process.

According to scientific experiments, such as the one conducted by ET AL McClure (2004), ET AL Plassman (2008) and Dayan (2008), Rocha and al (2010), a wide network of neural circuits is involved in assessments of risks, benefits, conflicts, intentionality, etc. (this weighting is closely related to serotonin in the event of risks, and dopamine in the case of benefits). Understanding the functionality of such systems is of fundamental importance in understanding the dynamics of the financial market, i.e. to record the perception of each individual in relation to general market sentiment, which can lead to hysteria (a bear market) or euphoria (a bull market). It is reasonable to suggest that there is a reliability factor in the market itself.

It is known, however, that the risk-benefit scenario generates a conflict in the decision-making process. In the event of a change in an individual's perceptions, the distance between these variables - risk & benefit - will also alter, to the point of not making any decision at all.

So if, for instance, the conflict associated with the financial negotiation of the action exceeds the average conflict existing in the market, then the market humor tends towards that of a “vendor” (a seller or bearish), as the final price will be influenced by the buyer (and for “buyer” the word “bullish” can also be used). Thus, the moves of individuals can be anticipated through a determined time anchor based on market sentiment.

II. Neuro Basis of The Decision-Making Process

A. *Neural Evidence*

In the literature on neuroscience, the contribution made by some areas of the brain related to the cognitive processes of an individual is mainly determined by the regions of the parietal, frontal and hippocampal cortex, reflecting the spatial representation, memory and the generation of action in space. Miller; Cohen (2001) proposed an integrative theory of prefrontal cortex, based on the original work of Fuster (1987) and Goldman - Rakic (1988). The authors asserted that cognitive control stems from the active maintenance of patterns of activity in the prefrontal cortex that represent goals and the means of achieving them. They also provided signs of bias to other brain structures, the net effect of which is to guide the flow of activity along neural pathways that establish the appropriate links between inputs, the internal mapping of states of mind, and the skills needed to perform a given task. In essence, the two theorized that the prefrontal cortex is capable of guiding the inputs and connections, thus permitting the cognitive control of actions.

Importantly, controlled behavior also involves a time variable. Relevant information for decision making should be anticipated and kept in mind for a certain time, in what is called short-term or working memory. Moreover, one can also say that these processes are limited in capacity and, therefore, must also be properly selected. In the sensory realm, the latter fact is known as attention.

Shimamura (2000), with his dynamic filtering theory, describes the prefrontal cortex acting as a high-level gating system, where there is a filtering mechanism that enhances goal-directed activations and inhibits irrelevant activations. This filtering mechanism enables executive control at various levels of processing, including the selection, maintenance, updating, and forwarding of these activations. It has also been used to explain emotional regulation.

From an anatomical point of view, the prefrontal cortex is connected with the sensory systems via the dorsal and ventrolateral parts of the cortex. They are related with the sensory element more than the neocortex orbitofrontal cortex. The information received from the sensory areas comes from the occipital, temporal and parietal cortices.

According to Passingham, 1993, and as cited by Squire et al. 2003, it is suggested that the basal ganglia - dopaminergic ventral tegmental area of the midbrain – constitute the most important driver of the reward signals, and thus influences the prefrontal cortex.

Important to the somatic marker hypothesis (SMH), Damasio (1991) suggests that the orbital prefrontal cortex is responsible for the appointment of persons, objects, and situations with an "affective significance." This fact is achieved by virtue of the association between past memories and these markers help the individual to make a decision. This dynamic is then called the "somatic marker".

When there are complex or even conflicting choices, it is not possible only to use cognitive processes, as they can suffer from overloads, resulting in the inability to reach a satisfactory result. In these cases, somatic markers may help in decision making, as they are associations between stimuli that induce an associated reward affective / physiological state. It is conjectured that somatic markers are stored in the brain in the ventromedial prefrontal cortex (vmPFC; subsection of the orbital prefrontal cortex) region. These combinations of markers may occur again during decision-making, and can influence our cognitive process. The entirety of this state directs or influences a certain decision as to how to act through the brain stem and the striatum (unconsciously), or by manifesting (consciously) with high cortical cognitive processing. Damasio proposes that somatic markers direct attention to the most advantageous options, thus simplifying the decision-making process. This hypothesis was inspired by the economic theory in which the model of human decision making is devoid of emotions, involving the assumption of full rationality - with full knowledge and information obtained from the environment - of individuals and their "reaction functions", which are expressed in a mathematical form, thus generating optimal decisions. In contrast to this idealization, the somatic marker hypothesis proposes that emotions play a critical role in the ability to make quick, rational decisions in complex and uncertain situations.

In the same line of thought as Damasio (1991), Steven Sloman produced another interpretation of dual processing theory in 1996. He divides them into logical groups of information based on their statistical regularity. In other words, this organization is nothing more than in direct proportion to the similarity with past experiences, still relying on the similarity and temporal relations to determine the reasoning rather than an underlying mechanical structure.

The other process of reasoning, in the opinion of Sloman (1996), was based on the fact that reason works on a type of logical structure to reach conclusions different to those in the associative system. He also believed that the system of rules based on reason always had control over the associative system, although the former does not completely suppress the latter.

Kahneman (2003) provided additional interpretation, differentiating the two types of processing, calling them intuition and reasoning. The first system, intuition, or System 1, is similar to associative thinking, and had a fast and automatic feature, usually with strong emotional ties involved in the reasoning process. The author goes even further, stating that this kind of reasoning is strongly based on habits formed in the past (anchored in past experiences), and that is very difficult to change or even manipulate. The second system, i.e., reasoning or system 2, works at a slower speed and is much more volatile, being subject to conscious judgments and attitudes.

System 2 is relatively recent in evolutionary terms specific to humans. As mentioned earlier, it is also known as the rule-based system; or rational analytical system, and is the general area held in the short-term memory system. Because of this, it has a limited capacity and is slower than system 1, which is correlated with general intelligence. This system allows the advent of hypothetical thinking, which is not allowed by system 1, and that is also distinct to humans.

Dual reasoning (or dual processing) postulates, therefore, that there are two systems at work in a mind or brain. The current theory is that there are two separate and distinct cognitive systems underlying thinking and reasoning, and that these different systems have been developed through human evolution. These systems are often referred to as being either implicit or explicit; however, some theorists, such as Goel et al. (2000), prefer to emphasize the functional side; that is, the differences between the two systems, and not the factor of consciousness, and therefore relate to systems simply as system 1 and system 2.

Goel et al. (2000) and Goel and Dolan (2003) produced neuropsychological evidence for the dual processing of human reasoning, using magnetic resonance imaging (fMRI) in their respective studies. The authors found that anatomically distinct parts of the brain were responsible for the two different types of reasoning; proving that the reasoning based on content activated the left temporal hemisphere, while considering the formal problem, abstract reasoning activated the parietal system. They concluded that different types of reasoning activate the semantic content of the two different systems in the brain.

They also found that different mental processes were competing for control of the response to problems presented to volunteers. The prefrontal cortex was instrumental in detecting and resolving conflicts, which are characteristics of the system 2 area, already typically associated with that same system. The ventral medial prefrontal (vmPFC) cortex, and medial orbitofrontal, known to be associated with more intuitive responses, or heuristic system area 1, is in competition with the prefrontal cortex.

The activation of the vmPFC is associated with suppressing the success of emotional responses to negative emotional signal. Patients with lesions in the vmPFC show defects both in emotional response and in the regulation of emotion, as shown in a study by Koenigs et al. (2007). The emotions of the patients in this study were closely associated with moral values, as well as maladjustment in terms of tolerance, anger, and frustration; in certain circumstances. We also emphasize that lesions in this area show personality changes, such as lack of empathy, irresponsibility and poor decision making, as described by Motzkin et al. (2011).

The right half of the ventromedial prefrontal cortex was associated with the regulation of the interaction between cognition and empathy (empathic responses). Hedonic responses (pleasure) were also associations made with the level of activity in the orbitofrontal cortex by Morten Kringelbach, in his work meeting "Pleasures of the Brain" in 2009. This finding contributes to others associated with the prefrontal ventromedial cortex when it comes to judging preference, for example. There is the idea that the ventromedial prefrontal cortex is important for the reactivation of associations, and the component related to past emotional events (Kringelbach, 2009).

Individuals' expectations can easily be manipulated by changing the anchor of past prices. This result is now a stylized fact in the area of neurosciences, and exploring it will provide a new slant to the events that took place in the financial market crises.

Neuroeconomics shows that human decisions are made based on a weighting between the impulse for immediate gain or its maximization in the future. And consequently, rationality plays an important role in this system, because each time that lag is also taken into consideration, with the appropriate expected discount rate, whereas impulsive preference is indicative of disproportionate gains in the short term.

B. Investment Simulation

The objective of this research protocol is to describe the format of the experiment for the present work, which counted on the help of the Marketing Research recruitment firm, A + Recruitment.

A total of eighty volunteers, equally divided into two samples were recruited - undergraduate students between the second and penultimate semesters (before graduation), as well as financial market professionals working in the area of treasury, brokerage or asset management trading desks, also called traders or brokers. To facilitate the criteria, the latter was called a group of "traders". Moreover, a pre-requirement was to have at least one year of experience in the relevant area.

For both, the incentive was offered at R$100.00 (one hundred Brazilian Reais) for undergraduate students, while for traders, this figure was R$180.00 (one hundred and eighty Brazilian Reais) at the end of each experiment.

The experiment included 40 traders, both subdivided into 20 men and 20 women to have a viable and reliable comparison of recruited groups.

Volunteers participated in a simulation of investments in the Sao Paulo Stock Exchange - BM&FBovespa - while their brain wave activity was recorded by an electroencephalogram (EEG). The total simulation time lasted 50 minutes, also subdivided into 25-minute intervals, primarily related to a bull market (bullish in financial jargon), and then a bearish market (also identified as bearish).

Thus, the purpose of this study was to characterize patterns of brain activity associated with the decision to buy, sell or hold a stock comprised of two experimental portfolios (called A - B and market High - Low), and to correlate these patterns of brain activities.

Volunteers encountered on the computer a portfolio of pre-selected shares, with an initial amount of two hundred (200) at prices first disclosed by the system.

In each "Trading Day", the volunteer had to take a number of decisions for each portfolio (approximately 25 minutes for both portfolios), which could be to: - buy (C), sell (V), or leave unchanged.

Market prices evolved either as in a buyer's market (bullish market), or a seller's (bearish market). Prices relied on the trajectory of past trading sessions and online news was also disclosed at the time. These were then provided to try to identify the type of market in which trading was being made, to negotiate voluntary actions.

The simulation was terminated when it reached 25 minutes for each portfolio, or if the volunteer reached the next screen "END".

C. The registration of EEG

EEG was run by a program named *Icelera*, where brain waves were read by 20 electrodes with amplitudes resolution of 100μV, while the impedance was 10 kOhms with a low-pass filter of 50 Hz, and a sampling rate of 256 Hz with 10 bits of resolution. The great advantage of this technique is the fact that it is portable and noninvasive, without the need to go to a specific hospital or laboratory. Two networked computers were used for the EEG (electroencephalogram) recording, while the subject performed a specific cognitive activity, which in this case was a simulation of trading. The solution and time required to make the decision was duly recorded for later analysis.

Thus, the decision and the individual time required that led to this decision were recorded for each event. Every decision regarding all volunteers, was stored in the performance database. Other important socioeconomic data (such as gender, age, work experience, position) for each protocol were also recorded in this performance database.

Correlation coefficients - $r_{i,j}$ - for the activity recorded from each electrode (i) in relation to the other 19 electrodes (ej) were also calculated for each event (EVE) in the cognitive activity of volunteers. Entropy - $h(r_i)$ - of the 19 correlations, $r_{i,j}$, was calculated for each electrode "i", and associated with each event of a given cognitive activity recorded for volunteers was based on the following formulas:

$$h(r_{i,j}) = -r_{i,j}\log_2 r_{i,j} - (1-r_{i,j})\log_2(1-r_{i,j}) \quad (1)$$

$$h(\check{r}_i) = -\check{r}_i\log_2\check{r}_i - (1-\check{r}_i)\log_2(1-\check{r}_i)\ onde\ \check{r}_i = {\textstyle\sum_{j=1}^{20} r_{i,j}}\Big/_{20} \quad (2)$$

$$h(r_{i,j}) = \sum_{j=1}^{20} h(r_{i,j}) - h(\check{r}_i) \quad (3)$$

The above formula - see Rocha (2009) - reflects the Shannon entropy, which quantifies the expected information contained in a message value. It provides an absolute limit on the best possible encoding, assuming that communication can be represented as a sequence of independent and identically distributed random variables.

The average uncertainty and the average operator shall be obtained by the following formula:

$$\langle u\rangle = \sum_{i=1}^{n} p(x_i)u_i = -\sum_{i=1}^{n} p(x_i)\log_b p(x_i) \quad (4)$$

The definition of entropy h (x) is used. In the case where b equals two (2), the equation of expected measures of the bits that need to specify the result of a random number in an experiment.

The Factor Analysis (FA) of base Entropy will then be used to build up the mapping Factors (MFs) that show how the entropy regression $h(r_i)$ covariates with all electrodes in a given cognitive task. In general, three factors explain more than 55% of covariation $h(r_i)$, restricting the dimensionality of the variables, therefore facilitating the outcome analysis, and as according to Rocha 2009. The FA identifies three different patterns of brain activity that explain, in general, good covariance " $h(r_i)$" and can also be associated with three different types of neural circuits in the making of a particular decision (Rocha et al, 2010; Rocha, 2013):

(A) The P1 pattern is proposed to reveal the activity of attached neural circuitry for recognizing the solutions of possible problems, and they also evaluate their risks, and of course, the benefits involved in decision making;

(B) The P3 pattern is proposed to reveal the activity of neural circuits responsible for the calculation and adjustment of action, justice and willingness to take into account the results calculated by P1 neural networks;

(C) The P2 pattern is proposed to reveal the activity of executive neural systems and charge to trigger the whole process of decision making. With this, one selects the action to be implemented taking into account the information provided by the P1 and P3 neural networks.

Thus, it will analyze all the decisions made by all volunteers to extract the brain dynamics in each conflict of risks and benefits, given a previously chosen event.

As previously mentioned, FA identifies three different patterns of brain activity - P1, P2 and P3 – with values totalling over 55% of the covariance of h (i) - and the values below this cut off are represented by the blank colour in the map, while 100% are the colour red - where P1 reflects the solutions of possible problems vis-à-vis their associated benefits, and of course, risks involved in decision making. P3 already implements the action glimpsed in P1 and, finally, the P2 pattern reveals executive neural systems, and triggers the whole process of decision making, as an anticipation effect - Rocha (2013). With this, you select the action to be implemented taking into account the information provided by P1 and P3 neural networks.

According Preuschoff et al (2008, pg.77): "(...) neurons in parts of the brain respond immediately (with minimal delay) to changes in expected reward and with short delay (about 1 to 2 seconds), to risk, the measured by payoff variance." One can thus assume that there is a neuronal dynamics at the time of decision making, during which time the overall situation is assessed, and then the scope and brain finally decide on doing the deed. Resuming the work of Pavlov via Fiorillo; Tobler; Schulz (2003) using the conditional stimulus, after a certain time, a decision is made.

Knutson et al (2003) also showed this fact, using magnetic resonance imaging in the nucleus accumbens in four-second intervals between stimulus and reward. This is consistent with the idea that dopamine neurons fire more when the expected reward increases. Similarly, activation significantly increases the reward point in time in which it is advertised. This anticipation effect is raised by Rocha (2013). However, Preuschoff et al (2008) also draws attention to the fact that observing the short-term response at the moment of realized risk, i.e., when the stimulus is switched off and the outcome (reward / no reward) is revealed. One would not have expected this because both rewarded and unrewarded trials are averaged. In other words, the average prediction error should be zero. Yet VTA neurons react positively on average to the realization of risk. It could be assumed that this is because of a fundamental asymmetry: neurons can reduce their firing rate (in response to an absence of reward) only to zero; they can increase their firing rate (in response to reward delivery) to a much higher extent - at least in principle.

In other words, risk may trigger a different type of neuronal circuitry. The author argues that in the context of decision making, the theory that assigns a positive role to emotions is the SMH (Bechara, Damasio, 2005). Recent research suggests that decision-making occurs in the activation of the amygdala, insula, and orbitofrontal cortex, playing a crucial role in emotional context.

However, financial risks are too recent to have had an impact on the human brain. While the brain may have been optimized to assess environmental risks, the latter is known to be very different from financial risks. For example, environmental risks usually do not have a leptokurtic distribution and independence generally found in financial data. Errors are bound to arise when assessing financial risk to the brain, which end up invoking processes intended to evaluate environmental risks. Thus, one should assume that the brain areas when assessing the financial risks are different from those encountered when evaluating a reward or expectation of reward. (Preuschoff et al, 2008).

In the case of this work it highlights the result with buying, selling or holding of investment strategy (after visual stimuli as a graphic and newspaper articles to guide their decisions) was only revealed at the end of each move (be it positive or negative). The ultimate goal of each volunteer was to maximize their portfolios.

Recalling that in this experiment, the sample was divided into between 40 undergraduate students and 40 professionals from the financial market, subdivided into 20 men and 20 women in each situation. The balance of the sample was taken as 16 decisions in each market - separated into high and low markets - for the first sample (undergraduate), while the second (traders) made 22 decisions.

The results of the factor analysis are presented below the brain maps, with the respective factors being presented in order of magnitude (in parentheses), with the ">" sign, at a significance level above 55%.

D. *Brain mapping technique with EEG*

Most ancient techniques to map the brain are based on a measurement of the electric field or the magnetic field induced by the ionic currents generated by neurons involved in brain processing. They are the electroencephalogram (or EEG) and magneto EEG (or MEG). The latest technique to make this type of measurement is supported by analysis of a brain's magnetic field, by varying the movement of water molecules that are stimulated by strong and short disruptions of the brain's magnetic field. This technique can provide both a static image of the anatomy of the brain, called magnetic resonance imaging (or MRI), or information on the transitional changes of blood flow to the activated brain areas, called functional MRI (or fMRI) . The latter is used to disclose possible brain injury and the objective of the fMRI is therefore to identify the brain areas that are activated during a specific brain processing activity.

To analyze the abovementioned disorders, medical scientists rely on very sensitive machinery with sensors to measure the dipoles reversed and displaced from their original positions. Special experiments then need to be done in bays, where patients (or volunteers) are placed, to avoid any strong motor drive.

Statistical analysis of the data on the dipole offset provides precise spatial information about many sets of neurons activated in both cortical and sub-cortical areas during a specific processing. However, because the measurements are about the transient influx of blood, fMRI has a very low temporal resolution. Statistical analysis requires at least two seconds of data sampling to provide reliable information on the activated cortical or subcortical areas.

Moreover, the electrical activity (electric field temporal variation) is recorded by a set of electrodes, two of them in the headset. In other words, the electroencephalogram (EEG) is a weighted sum of the electric currents (2s sources - two seconds) generated by sets of neurons that are activated in different cortical areas.

Rocha et al (Foz et al, 2002; Rocha, Massad Jr. and Pereira, 2004; Rocha et al, 2005; Arruda, Rocha and Rocha, 2008; Rocha et al, 2010) developed a methodology for mapping the brain activity recorded from the electroencephalogram (EEG) that allows the study of the decision-making process both in simulated conditions as real.

The analysis of the EEG epochs is associated with specific moments of the cognitive task under study, and allows its characterization by FA (FA) through major patterns of the brain activity underlying finding a solution for the task at hand.

Rocha et al. (2006) used this technique to study the brain activity associated with the choice of buying products with different degrees of risk assessment, and showed that the emotional valence associated with each product correlates positively with brain activity recorded by frontal and parietal electrodes. These authors showed that the evaluation of satisfaction with an aesthetic dermatological treatment correlates with the activity of neural circuits that evaluate beauty both in personnel and social contexts.

Massad (2009) studied the brain activity during decision-making in veterinary diagnostic. The EEG was recorded while volunteers read clinical history data associated with an RX examined and decided on the diagnosis. The brain mapping identified a brain circuitry associated with the analysis of visual information and executive control tasks, with a pattern of activity similar to the 3 phases of the process. In addition, the FA has allowed the identification of two other patterns of brain activity, one of them associated the process of integration of clinical and radiological data, and the other with the diagnostic decision-making process.

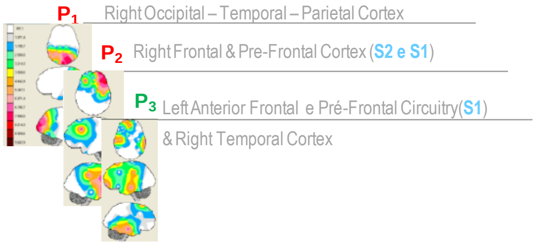
III. MAIN FINDINGS:

In the case of professional financial market trading desks, noting that traders are also called or "operators or brokers", the first pattern (P1) brain mapping identified occipital - temporal-parietal areas - Oz > T5> O2> P3> Pz> P4. The group of traders initiate moves with the right side of the brain's hemisphere dominating first impressions, leading to negative feelings (possibly uncertainty).

And the third pattern (P3) was mainly the frontal area - Fp2> F8> F4> F3> C4 - indicating that the analysis and monitoring of the scenarios was made by distinct neuronal circuits. However, in the latter (P3), although with less intensity, the left hemisphere is emphasized, culminating in a possibly positive emotion in relation to moves made. There is a possible drive system 1 related to the prefrontal and ventromedial orbito-frontal areas.

The revelation of the results was confirmed and possibly also suggests an instinctive mental accounting (heuristic) by participants at bullish market.

The final decision (P2) was on account of the reward system, since the right frontal cortex and anterior prefrontal region were activated - Fp2> F8> F4> F3> C4 - with bolder / aggressive investment attempts.



P1	P2	P3
Oz(0.82) | T5(0.77) | O2(0.72) | P3(0.63) | Pz(0.63) | P4(0.60)	Fp2(0.86) | F8(0.79) | F4(0.76) | F3(0.76) | C4(0.67)	T4(0.70) | T6(0.66) | T3(0.66) | Fp1(0.65) | Fz(0.58) | C3(0.57)

(*) The magnitude of factors higher than 0.55 is shown in brackets.

Figure 1 – Traders' Brain Mapping in Bullish Market

Increased use of neural circuits in buy vs. sale orders may again be due to higher refusal of the latter.

Table 1 – Number of Orders

Orders	Buy	Sell
Accepted	272	119
Denied	142	271

Despite the homogeneity of the group, i.e., all volunteers worked in different trading areas, such as brokerage desk, financial or asset management and hedge funds. This can be seen in chart below.

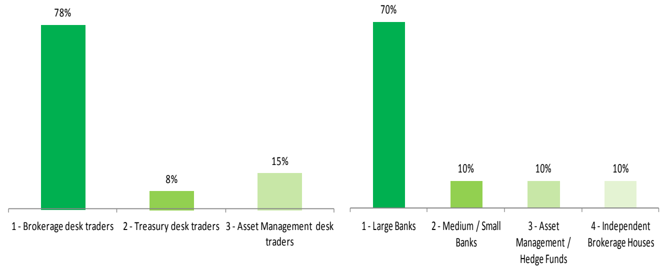


Figure 2 – Sample Characteristics

The frontal and prefrontal circuit is, according to Rocha (2013), responsible for "associative based reasoning" type rules (or rules based on intuition), as has been observed in studies by Goel ET AL (2000).

The group proved to make more heterogeneous decisions with standard deviation of R$33,595, and 42 with negative values. It is also worth mentioning that the average decision time of this group was at 49.2 seconds. This may also suggest a temporal discount compared to the expectation of reward, as advocated by Muller and Cohen (2001), since the activation of the final decision-making process occurred in the region of the frontal cortex and right prefrontal region.

Although speed is an indication of system domain 1 (heuristic bias), it should be emphasized that the decision was made in system 2 (cognitive control), showing that safety and emotional control were involved at some stage.

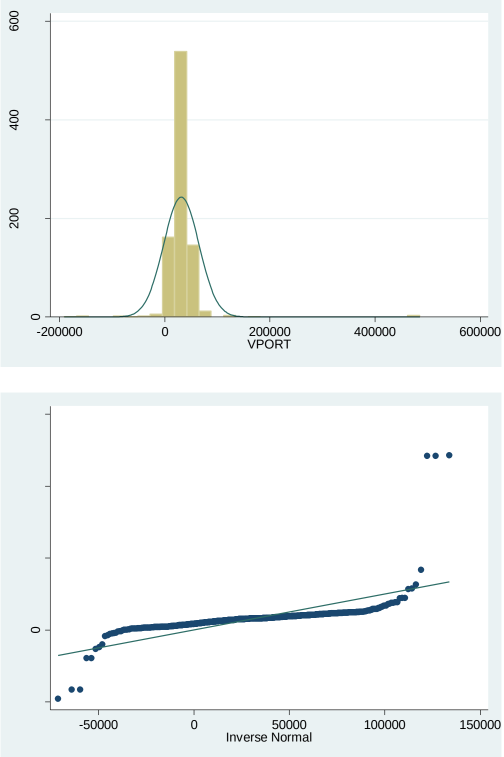


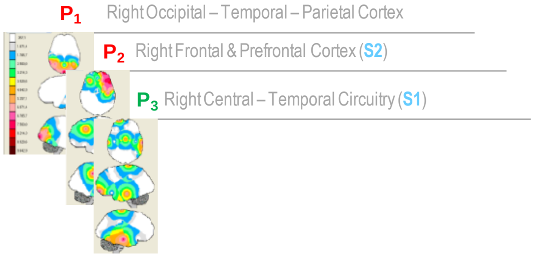
Figure 3 – Histogram and Normality Tests from Traders' Decision in Bullish Market

In adverse market, noting that this is also called bearish, the group of traders showed activation in the temporal-parietal areas - occipital (Oz> T5> P4> P3> O2> O1) and the third pattern, especially in the temporal region - T4> Fp1> T3> T6> Cz.

However, the final decision (P2) showed marked activation of the frontal and right prefrontal regions - Fp2> F8> F4> F3> C4 - suggesting a lateralization of the decision-making process.

In a down trending market, which is often unpredictable, there was a brain circuit activation of the occipital - temporal and parietal lobes in the case of the first pattern (P1), which supports the fact that the activation occurs in different neuronal circuits, when compared to other patterns.

The second pattern (P2), as it was more intense, was dominated by system 2 of cognitive control on the right side, possibly striving to implement the best strategy for certain games in order to maximize portfolio value. P3 is already related to system 1, or intuitive moves, because uncertainty prevails in a bearish market, and it is not known beforehand whether the outcome was positive or negative. In addition, the area on the right side (negative emotion) of the brain indicates some kind of dissonance regarding the moves made.



P1	P2	P3
Oz(0.86) | T5(0.77) | P4(0.63) | P3(0.63) | O2(0.60) | O1(0.56)	Fp2(0.85) | F8(0.77) | F4(0.75) | F3(0.73) | C4(0.72)	T4(0.75) | Fp1(0.71) | T3(0.65) | T6(0.59) | Cz(0.57)

(*)The magnitude of factors higher than 0.55 is shown in brackets.

Figure 4 – Traders' Brain Mapping in Bearish Market

However, losses were more significant in the down market, according to the histogram and QQ plot. There were thirteen volunteers, recruited from among the forty, which ended with portfolio simulation values in a negative quadrant.

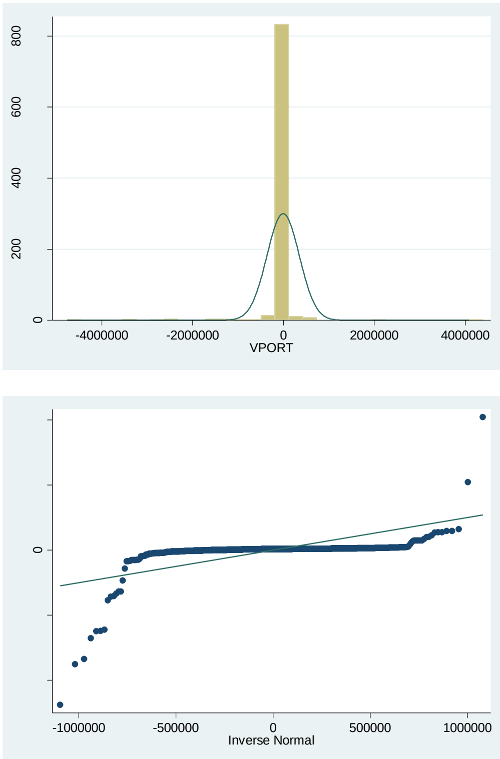


Figure 3 – Histogram and Normality Tests from Traders' Decision in Bearish Market

It is important to identify, in general, that in high and low markets, the circuits triggered by different trading strategies by the participants in the simulation also diverged; possibly indicating a greater involvement a rule of associative type or "instance-based" versus of the rule of reason (cognitive control), that is, following some experience anchored in the past, as advocated by Rocha (2013) and Sloman (1996).

This is true even in terms of decision times and the intensity of neuronal circuits, as in the case of sales that took longer to make the biggest decisions (making sure that this was the time to take profits), as advocated by the modern theory of finances.

IV. CONCLUSION

The advantage of this new methodology in terms of neuroeconomics is the fact that besides being non-invasive, it can determine in which areas of the brain the cognitive activity took place, and show how relevant this was for the decision.

Recalling Daniel Kahneman, he stresses that: "Economic analysis is more congenial to wants and preferences than hedonic experiences, and the current meaning of utility in economics and decision research is a positivistic version of wantability: utility is a theoretical construct inferred from observed choices".

This new approach will help not only add coherence to the theory itself, but also provides an important implication related to the attempt to draw a more realistic hypothesis under our neurobiological rules.

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