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From traditional finance to neurofinance: Literature review

Ali Ahmed Faris [1], Hayder Khudhair Jwan [2], Karrar Hatam Attieh Al-Bidairi [3]
[1,2] Faculty of Administration and Economics, University of Kerbala, Iraq
[3] University of Al–Qadisiyah, Iraq

ABSTRACT

The research aims to study a new branch to financial decision-making called neuro-finance, as it provides an another explanation for the failure of behavioral finance, which came recently in research and studies as a new way to analyze the factors that have a role in financial decision, One of the objectives of this research is to develop a systematic review based on many published papers and articles on neurofinance to organize the main ideas and issues that have addressed the neurophysiological links of financial choices. After reviewing many studies on neurofinance, we conclude that researchers debate about neurofinance in the early stages, but the results reached by most researchers are that neurofinance is of wide interest by researchers in financial management, and this research is important not only for reviewing previous studies, but rather a guide to assist researchers and scholars interested in this topic by collecting and analyzing previous studies.

Keywords: Traditional finance, Behavioral finance, Neurofinance, Neuroeconomics, Neuroscience, Brain.

Corresponding Author:

Ali Ahmed Faris
Faculty of Administration and Economics,
University of Kerbala, Iraq
Email: Ali.ahmed@uokerbala.edu.iq

1. Introduction

Finance is concerned with the study of financial markets, their phenomena and all their developments, and particularly the study of the effects on human behavior. This process is subject to many factors, foremost of which is the investor's personality, inclinations, desires, and interests, which are embodied in his investment decision. And that there are many theories that study the behavior of individual and institutional investors. It began with traditional finance, which gives a description about how prices develop and how economic resources are best allocated when financial choices are not time-limited and risky. Prices reflect all the information that is presented to investors and are based on the premise of rationality when making a decision.

Reducing ideal rationality leads to large-scale risks for financial markets, such as the emergence of economic bubbles, which is the most important indicator of the inability of investors to logically evaluate and integrate information into their investment decisions, and this is what led to the emergence of behavioral finance, because investor decisions are affected by behavioral characteristics and have been studied in Previous research by financial researchers over the past two decades. The results of these studies are that some investors self-govern themselves within financial knowledge, i.e., what is known as behavioral finance. These terms began to appear in magazines, research, and daily newspapers in the nineties. According to Behavioral finance we now have explanation about why and how markets are inefficient [1][2][3][4]. Behavioral finance has demonstrated that investors' decisions are affected by their emotions and psychological biases and these influences and biases can be a source to explain all kinds of market anomalies and specifically stock market distortions, such as extreme rises or falls in stock prices. As a result of the role of these behavioral biases on financial markets, many

researchers have questioned why these biases arise and if the findings from neuroscience can further made the existing models better, leading to the development of the field of neurofinance as a new trend in finance. And that neural finance studies the empirical nature of the cognitive processes associated with obtaining and processing information in decision-making, and that neural finance assumes that investors have different psychological components, and these processes may affect the ability of investors to make fully rational investment decisions, and that neural finance goes beyond behavioral finance. By identifying the physiological causes underlying deviations from rational behavior, it can be argued that neurofinance is a combination of medicine and psychology with finance [5] [6] and developments in the study of neurofinance using the brain have begun. Because investor emotions affect financial decision-making.

Thus, the question of this research was formatted as follows: What is the meaning of neurofinance in scientific studies of decision-making and what is the prevailing trend? Therefore, the research suggests, it is necessary to check the flow of information and dissemination about neurofinance. Many studies have dealt with neurofinance, and the studies have agreed that neurofinance provides another explanation for the failure of classical theories, and some of them are mentioned below.

Researchers [7] who initiated developments in the field of neurofinance studies using the brain. In this study, they examined the function of the human brain's emotions in making financial decisions. In addition, they evaluated the analysis of fMRI brain-imaging studies that influence what expectations of achievement and defeat might bear distinct neural hallmarks. They find that distinct neural circuits connected with anticipatory influence underpin many forms of financial options and suggest that the increased activation of these circuits could lead to investment errors. Thus, consideration of expected neural mechanisms may insert predictive power to the rational actor model. The study [8] aims to improve commerce results and a good understanding of the financial markets, by detecting the physiological features that have a role in commerce behavior and linking these features to the passage or failure of trading and developing tools and training methods to make performance trading better. Although neuro-finance and neuro-economics use many similar techniques, the main difference between them is that neurofinance concentrates on trade and markets. Many academic theories depend on the presumption that people act logically and behavioral finance deals with the selection of investors based on behavioral biases. In contrast, neurofinance tries to realize behavior by checking the processes in the brain when exposed to financial risk. The study aims [9] to bind the work of the brain with investment behavior when making financial decisions, which explains why humans are imbalanced according to the rules of the traditional theory of finance. Neuroscience checks the functioning of the human mind and how financial decision-making is affected by the effectiveness of neural base. This is when neuroscience is studied with respect to the investment surrounding, as well as studying the role of important parts of the brain and enzymes such as, dopamine, serotonin, amygdala, and frontal cortex in the events of loss, increase or volatility of stock prices. The researchers concluded that sentiments have a key role in investment decision-making. In this research, the researchers [10] tried to reach the educational part of behavioral financing and financing for the analysis. The researchers used the data collected through a survey of higher education institutions in the Gulf Cooperation Council countries because these materials must be studied. in the classrooms. Researchers have determined the level of awareness of students in classrooms in general and among students specializing in finance in particular. The researchers concluded that the students don’t realize anything related to behavioral or neural finance. Researchers recommend repeating this study on a sample covering many countries. The study [11] aims to study how decisions are made, considering the role that emotion plays. In this paper, researchers use the concepts to develop neurofinance modeling for the Brazilian stock market, presuming that the humor sense of investor depends on risk-reward ratio, and market sentiment. It is suggested that market sentiments be sensitive to the quality of news conveyed by the media. However, there is no claim that the research model provides a better understanding of stock market behavior which is important, but the fact is that it could be examined empirically as is done in this research. This type of approach gives new interpretations for global systemic risks. Ardalan [2017] investigates the implications of neurofinance in relation to the efficient market hypothesis. We conclude from the research that thinking forces an effort on the mind, meaning that thinking is a relatively cumbersome cognitive process, biologically costly and neurologically costly. The researcher concluded through the research that people made an equilibrium between the costs and advantages of thinking through the mathematical model used, and that such a balance makes financial markets inefficient. As for the two researchers [12] they analyzed the investment decisions of individuals through the neurofinance approach. The researchers present the factors affecting investment decisions, which include neurological processes. The researchers conducted a contextual analysis to study decisions and brain behavior. This analysis has significant implications for the exploration and research of brain neurons and their effects on psychological

biases. Neurofinance has become an efficient tool for making efficient economic decisions through brain mapping techniques. In this paper, the two researchers discuss the interaction between behavioral psychology and neuroscience and economic and investment decision-making. This research relies heavily on secondary information and available research studies to conduct contextual analysis. The researchers recommend through this research the necessity of studying the functions of the impulsive response. Because neurofinance must form new psychological measures and technology to further check the attitude of individual investors. As for the study [14], it aims to propose an integrative framework that combines financial knowledge, human attitude, and his brain. The brain is the most complex organ in the human being and is considered a black box. The complicated machinery of the brain is responsible for handling human decisions and behavior. Advances in neuroscience detect that training the brain to guide good decision-making processes under uncertainties is feasible. This contribution occurs for the first time to integrates neuroscience branches from plasticity and decision-making with market flexibility from studies related to economics and management, which explains their symmetry and opens a new interface for discussion about its learning from these two branches to increase the explanatory force of financial decision-making. and get new insights into financial decision makers making better financial decisions in times of uncertainty. As for the study [15], it aims to explain the types of eye movement in first stages of information gaining, and to dismantle the independent effect of color and impulsivity in modifying the distribution of attention towards many sources of financial information. The eye movement behavior of 81 healthy adults was monitored by eye-tracking technology. A KIID environmental protocol has been made to control many individual differences. The distribution of attention on the variable information resources included in the KIIDs was detected and found to be modulated by color and impulsivity independently, with the former having a large role over the latter. Adding red or blue information to some sections of the KIID makes attention to the entire document increased. The overall BIS-11 scores had an inverse relationship to the first and mean duration of fixation in the neutral mode. The researchers concluded that stimulus-related incremental concentration allocation mechanisms affect information gaining while reading financial prospectuses. Regulators should consider such a guide when designing disclosure documents to increase investor security. The study [16] removed event-related potentials (ERPs) from the electrical data of the brain when entrant (senior company managers) did a choice test in which they decided whether to allow their enterprises to stabilize in an industrial area, whether small or large. As extract, this study checked the neural basis of herding behavior decisions in corporate groups. Behavioral findings initially demonstrated a patronizing tendency in senior administrative business decisions: participants showed an increased approbation rate in the high occupancy rate condition than in the low occupancy rate condition. ERP findings indicated that non-coordination options led to increased risk perception and higher response struggle (reflected by a greater amplitude of N2) compared to grazing options. In contrast, grazing options resulted in a better rating of participants and greater confidence in decision-making (reflected by a greater LPP amplitude) than did the nonconformance options. As a result of these findings, this study supplies new insights into the neural basis of patronizing decisions made by top business executives. The study [17] wants to find the relations between neural processes and financial attitude from a multidisciplinary view. It emphasizes the use of neuroimaging techniques in making a map for brain regions to help recognize processes in the cognitive regions of brain. The research makes another question about people's preferences and options during making their decisions. A specific focus on injury-induced brain dysfunction and its effect on decision-making is an important view of this study and is summarized by a meta-analytic forest scheme. In this paper, the researchers present cases in which emotional processing is changed by brain trauma and may lead to more beneficial decisions, in dangerous situations.

2. The transition from traditional finance to neuro-finance

through behavioral finance Traditional financial theories are based on the presumptions that investors make decisions reasonably so that they get feedback for the money they put in the stock markets, so it is important for investors to get reasonable behavior patterns that conventional finance provides powerful experimental support for the capital asset pricing model and option pricing models. Fama [19] who has succeeded to some extent in traditional finance, introduced the efficient market hypothesis, which explains that financial prices include all present information and can be considered optimal estimates of the real investment value at all times. The basic assumption of the efficient market hypothesis is that people act rationally, allocate their money optimally, and process all information available in the market during investment decision making [20] [21] [22]. The efficient market hypothesis suppose that investors' decisions depend on the predictable utility theory, which believes in rationality and explain that investors make appropriate decisions between the different alternatives

[23] [24] and that the basis of the efficient market hypothesis (EMH) is that the investor cannot outperform the market because all the available information is already there and included in stock quotes [19] [25]. However, despite all these results, the efficient market hypothesis has faced gradual failures especially when "anomalous" behaviors that oppose the efficient market hypothesis were found [5]. Criticisms of research and study findings have begun to assume that investors act rationally. Although the idea of rational behavior theory that depend on the efficient market hypothesis has been useful in forming economic theories and patterns, in recent years many of psychologists and behaviorists have registered powerful and systematic violations of the foundations of reasonable behavior on the efficient market hypothesis, by testing its validity as a descriptive theory to take resolution [26]. The term „limited rationality" represents stressing the limits of human ability to optimally adapt to a complex environment and that investors tend to bias, and these behavioral biases can lead to a deviation in stock prices from their true values, which it leads to inefficiencies in the markets [27]. Behavioral finance is the process of selecting an investment substitute from many alternatives. So, the activity that comes after the appropriate assessment of all substitutions [28]. It collects single behavior with market phenomena and uses knowledge from both psychological fields and financial theories [29], usually identifying and describing anomalies in market prices and the biases of investor decisions. The cognitive biases of investors do not demonstrate the reasons for the behavior, and as a result they have not been shown to be generalizable or predictive modeling. Neurofinance has come to focus on the underlying biological and psychological methods that underlie the development of individual biases, unreasonable behavior, and buying and selling decisions. Neurofinance uses research materials and techniques borrowed from neuroscience, and new economists are gaining insights to form comprehensive economic patterns of human economic attitude and decision-making [30] [31]. Neuroscience has developed from neuroscience and psychology and wants to know how the human brain works when making decisions and that the brain is affected by many individual decisions that occur in the brain outside of mind, that are independent in nature, and that neuroscience studies specific areas of the brain responsible for making the decision. These different brain regions interact with each other by neural pathways and mechanisms that govern human feelings, behavior, and activities [17] [32]. It seeks to describe the calculations that the brain performs to make financial decisions, and to know how these accounts are linked to attitude [33]. And the truth behind making an investment decision is much more than just being guided by the brain. Rather, it is based on awareness because financial matters have a major role on the emotions of people and make financial decisions in conditions of uncertainty, and ignoring this aspect will result in an incomplete awareness of human behavior [34].Emotions are automatic processes connected with positive or negative utility and the brain works on two forms of goal-directed behaviors, mainly, profit-seeking and loss-avoidance, that could be independently activated or deactivated [35].

The search to understand how the human brain processes information for decision-making a new event is not. However, many researchers from many fields have been involved to learn about this phenomenon and find solutions to it. Neuroeconomics, Neurofinance, Neuropolitics, and Neuromarketing [32]. These interdisciplinary fields connect knowledge and technology in neuroscience to test the physiology of the neurological circuits that enter in all kinds of options that investors make. By immersing themselves in the working of the human brain, neuroscience is a base for developing neuroscientific knowledge to influence economic choices [36]. The interest in cognitive neuroscience research in the applied social sciences has increased, and among these new types we can find the field of neurofinance, which wants to respond to the behavior of human decision-makers by the materials of neuroscience and the possibility of multiple substitutions and to advance the period of action [37]. [38]. The fields of neuroeconomics and neurofinance are a mixture of neurobiology, economics, and finance. Neuroscience is the study of the nervous system. Using images of special areas of the brain during making a decision gives insight into what is happening in the brain. Currently, strong and commonly used imaging technologies are present that include eelectroencephalography (EEG), positron emission tomography [PET], and (fMRI). Using these imaging and measurement tools, experiments can be conducted to detect classification of human perception and emotion during decision making. Scientific advances in physiology and genetic analysis of human, as well as advanced experimental methods from cognitive psychologists, neuroscientists, and psychologists, allow addressing summarizing questions such as how to map human perception and emotion to special neural substrates. The scientist notes basic biological and psychological mechanism on which the investor's attitude is based [39]

Neurofinance is a rapidly spreading paradigm. It wants to give explanations for human decision when illogical behavior and their choice of risk buying and selling behaviors manifest through a combination of biology, emotion, brain activity, and neurotic behavior of investors [40]. The comparison between traditional finance, neurofinance and behavioral finance can be summarized in Table [1].

Table1. The difference between traditional finance, neurofinance and behavioral finance

Traditional finance	Behavioral finance	Neurofinance
traditional finance trust in logical markets and logical investors.	Behavioral finance believes in the presence of illogical markets and illogical investors.	Neurofinance assesses the investment behavior of the emotional people.
traditional finance is helpful in forming a logical portfolio.	Behavioral finance helps to form a perfect portfolio.	Neuro Finance helps to form a perfect portfolio.
traditional finance theories depend on presumptions that oversimplify real market conditions.	Behavioral finance explains problems through the psychology.	Neurofinance enforces neurotechnology to learn about the behavior of investors in the financial market.
traditional finance demonstrates how an investor could act.	Behavioral finance demonstrates how an investor proceed.	Neurofinance demonstrates how and why the decision is made with the investor's behavior and brain.
Traditional financial assumptions believe in rational financial behavior.	Behavioral finance assumptions believe in known financial behavior.	Neurofinance helps to understand the internal actions that lead to thinking that appears as external action.
It is the basis of financial management theories. Such as: Agency Theory, MM Theory, Portfolio Theory etc.	Behavioral finance is complementary to traditional finance, as the view based on behavioral finance refers to the psychological aspects of investors. The theories in this entry are: probability theory, framing effect, etc	It is an approach that blends several areas of financial management and data science with other fields of science such as medicine, science and technology to produce new concepts and perspectives. Such as: neurofinance, internet finance, etc.

We see through Table 2, some of the most common financial and neurological terms, which are as follows:

Table 2. The most common financial and neurological terms

Term	References	Concepts
Ambiguity	[41]	It refers to uncertainties in which the likelihood of results and events are unknown, in contrary to risks where the likelihood is known.
Bull and bear market	[24]	A bull market is a phase of the financial market when the prices for a group of assets rise.
Behavioral effect	[43]	It means the tendency of investors to keep the shares that fall in price and sell the shares that increase in price.
Efficient market	[44]	It says that all present information appears in the prices of the assets. So, it is a complete, rapid and unbiased reflection of all information.
Expected utility theory	[45]	This theory states that humans use this theory to make decisions in situations of uncertainty by making a comparison between the predictable utility values which reflect the average of possible outcomes under certain conditions. This is done by determining the weights according to the probability of the results.
Initial public offering	[46]	It is the sale of the company's shares for the first time (the initial issue) in the stock market.
Irrational exuberance	[47]	Is that investors develop excessive confidence in the financial markets and this confidence is placed incorrectly, and they expect beneficial prices to continue to rise, meaning that the growth of assets will remain strong. We conclude that illogical exuberance has a role in the financial crisis.
Market volatility	[48]	Market volatility defines the degree of variation in the prices of market during a given period of time.

Term	References	Concepts
Modern portfolio theory	[49] [50]	In 1952, Markowitz's entry appears. it is considered the pioneering basis modern portfolio theory, which has a combination of investment materials that fulfill the best exchange between return and risk. An efficient portfolio achieves the highest return at a given level of risk.
Primary/secondary rewards	[51]	Primary rewards are associated with food and shelter, while secondary rewards are unlike primary rewards that have an innate value and are necessary to maintain equilibrium, secondary rewards are not directly related to survival and gain value by an acquired association with lower-level rewards.
Realization utility theory	[52]	Investors extract benefit by realizing profits and losses on the assets they own. And that the magnitude of benefit based on the difference between the selling price and the purchase price, and that the benefit is positive if the investor makes profits, and negative if the investor makes a loss.
Risk	[54]	It is a measure of uncertainty about the future return of an investment, and it is evaluated over the time horizon and compared with reference standards. Variance is the most commonly used measure of dispersion and is used to measure investment risk.
Allele	[55]	Alleles are different shapes of specific genes, and some genes have different forms, which are present at the same genetic locus on a chromosome. Humans are diploid because each gene is represented by two copies at each genetic locus. Researchers have found that the gene allele is associated with pathological gambling, and thus the dopamine pathways are strongly associated with and through the behavior of problem gamblers in general.
Bold signal	[56]	This signal depends on the blood oxygen level (BOLD as measured by [fMRI]. And that this signal is used to understand the neural actions of brain regions.
Dopamine	[57]	Dopamine is a chemical substance released from neural cells to give a signal to other neural cells to make a decision.
Electroencephalogram EEG	[58]	An electroencephalogram (EEG) records the brain's electrical activity with electrodes connected to the scalp. Electroencephalogram (EEG) results show changes in the brain's electrical activity without surgery with high temporal accuracy.
Functional MRI	[59]	Functional magnetic resonanceimaging measures brain activity by determining abnormalities related to blood flow. This technique depend on the connection between cerebral flow and neuronal activation. When using a region of the brain, blood flow increases to that area, and the neural activity associated with the event or stimulus is measured by contrasting the BOLD signal.
Genetic polymorphisms	[60]	Genetic polymorphism when an extra allele can be found in a particular site within a group of monkeys.
Gray matter	[61]	The central area of the nervous system. Gray matter is different from white matter as it has many cell bodies and relatively few myelinated axons.
Homozygous	[62]	It is when two copies of one allele that codes for a some traits are found in dichotomous organisms. And those traits are inherited by living organisms' reproduction. It is distinguished by having two different groups of alleles.
Monoamine oxidase-A [MAOA]	[64]	It is an enzyme encoded in humans by the MAOA gene and this gene in the family of neighboring genes that encode many cellular enzymes that stimulate the deamination of amines, such as dopamine.
Monozygotic and dizygotic	[65]	Monozygotic twins arises from a single cell, which divides to forms two fetuses . Dizygotic twins arise from two types of zygotes.

Term	References	Concepts
Reaction time	[66]	Mental time measurement is the study of speed of processing or reaction time to understand the content, duration, and chronology of mental processes. Reaction time is measured between the onset of a stimulus and a person response.
Reinforcement learning	[67]	Reinforcement learning defines how the person learns by interacting with the surrounding and by taking actions such as maximizing future cumulative rewards.
Resting-state activity	[68]	It refers to the activity of neurons calculated by neuroimaging (functional magnetic resonance imaging) during a state in which a clear task is not being doing.
Risk prediction error	[69]	Forecasting risk is the risk associated with an uncertain outcome and is measured as the variance of reward, if the risk prediction is judged incorrectly, it is the error in predicting the risk which can be used to improve future estimates of risk prediction.
Serotonin [5-HT]	[70]	it is a monoamine neurotransmitter that has an effect in the regulation of mood, emotion and decision-making, and it is called the hormone of happiness.
Transcranial magnetic stimulation TMS	[71]	It is used to stimulate special areas of surface layers of the brain. It depends on the frequency of stimulation and can induce strengthening or suppression of cortical activity.
Nucleus accumbens	[72]	The nucleus accumbens is an important area of the brain. It is activated when a person expects a reward. The neurotransmitters that affect the nucleus accumbens is dopamine (the pleasure neurotransmitter) and serotonin is somewhat inhibitory.
Insula	[73]	It is a part of the cerebral cortex deep into the lateral sulcus in each hemisphere of the brain.

3. Neuro-finance, decision-making and the human brain

People make decisions, big or small, that are important or not in their financial planning. Cognitive psychology try to understand the thinking of people about their options in different areas of investment. At present, the demand for stock markets is directed to people based on their emotions, behavior, feelings and mood, and these factors affect investment decisions and thus affect prices. Whereas institutional investors are people who have large sums of money, which they need to invest in many stock markets, the best outcome for an individual, group or organization provides a basis for opening behavioral finance [74].

Neurofinance is very necessary for understanding the role of brain activity in individual investor financial decision making. Neurofinance is a rapidly developing paradigm that wants to give illustration for decision of human when illogical behavior and their choice at risk are manifested by combining biology, emotion, brain actions, and neurotic attitude. For several years, using many strategies, social and natural scientists have been trying to understand how individuals make investment decisions. And that the human brain consists of different regions in the brain that are closely linked, and the interaction of these regions is reflected in the final human behavior. Information gets in the limbic cortex, then goes to the motor and loops of cognition and it is basis for the formation of the important plans which transferred to final decision.

In neuroscience, the brain is classified into three parts [forebrain, midbrain, hindbrain]. The forebrain contains the limbic system, it is the largest part of the brain. cerebral cortex is associated with some larger activities of brain, which refers to the interconnected part of brain [32]. The middle part of the brain is important in vision, hearing, eye movement and body movement. The posterior part contains the cerebellum, pons, and medulla oblongata, which work together to stimulate vital bodily processes, and the anterior part has an important role in decision-making [34]. The forebrain has an essential role in decision-making, and the limbic system of brain is the central area that is essential for processing emotions. This part of the brain is considered the top of the brain [34] [32]

Neurofinance seeks to analyze financial markets through the application of neurotechnology to monitor and understand the behavior of market investors. The main objectives of neurofinance are to get a good understanding of financial markets by detecting the physiological features that influence trading behavior and linking these features to trading outcomes. Appropriate methods, technology, and training have been developed

to support trading performance. Neurofinance supposes that market participants have many psychophysiological makeups that influence their capacity to make industrial decisions and their investment performance. behavioral finance differs from neural finance in that the former discus people action and interaction in the financial decision-making process and interprets these actions based on well-established psychological terms and theories, while the latter checks why and how these behaviors happen based on the study of the human brain and hormonal activities. neuroeconomics wants to understand the physiological background of economic decision-making, while neurofinance focuses on financial markets and the actions of its participants. It examines the processing of the human brain for financial information and how people make decisions. Neurofinance is a recent field that aims to reveal neural mechanisms through which decisions are made in the field of finance [75]. In September 2005, Knutson & Kuhnen's first neurofinance study was published. Using functional magnetic resonance imaging, this study explains that divergence from rationality in financial decision-making has an special neural method, arising from brain areas. When activating the nucleus (NAcc) while continuing to risk options. results confirmed that both risk-seeking and risk-avoiding options could be guided by different neutral circuits containing the anterior NAcc2 insula. The nucleus accumbens transmits excitement, expectation, and pleasant sensations to the frontal lobe. Dopamine plays a key role in stimulating the NAcc by forming a strong sense of excitement or anticipation and thus converting impulses into decisions and decisions into action. In another study, the researchers found that activation of the NAcc represents the prediction of profit [reward], while activation of the anterior amygdala represents the expectation of loss. In references [76] [83] [84] [85] it is possible to assume that positive and negative price changes in rising and falling markets are determined according to market sentiment and emotions that lead to investor disturbances, culminating in euphoria (positive state) or hysteria (negative state). Given that risk and reward are analytical variables from a financial point of view, while the topic is treated from a neurological perspective, we expect that the fluctuations of return resulting from market sentiment are brain-stimulated in the case of gain and loss.

Perception of a possible reward in the environment leads to activation of the reward system in the brain. In general, it coordinates the search, assessment, and pursuit of possible rewards. The information-carrying neurons in the reward system relay the signals by dopamine. (see Figure 1).

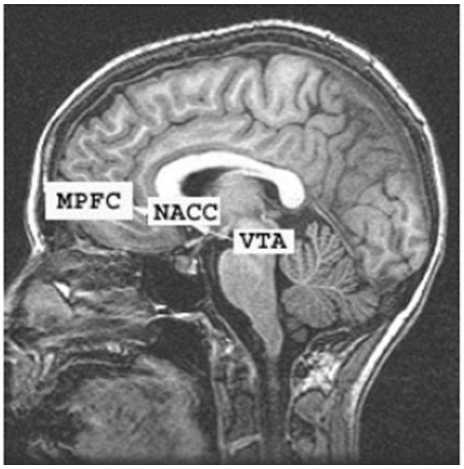

Figure 1. The main structural components of the reward system [76]

An fMRI study shows that decisions that reveal risk avoidance in the context of reward and a tendency to take risk in the context of losses (i.e. typical behavior surrounding risk according to probability theory) are accompanied by activation of parts of the amygdala that are not activated when making atypical decisions, such as propensity To risk in the context of reward and to avoid risk in case of losses [78] [82]. Functional magnetic resonance imaging (fMRI) experiments showed how the nucleus accumbens interacts with dopamine in various situations involving an expected reward [76] [81]:

- Unexpected reward a strong reaction and sense of pleasure in the reward circuit is transmitted to the prefrontal cortex.
- Profits equal expected reward - little or no reaction in the profit circle.
- Gain less than expected reward - activity in the loss circuit of the limbic system, especially the frontal part.

The technology of (fMRI) depends on measuring consumption of oxygen in different areas of brain, which allows identifying the areas that are active during the performance of an intellectual or emotional process in a specific period. This allows neuroscientists to design 2D or 3D images, sometimes in color, to get better quality and more information from the brain as shown in Figure 2.

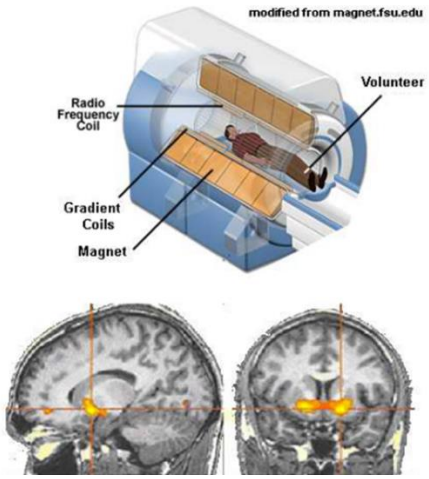

Figure 2. Functional MRI

4. Conclusions

Based on the explanation of the development of theories in financial management, it is a long stage from 1844 until now, which indicates that the financial sector is one of the most developed fields. The traditional view is the basis, followed by the classical view, which shows weaknesses in the assumptions of traditional finance. After that, there is still a lack of behavioral opinions on explaining the investor's irrationality in making decisions. Then the concept of neurofinance emerged as a field of research linking medical sciences, neurosciences, and neuroanatomy with funding. The researchers divided the development of the theory in financial management into three stages, the first stage, which begins with the traditional opinion, then moves to the second view of behavior-based financing and is currently entering the third stage, which is neural financing, as neural financing tries to answer how individuals make financial decisions and we conclude from research and studies Prior to neurofinance, some areas of the brain are activated before making a decision. When the investor predicts the rise in stock prices in companies, it creates a state of euphoria in the investor, which activates the area of the nucleus accumbens, which in turn stimulates the investor to make the investment. The study of neurophysiology does not end in the form of neuroeconomics with limited study. Rather, it is an upcoming field of modern finance, as the study of human behavior and reactions can extend to the extent of studying neuroscience and neuroscience to search for biases in investor behavior. Hence, the researchers seek to find a conceptual and applied framework that includes all the financial and neurological elements active in the investment decision-making process to bridge the scientific and applied gap in academic studies on causes of anomalies in the financial markets.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Author contribution

Ali Ahmed Faris contributed to the conceptualization, methodology, and literature review of the study. Hayder Khudhair Jwan contributed to the data collection, analysis, and interpretation of the findings. Karrar Hatam Attieh Al-Bidairi contributed to the critical revision of the manuscript and provided valuable insights into the field of neurofinance. All authors were involved in the writing and editing of the manuscript and approved the final version for publication.

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