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Risk-Taking and Optimism of Investors: investigation and analysis of the dimensions of the neurofinancial model based on the measurement of hormones with a scientometric approach

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ABSTRACT

Since traders' decisions are influenced by various factors, the purpose of this research is to investigate the behavior of investors based on the analysis and measurement of hormones with a scientometric approach.

This research was done in two stages. In the first step, using the scientometric method, general information and experimental backgrounds of neurofinance were collected. Then the researcher measured the effect of Testosterone, T4 and TSH hormones on investors' behavior through blood tests. In the first step, the data of 47 articles downloaded from the Scopus database in Vosviewer software was analyzed to draw bibliographic maps related to them. A map of key words, authors and countries that have done the most studies were identified and presented. The annual review of articles showed that neurofinance is an emerging field in scientific research. The first work indexed in Scopus goes back to 2006. The most frequent word is "risk aversion" which has established the most connection with the words "profitability and economy". The results showed that 18 countries collaborated in writing at least 5 articles and received at least 10 citations for their articles. Hormones analysis, in the second step, is based on Data were collected through questionnaires and clinical tests and analyzed using the structural equation method. A blood test was used to measurements. The sample includes 77 known investors. Data were analyzed with smart pls software. The results show that Testosterone is the only hormone that has a direct and significant effect on risk-taking. And TSH and T4 hormones have the opposite effect on risk taking.

Keywords: financial decision making, risk aversion, profitability, neurofinance.

1. Introduction

At present, behavioral finance deals with the application of psychology in financial issues and examines the effects of these behaviors on financial markets by examining the behavior of investors. This field has emerged in recent decades in response to the shortcomings of the standard financial theory in explaining the behaviors observed in investors and financial markets, and it is a challenge that is best suited to the neoclassical paradigm (Gippel, 2013). Kahneman and Tversky (2013) found that human decision-making in conditions of uncertainty is not the way that is predicted in conventional economic theories. They found that the choice in conditions of uncertainty is the result of several different decisions from people's behavior (Kian et al. 2018).

Neuro finance is a new field of research that tries to understand financial decision-making with a combination of psychology and neuroscience perspectives along with financial theories. Analyzing investor behavior is a new field in the field of financial behavior, which is considered a good tool for acquiring knowledge in this field.

By using behavioral experiments, neurofinance examines how we evaluate information about the nature of uncertain, time-taking, risky, and strategic financial choices, and examines how financial decisions are influenced by emotions, psychological biases, stress, neuroscience and individual differences (such as gender, genes, neuroanatomy, personality, and hormones). The use of the neurofinancial approach is to understand financial behaviors with combinations of perspectives from other fields such as psychology, neuroscience and standard finance theories.

In addition to explaining individual and market behavior as a function of standard financial variables, neurofinance also intends to explain how neural and physiological signals are related and create individual differences in financial decision-making. Since the discussion of neuro-financial concepts is in its initial stage in the field of applied social sciences, it still does not have a complete understanding of the research methods and theories required for proper research in financial affairs.

The current research is one of the latest research projects to investigate the neural processing of financial behaviors such as risk and decision-making mistakes. Explaining the pattern of human behavior in economics with the help of psychology and psychiatry is one of the things that goes through its initial stages in human sciences. Among the criticisms of the neurofinance method is its generalizability and methodology. Also, Brain and neurology tests have high costs. Therefore, in this research, we are trying to present a model that explains and predicts financial behavior of investors.

2. Theoretical foundations and background

Hormones are chemical messengers that are secreted by endocrine glands throughout the body and control, regulate and coordinate bodily activities by receiving and sending signals to brain neurons. About 50 different hormones are secreted throughout the body through the bloodstream and the Lymph system. These hormones are designed to affect body processes such as metabolism, mental state, sexual function, growth, etc. Hormonal imbalance can cause important problems such as weight gain, skin changes, mood changes, and lack of energy. While there are many types of hormones, this research only examines hormones such as cortisol (stress hormone) and Testosterone (risk-taking hormone), which are effective in the process of financial decisions and trading. The aim of this research is to provide a model based on the neurofinance approach on the financial behaviors of capital market participants. From this research model, the financial behaviors of investors can be examined according to the level of hormones for predicting the behavior of investors. Dealers of financial assets and also investment advisors can use the results of this research. (Nofisengar, John R. et al, 2020).

Ceravolo et al. (2019) investigated the effect of masculinity on the face and performance of stock exchange fund managers. They found that the fund managers who had the least amount of Testosterone, the alpha of their stock portfolio was almost 5% higher than the fund managers with the highest amount of Testosterone. Shaker et al. (2019) used the face width-to-height ratio of CEOs of 104 banks and compared the financial risk of their banks from 2006 to 2014. Bank stocks with more masculine CEOs had more volatile stock returns and higher unique risk. They found that higher CEO facial masculinity led to an 8% increase in banks' stock returns.

Risk taking and optimism are two behavioral characteristics of managers; therefore, these two behavioral factors and the level of hormones affecting them were investigated. The results showed that the level of hormones, gender and age have significant effects on risk and optimism. These findings are in line with the results of neurofinancial research (Nooraei et al. 2019).

Any injury in thyroid function and changes in thyroid hormone storage during the development of the nervous system leads to severe and irreversible changes in the structure and function of the brain. The time and duration of thyroid hormone deficiency affects the development in different parts of the central nervous system. However, neurological symptoms are usually seen in adults with both hyperthyroidism and hypothyroidism (Borhani Haghighi, 2016). In addition to physical symptoms, hypothyroidism is often associated with depression, anxiety, psychomotor slowness, and cognitive dysfunction (Amiri et al., 2015).

In addition to explaining individual and market behavior, neurofinance, as a function of traditional financial variables, aims to explain how neural signals and physiology relate and create individual differences in financial decisions (Ceravolo et al. 2021). Nofsinger et al. (2020) in their study entitled "Decision making, financial risk aversion and behavioral biases: the role of Testosterone and stress" examined the Testosterone and cortisol levels of financial graduate students in three investment sessions. The results showed that the level of Testosterone and cortisol of the participants has a positive relationship with financial risk in a competitive environment. However, Testosterone is also associated with a more diverse selection of securities. It was found that participants with higher Testosterone, when allocating, choose riskier assets to earn higher premiums, but at the same time, choose more diversified options to reduce decentralized risk. In the end, success in training leads to an increase in Testosterone levels in the post-session phase. Patterson (2007) showed that cortisol levels among market participants increase during periods of market volatility and possibly lead to a collective change in financial decision-making that reinforces the market trend.

Most of the current research is limited to western industrialized countries. We know that different cultures perceive and process information differently (Poldark, 2006). This possibility may lead to different behavioral preferences that lead to different behaviors. Kuhnen and Bran Knutson (2005) explained that investors systematically deviate from rationality when making financial decisions, but the mechanisms related to this deviation have not yet been identified. Using event-related fMRI, we investigated whether neural activity can predict optimal and non-traditional options in a financial decision.

We defined two types of deviations from the optimal investment strategy of a rational neural agent as risky errors and probable errors. Intermediate accrual is activated before risky and risk-taking choices, while this lower question is activated before risk-free choices and risk-averse errors. These findings show that distinct neural circuits with predicted effects explain different types of financial options and show that the excessive activity of these circuits may lead to investment mistakes. Therefore, paying attention to neural preventive mechanisms may add predictive power to the active rational model in economic decision making. Frydman et al. (2016) have used fMRI as a research tool to predict financial behaviors. Their findings help to understand how the brain works. To collect data on neural activity, fMRI is used, which is a magnetic resonance imaging technique that is dependent on the oxygen level of the blood.

Also, EEG tools have been used to evaluate which part of the brain is active, in the moments before and during the financial decision, the results did not show any evidence of differences in success in financial decision making between men and women, the EEG showed that men and women use different sets of neurons (Da Rocha, Vito, 2013, Massad, Da Rocha, Lima, 2010). Frydman et al. (2014) continued their studies in financial decision-making using FMRI and behavioral finance, and other researchers continued their work. Da Rochaet al. (2013, 2014) showed how financial decision studies can be used in neurofinance and behavioral finance. Finally, the research in the field of neurofinance by Brazilian Armando Da Rocha has cast a wide net with Ascher et al., 2016 in Portugal investigating EEG and conducting some important theoretical research with the main topic of changes and its impact on studies in finance with the emergence are neurofinance.

Mousazadeh et al. (2022) investigated the effectiveness of Testosterone hormone on the decisions and attitude of investors. They used an

experimental research method with a pre-test-post-test design with a control group. The statistical population includes all accounting students of Islamic Azad University of Tehran province who have been active in the stock market for one year. Then available at Azad University of Tehran Branch and Damavand as an example. After selection and screening, 80 people were selected as samples and randomly divided into two groups of 40 people (experiment and control). The tool used by the researcher was a form and content validity questionnaire, and Cronbach's alpha test was used for reliability. Finally, the data was analyzed by covariance test. The results show the effect of Testosterone on decision-making and investor's attitude. Testosterone is one of the most important male hormones that plays an effective role in the formation of facial features and the emergence of behavioral characteristics of people, including risk-taking. Recent researches in the field of accounting and finance, by measuring the CEO's Testosterone level, have found evidence of the existence of a relationship between the CEO's biological characteristics and the company's economic decisions.

Therefore, in the present study, the effect of the ratio of the width to the height of the CEO's face was investigated as one of the criteria for measuring the Testosterone level of the companies risk-taking. For this purpose, a sample consisting of 49 companies accepted in the Tehran Stock Exchange during the years 2004 to 2006 was selected and the multivariable regression model was tested based on the panel data technique. The results of the research showed that the high level of Testosterone hormone of the CEO increases the risk tolerance of the company. The findings of the research, while filling the research gap in this area, can be useful for investors, the stock exchange organization and other stakeholders of accounting information in decision-making.

In a research, Kamia et al. (2016) studied the effect of the CEO's Testosterone level on the risk-taking of companies in the American capital market. In this research, the width-to-height ratio of the CEO's face was tested as a criterion for measuring the Testosterone level. The research Findings indicates that the high level of Testosterone hormone of the CEO increases the companies risk-taking. Mills (2014) based on the sample of 968 male managers of companies active in the American stock exchange during the years from 2002 to 2013, he investigated the relationship between the width-to-height ratio of the CEO's face as a criterion for measuring the level of Testosterone with the company's financial policies, and came to the conclusion that the CEO's Testosterone level has a significant effect on the company's financial decisions. If the level of Testosterone in its manager is higher, the probability of making bold financial decisions increases.

Currently, "behavioral finance" is a challenge that has become the standard financial paradigm in the best possible way, and in this regard, the comparative market hypothesis has been used as a substitute for the efficient market hypothesis (Gippel, 2013). Behavioral finance uses cognitive psychology, which is a branch of psychology that seeks to understand internal mental processes such as image processing, memory, thinking, learning, feeling, problem solving and decision making, judgment and language (Da Rocha et al., 2013). Cognitive psychology examines emotion as a cognitive analytical product of a stimulus or event and uses a large number of experimental methods to find biases and discoveries as well as other interferences in reasoning. NNS have two main goals: to understand the neural processes involved in decision-making, which are explained by standard financial theories; and to discover the reasons for the failure of these theories, which is important for solving new research in finance (Da Rocha et al., 2013).

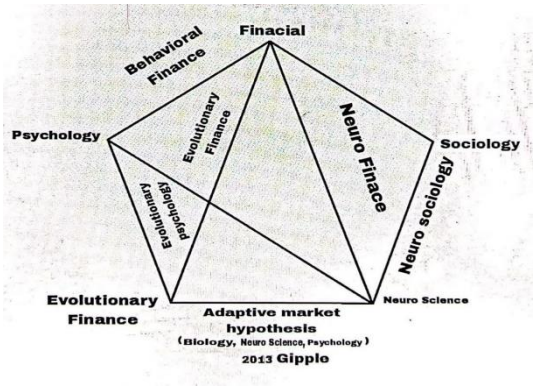

Figure 1. Comparative hypothesis of financial and neuro-financial behavior

Adaptive market hypothesis (psychology, neuroscience, biology): Geipel (2013)

Financial decision-making: from rationality to neural approach

The expected rationality of decision makers is related to the concept of economic man that comes from Stuart Mill (19th century). This is an effort to maximize the return and minimize the risk for each decision. For decision-making, rationality is a term that has many meanings, but in philosophy, it means the conscious use of logic (Da Rocha, 2013).

Therefore, the rational decision-making process should be applied in logic, objectivity, obedience to rationality and laws. The homogeneity of the behavior of all economic factors is another field of Economicus Homo (Economic Man). This "rational man" is the core for developing models and appropriate logical and expected behavior that creates easy mathematical modeling and provides the possibility of generalization of the relationship between cause and effect in financial decision-making studies. Joseph Huber (1982), limited access to internal and external information for decision-making, introduced the concept of rationality boundary or rationality limitation, while the agent's inability to access information partially ignores the level of rationality used to make decisions. However, theories of bounded rationality still separate reason from emotion. Bounded rationality, the hypothesis Finance and economics such as efficient market hypothesis (EMH), expected utility theory (EUT) and others to a more realistic and practical approach and enabled many economists to incorporate bounded rationality into models of their financial and market behavior (Tetsang, 2006). Lu and Ripen (2002) also point out that market volatility can be explained by the efficient market hypothesis (EMH) and rational expectations only if the risk is close to unrealistic levels. The evolution of cognitive psychology in financial decision-making with the research done by Kahneman (2013).

Kahneman (2013) identify several personal factors that are effective on a person's decision-making and can understand the effect of many internal and external variables that directly affect the decision-making process. The decision itself is not connected, but at that moment it reaches the brain as a mental process and shows the limitations of the individual's cognition. This evolution brings a new concept called neuroeconomics to the center of the scientific world of finance and economics. It is an interdisciplinary field that seeks to explain decision-making (Kahneman, 2003).

Kuhnen and Knutson (2005) and Lu and Rapen (2002), stated that neurofinance is beyond the aspects of psychology and a deeper understanding of the minds of decision makers. This model has created a realistic decision-making model and has been able to explain a wide range of economic behavior of an individual. In this way, Saper and Zak (2008), by using neurological and physiological tools, start using games and experiments used in behavioral economics studies. Neuroscience brings the agent of human behavior closer to financial science, and with the help of neuroscientists, financial decision makers from "Economic Homo to Sapiens Homo".

This term was first used by David Edwards (2004), a term to align with a new science that transforms the analysis of financial markets using nanotechnology into a scenario of business behavior. The first studies in the field of neurofinance were by Willoughby and Gering. (2002) used electroencephalography (EEG) to analyze brain activity related to financial decision-making in a monetary betting task. This research showed that the event-related negative brain potential was probably generated by the midbrain cortex near the cortex. Previously, the time when the financial choice leads to failure was wider than when the financial choice was successful. (Da Rocha, Vyaito, 2013).

Some researchers began to use neurofinance as a keyword to identify scientific studies that use the tools of neuroscience and psychology to understand the heterogeneity of financial decision making. Although in the last five years, the terms of objective financial reforms have become very widespread in scientific circles, it is noteworthy that some researchers use this term as a key word in studies that do not use neuroscience tools, which It can distort new research in this field. It is noteworthy that neuroscience is an interdisciplinary science that has different disciplines that may not have a direct relationship with financial problems. In the neuroscience section presented by Sapra et al. (2012), there is a special field for financial scientists, cognitive neuroscience.

Like language, self-awareness, memory, is subject to cognitive impairment (Sapra et al. 2012). Even with this apparent limitation. Admittedly, those limitations are not very clear between the fields of neuroscience, and sometimes there is a need for integration to

another level, for a deeper examination of financial issues. Analyzes according to the point that investors are rational or irrational, according to the brain regions used when financial decisions are made using some brain mapping equipment or physiophysiology. Neurofinance as a combined effort of neuroscience and finance to better understand the dynamics of decision-making, seeks a type of knowledge that includes neural mechanisms, benefits and risk analysis in this knowledge (Armando, Da Rocha, (2013), therefore Neurofinance is a combination of the neurofinance approach, financial decisions and their reflection in the brain, and it can be like a bridge between psychology, the brain and the behavior of investors (Sapra et al. 2012) about tools, financing neurofinance using technology Brain imaging is carried out in a laboratory, specific neural characteristics related to the acquisition and processing of information related to financial decision making.

The fine lines between neurofinance and behavioral finance

Le Nescher, Paysan, and Bossarts (2015) found that articles that use the term neurofinance in keywords are an excellent example of behavioral finance research and not neurofinance, because these articles are without the use of neurofinance research tools have been done and they have not used the scales required for neuroeconomics studies. The incompatibility between neurofinance and behavioral finance, according to the approach of Geipel (2013), is at a point where Scientists are starting to use the term neuroeconomics in behavioral finance

Emphasize the empirical methods that are most helpful in behavioral finance studies. The difference between behavioral finance and neurofinance is that in behavioral finance, it has already been explained about the behavior and interaction of people in the financial decision-making process and the analysis of these actions based on psychological concepts and theories, while Neurofinance examines why and how these behaviors are performed based on observations in the brain and hormonal activities of people. (Tetsang, 2006)

Behavioral finance uses cognitive psychology, which is a branch of psychology that seeks to understand internal mind processes such as image processing, memory, thinking, learning, emotion, problem solving and decision making, judgment, and language. Da Rochaet al., (2013). The perspective of psychology examines emotion as a product of cognitive analysis of a stimulus or event, and from a large number of experimental methods to find neuroses and discoveries, as well as other interventions in rationality. Uses. Currently, "behavioral finance" is a challenge that has been transformed into the neoclassical paradigm in the best possible way (Gippel, 2013).

In fact, progress in neuroscience leads to progress in behavioral finance research, but this issue cannot be considered for studies on neurofinance, these two methods have different units of analysis and different models. Neurofinance uses the brain as a unit of analysis. Instead, behavioral finance uses the individual. Geipel (2013) has also used Kuhn's concept of ordinary and extraordinary science (revolution) to show emerging parts in the integration of two or more fields.

Table 1. Neuro financial research and its results

Results	Title	Author
Using event-related fMRI, they investigated whether predictive neural activity can predict optimal and unconventional options in a financial decision. Two types of deviations from the optimal factor-neutral investment strategy are defined as risk-neutral errors and error-induced errors. A risky choice) such as risky errors are produced by the NAcc activity, while the anterior insula produces a risk-free choice such as risk-averse errors. The findings of this study show that each independent neural circuit is related to a type of financial choice.	The neural basis of financial risk-taking	Kuhnen et al. 2005
This research aims to investigate the new approach to financial decision-making, the so-called "neurofinance", which has recently become the center of many discussions as a new method for scholars in management and accounting, by searching neurofinance articles in order to organize ideas, methods, the main processes and issues that are dedicated to this topic. The results showed that a significant number of articles, which made a direct contribution to this issue. The author network shows the dispersion of authors, and only three of them have more than two public works related to this topic.	Neurofinance: A systematic review of a new way to look for financial decisions	David Srer, Wesley Vieira da Silva, Clodimar Pereira da Vaiga, Elso Suoza (2016)

Results	Title	Author
The first studies in the field of neuroscience were conducted by Willioby and Gering (2002) using electroencephalography (EEG) to analyze brain activity related to financial decision-making in a monetary betting task. This research showed that the negative event-related brain potential, probably generated by the midbrain near the prefrontal cortex, was larger in amplitude when the financial choice resulted in failure than when the financial choice was successful (Da Rocha, Viaito, 2013).	Neurofinance: How we can make financial decisions	Da Rocha, Viaito, 2013
This research has a valuable role in examining financial matters such as efficient market hypothesis, limited rationality, behavioral finance and neurofinance. The difference between behavioral finance and neurofinance is that it has previously been interpreted about how people behave and interact in the financial decision-making process and interpret these actions based on psychological concepts and theories, while neurofinance examines why and how. These behaviors are based on observations in the brain and hormonal activities of people.	Behavioral investment, bounded rationality, neural finance and traditional finance	Tseng (2006)
This research shows the effects of behavioral states and emotions in financial decisions. The evidence shows that independent brain systems affect processes related to risk taking and risk aversion in financial affairs. Excessive activation or suppression of the system leads to mistakes in the selection of investments.	Causation and financial decision making: How neuroscientists can learn from market participants.	Peterson (2007
He has used Kuhn's concept of ordinary and extraordinary science (revolution) to show emerging parts in the integration of two or more fields. Currently, "behavioral finance" is a challenge that has become the neoclassical paradigm in the best way.	A revolution in finance?	Gipple 2013)
This article examined the impact of neurofinance, the results of the study of the human brain and its financial decision-making behavior explain why humans are not balanced according to the rules of popular financial theories.	A New Era of Finance: Neurofinance and Investment Behavior	Jinda Wall (2016)
Testosterone is positively related to choosing more diversified securities. Specifically, participants with higher Testosterone choose higher risk in their asset allocation to obtain higher returns.	Decision making, financial risk aversion and behavioral bias: the role of Testosterone and stress	John Nofsinger Fernando Peterson Robert T. Diller (2015)
The results of the research show that the high level of Testosterone in the CEO increases risk-taking in the company. In other words, managers with high Testosterone levels have a double motivation for competition, dominance or power and are more likely to engage in highly risky behaviors in the company. Therefore, it can be argued that the composition of the CEO's face (higher ratio of width to height of the CEO's face) makes him more risk-taking.	Testosterone level of CEO and company's risk tolerance	Safari Graili, Rezaei Pitehnoi, Nowrozi (2015)
The behavior of irrational disruptive traders causes the stock prices to deviate from the fundamental factors. Many perceptual and behavioral errors were identified in behavioral finance theory, but the issue of why people make behavioral errors and how to overcome these errors has not been discussed.	Dimensions and approaches of behavioral finance theory	Darabi, Chenari Bouket (2015)
The existence of distortions has led to the realization of the existence of behavioral finance. But since this school also only showed the signs and symptoms and was unable to mention the causes, the researchers found another school where the cause of behavioral disturbances originated. This new school, which is derived from the nervous system of humans and its effect on decisions, especially financial and economic decisions, has become known as the school of neurofinance.	Behavioral finance, the transition stage from standard finance to Neurofinas	Eslami Bidgoli, Kordloui (2009)
Much of the research in the field of neurofinance focuses on business behaviors. Therefore, examining brain function can also be considered for other investor behaviors and provide practical results. Among these behaviors in which brain function can be studied, decisions related to personal financial planning, such as wealth management, retirement planning, credit acquisition, etc., can be mentioned. However, research in the field of neurofinance faces limitations due to the fact that it takes place in a laboratory environment.	Neurofinance, the future horizon of behavioral finance	Khajovi, Fatahi Nafchi (2012)
They investigated the effectiveness of Testosterone hormone on the decisions and attitude of investors. They used an experimental research method with a pre-test-post-test design with a control group. The statistical population includes all accounting students of the Islamic Azad University of Tehran province who have worked in the stock market for one year. After that, 80 people were selected as a sample and randomly assigned to two groups of 40 people (experimental and control). Testosterone hormone was injected intramuscularly for the test group and placebo (distilled water) for the control group. The tool used by the researcher is a form and content validity questionnaire, and Cronbach's alpha test was used for reliability. Finally, the data was analyzed through the covariance test. The results have shown the effect of Testosterone on decision-making and investor's attitude.	Testosterone injection and decision making	Mouszadeh et al. (2022)
Hormones are chemical messengers that are secreted by endocrine glands throughout the body and control, regulate and coordinate bodily activities through the reception and transmission of brain neuron signals. About 50 different hormones are secreted throughout the body through the bloodstream and the lymphatic system. These hormones are designed to affect body processes such as metabolism, mental state,	Hormones and decision-making performance	Nofisenger, John R. (2020).

Results	Title	Author
sexual function, growth, etc. Hormonal imbalance can cause important problems such as weight gain, skin changes, mood changes and lack of energy. While there are many types of hormones, this research only examines hormones such as cortisol (stress hormone) and Testosterone (risk-taking hormone), which are effective in the process of financial decisions and trading. The purpose of this research is to present a model according to the neurofinance approach on the financial behaviors of capital market participants. From the model of this research, it is possible to examine the financial behavior of investors according to the level of hormones and use it to predict the behavior of investors. Producers and sellers of financial assets, investment advisors can use the results of this research		

Scientometric research method

In the following, the topic related to scientometrics of the articles published in Scopus scientific database is presented. The meaning of scientometrics is the technique of analysis such as Ves Weaver, Vision and Pazhek, etc, and statistical and quantitative analysis of scientific texts with the help of bibliographic software. The general process of doing the work is that the keywords of the article are checked in various scientific databases such as Scopus, Web of Science, PubMed, etc. and the required information is entered into an Excel form and then entered into one of the bibliographic software and then the output of maps is received.

First, the key words of neurofinance, financial decision making, optimism and pessimism and risk tolerance were searched in Scopus scientific database. Scopus is one of the most reliable international scientific citation indexes that contains information about 60 million documents from the products of approximately five thousand scientific publishers from all over the world. In the first step, 800 articles were displayed, but since these articles were related to all the fields in the database, in the next step, advanced search filters were applied to the keywords. The advanced search was limited to articles and reviews and commercial articles published or being published in English between 2006 and 2023, and filters related to finance, accounting, economics, and business were activated.

This search was conducted on October 12, 2023, equivalent to Mehr 20, 1402, and the results are related to this date, and therefore, the possibility of changes after this date is not far from expected. The annual review of articles showed that neurofinance is an emerging field in scientific research and the first work indexed in the Scopus database dates back to 2006.

Findings

By looking at the chart, you can see that after 2006, neurofinance suffered stagnation for four years, and then in 2012, there were two articles in this field.
Other publications of articles in 2023 are decreasing and so far, this year 2 articles have been published in this field. It is still possible to increase the release until the end of the year.

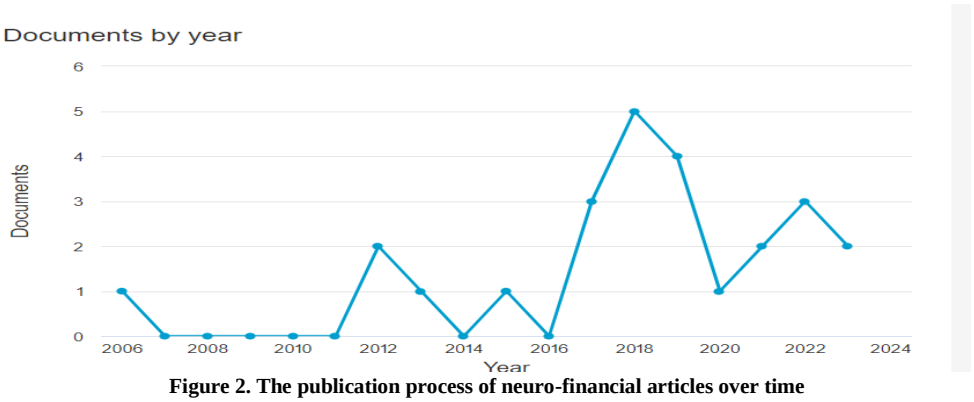

Figure 2. The publication process of neuro-financial articles over time

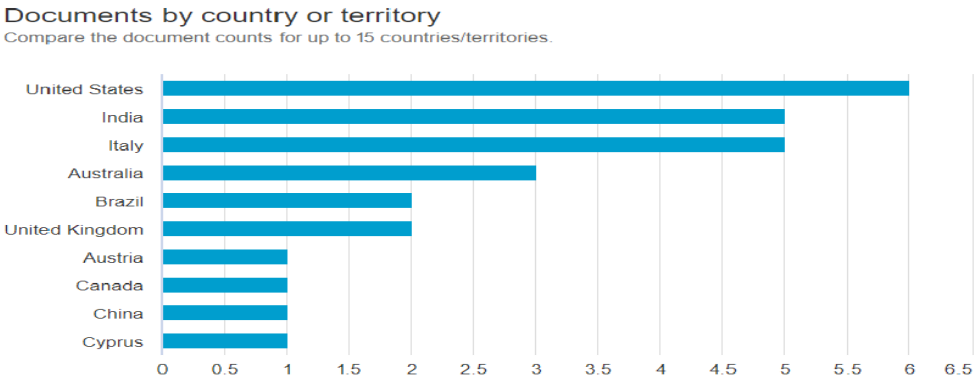

Figure 3. Publication process of each country/region in terms of number

According to Tasawar, the most active farmer in financial research is the United States with an average of 6 articles published. Then India and Italy with 5 articles and Australia with 3 articles are in the next ranks.

It is worth pondering that, besides the fact that Asian farmers are not interested in neuro finance, there is no record of neuro finance from Iranian farmers in scopus, and Iranian researchers can look at this issue as an opportunity and take action to research and publish their articles.

The latest indexed work

Article: "Perceptions of Biased Risk: Evidence from Test Market and Financial Markets" written by Payzan et al., the latest financial article of neurofinance in scopus.

This article has not received any citations due to its newness.

The most widely cited neurofinance

The most cited article in this field is "Towards an effective neurofinancial account of financial risk taking" written by Wu et al., which was published in 2012 and has received 74 citations so far.

Another highly cited article, "A Revolution in Finance?" It's called Gippel, which was written in 2013 and has been referred to this article 65 times so far. In 2018, Nadler et al. wrote a paper titled "Wall Street Bulls: An Empirical Analysis of Testosterone and Asset Trading," which became one of the most cited neurofinance papers with 50 citations.

"Finance" is written by Wu et al., which was written in 2012 and has 74 quotations so far.

Fig. 4 Co-occurrence map of keywords in the passage of time

The co-occurrence of keywords is a type of content analysis to reveal patterns and determine subject trends in specific research areas. The information of 47 articles was downloaded. From the Scopus database, VOSViewer bibliometric software is available to create maps based on 26 of them. Wes Viewer is a free software for creating and visualizing and exploring these maps. From this tool to create and visualize networks of 27 network data. For doing this, Bibliography used, which are usually called "maps". The maps have items that are determined based on the researcher's wishes and goals, which can include the collaboration of authors (authors, countries, organizations) (co-occurrence of keywords) all words, words of authors, indexed words (citations) of authors, articles, sources, organizations, countries (bibliographic pairs), articles, sources, authors, organizations, countries (references and authors) are cited. The required information is extracted from databases. Maps created with the help of circles and lines to 31 and dimension 30, Pub. Mode 29, Scopus Lens 28, Web of Science

The show comes out. A colored circle is assigned to each item, the bigger the item's weight and strength, the larger the circle size. Communication between items is established with lines. The stronger the connection, the thicker and shorter the line. Also, 32 categories of items that are more similar to each other are displayed with the same colors, which are called "clusters".

The authors used 1270 keywords to write articles related to neurofinance. Using the software, the researcher sought to find those keywords that were used together 4 times in different articles. The number of this occurrence was 84 words, which the researcher after checking one by one and removing repeated keywords or the same keywords with different writing forms and removing specific names (such as countries and people) reached the number of 15 of the words. According to the box below, it can be seen that this map is drawn for the articles published between 2006 and 2023. In this map, the colors are divided into blue, green and yellow spectrum. There are no words among the words. The blue circle is not observed and all the circles tend to green, green/yellow and yellow. In the interpretation of this situation, it can be stated that there was no co-occurrence between the keywords before 2017, but from this year onwards, the word economy, finance, financial markets and profitability due to the darker green color of dedicated circles have been used by the authors in various articles. From the green/yellow color, it can be inferred that in the years 2018 to 2020, the authors used words like Risk taking, investment, failure analysis, performance, emotions and optimism and behavioral studies were trending and from then until 2023, words like financial decision making and risky behaviors became trends.

Examining the lines of communication between keywords depict the intensity of co-occurrences. The thicker the line and the shorter the length of the line, it means that those two words have been used together more times in various articles. For example, in the picture above, you can see that the most frequent word according to the size of the circle is the word "risk tolerance" which has the most connection with the words "profitability and economy". Or the word "investment" has the strongest connection with "economy, financial markets and financial decision-making". If this map is examined from another point of view, by following the "unestablished" links, it is possible to reach areas in which neurofinance has not made progress. For example, there is no connection between the key words "optimism, financial decision-making and profitability" and therefore researchers can solve this research gap by conducting research on these words.

To publish articles, authors, organizations and different countries cooperate with each other. Wes Viewer software has the ability to categorize partner countries in clusters of the same color. In this illustrated map, 4 clusters with red, green, blue and yellow colors can be seen, which contain 18 items. For the publication of 47 articles that were downloaded from Scopus, 61 countries had cooperated among these 61 countries, according to the researcher's opinion, Wes Weaver was able to find 18 countries that cooperated in writing at least 5 articles and at least 10 citations. They had received their articles.

A review of the above map shows that the financial sector is the area of interest for European countries.

According to the size of the circles, which indicates the weight of the item, Britain has had the most cooperation with other countries, and the number of communication lines shows that it has published joint articles with 15 countries, and the United States ranks second with 14 joint articles and France with 9 shared articles are in third place. Among the Asian

countries, China with the United States, France, Australia, the Netherlands, Sweden, Denmark and Indonesia, which is considered a European/Asian country, has had the closest cooperation with the Netherlands and the United States.

Examining the map showed that if Iranian researchers are looking to index their articles and researches in Scopus, they can increase their chances of publication by collaborating with authors from the United States and Great Britain, and they can even choose a co-author from countries that have no line. No communication has been established between them (such as Poland and Canada) regarding registering a new record in the field of cooperation Countries should take action.

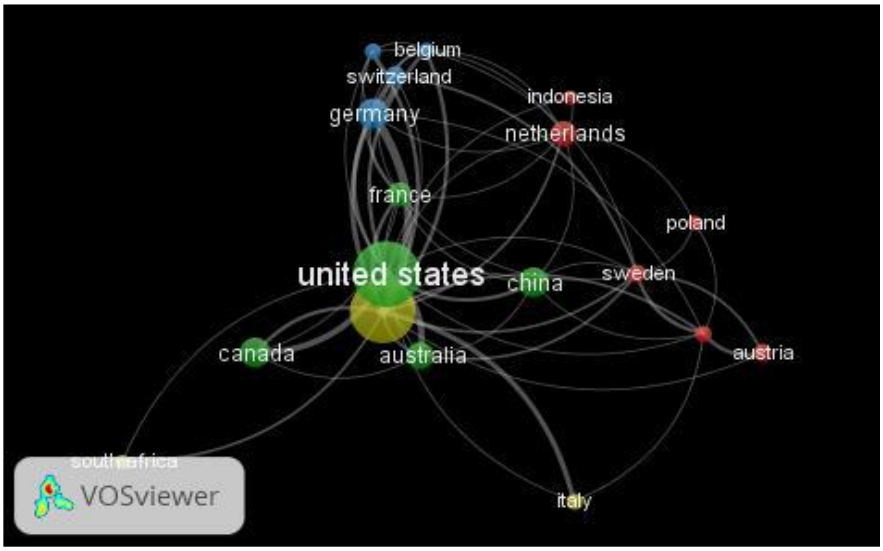

Figure 5. Cooperation map of different countries in the publication of financial articles

Table 2. Cooperation between countries in the financial field

Name of the country	Number of items	Cluster number
Netherlands - Indonesia - Poland - Sweden - Austria - Denmark	6	1 - red
United States of America - Canada - Australia - France - China	5	2 -Green
Germany-Belgium-Spain-Switzerland	4	3 -Blue
Britain - Italy - South Africa	3	4 -Yellow
	Total: 18	

Research variables

Hormones are designed to affect body processes such as metabolism, mental state, sexual function, growth, etc. Hormonal imbalance can cause important problems such as weight gain, skin changes, mood changes and lack of energy. While there are different types of hormones, this research only examines hormones such as T4 and TSH, which are effective in the process of financial and trading decisions (Noraee et al., 2020).

From the point of view of the financial field, risk tolerance can be seen as the possibility of losses in any type of investment, and bearing financial risk is a mental characteristic and a genetic predisposition, the parameters for evaluating people's risk tolerance can be grouped as follows: The meaning of risk taking for people (loss, lack of Certainty, luck, excitement). Choosing between investing in the stock market or the bank. Reaction to news of price increase or decrease. Risk in the field of investment is related to the future cash flows of each investment, and the probability of the actual return is different from what is expected, so

the greater the variability of the results, the riskier the investment will be (Khajovi and Fatahi, 2012).
Testosterone is the main male sex hormone and the dominant androgen; It means that it stimulates the development of male characteristics. The level of this hormone is naturally higher in men than in women. It has been introduced as one of the most important health hormones, if its level is constantly fluctuating, it can lead to adverse symptoms that require a visit to the doctor. A decrease in the level of blood Testosterone leads to a decrease in infertility, muscle mass, short temper, depression, aggression, etc. and will ultimately lead to a decrease in concentration and a change in people's financial behavior (Herbert et al., 2018).

Optimism and pessimism are considered generalized expectations of positive and negative outcomes, and these variables represent relatively fixed individual differences effective in increasing or decreasing psychological well-being. Optimism is related to positive events and leads a person to such consequences; pessimism is related to negative events and leads a person to those consequences. Optimism and pessimism can be measured by documentary style questionnaire and verbal explanation content analysis (Seligman, 2005).

Due to the fact that the subject of neurofinance is in the early stages of its work, it is placed in the field of applied social sciences, it still does not have a correct understanding of research methods and also the theories necessary for proper research in financial affairs, in the studies of risk-taking and optimism, the place of hormone is often Testosterone and cortisol have been analyzed, therefore, in this research, an attempt has been made to provide a model that explains and predicts the financial behavior of capital market investors with regard to hormonal changes. Therefore, the main research question is, what effect does the level of hormones have on the behavior of investors?

The conceptual model of research and its variables

Based on the study and review of the subject literature and with the help of the research background, the conceptual model of the research is presented based on the following variables, the neural factor of Testosterone, T4 and TSH hormones as independent variables and the behavioral factor of risk-taking and optimism as dependent variables.

Research questions

1) 1)To what extent can changes in Testosterone hormone affect the risk-taking of investors
2) To what extent can changes in Testosterone hormone affect investors' optimism?
3) To what extent can changes in T4 hormone affect the risk-taking of investors?
4) To what extent can changes in T4 hormone affect investors' optimism?
5) To what extent can changes in TSH hormone affect the risk-taking of investors?
6) To what extent can changes in TSH hormone affect investors' optimism?

Research model methodology

The research done is fundamental and practical in terms of purpose. The data collection method is field and cross-sectional in terms of time. In this research, the required data and information have been collected through blood test methods and interviews. In order to check and control the hormonal changes of the participants, clinical tests and blood tests have been used. The test sheets were reviewed by a general physician to confirm the physiological part of the research. The statistical sample of the research is 77 people (57 men, 20 women) from professional investors working in the capital market as an available sample, in order to conduct tests and complete questionnaires. The sample selection conditions were such that their literacy level was at least a master's degree**.**

The selection criteria of the participants were at least one year of activity in the stock market, the age range of the investor between 25 and 60 years, the amount of capital more than 15 million Tomans, as well as not taking psychoactive drugs and not smoking in the last 48 hours. The participants must visit the medical diagnosis laboratory in person and the test costs have already been paid by the researcher. To collect the hormones, the participants attended a medical laboratory. Blood samples were collected using special kits Diazyn and tested using a fully automatic ELISA reader.

The hormones of investors participating in this research, Testosterone, T4 and TSH were collected quantitatively and numerically. The data was entered into Excel software and then the average level of hormones was calculated, then it was processed in

smart pls software based on the final research model of the relationship between hormone levels and financial behaviors. Daniel Kahneman's risk questionnaire in fast and slow thinking (2011) and Siligman's optimism questionnaire (2006) were used to design the questionnaires. The reliability of the questionnaire was checked by Cronbach's test. It was used to check the validity of items that were prepared using the opinions of professors and experts.

Results from the Hormonal behavior Analysis

After collecting the data of 77 studied samples, in order to test the research questions, the structural equation modeling method was used by the partial least squares method and the data were processed and analyzed with the statistical software smart pls version 3.

The results obtained from age conditions, history of activity in the capital market and work history of the respondents after being compiled in Table 2 show that the average age of the sample was 41.7 years with a standard deviation of 8.1 years. The youngest person was 25 years old and the oldest person was 57 years old. The average activity experience of the studied people in the capital market was 9.9 with a standard deviation of 3.6 years and their average work experience was 13.5 with a standard deviation of 6.1 years.

The hormones of investors in this research include Testosterone, T4 and TSH, which are collected numerically, these numbers are coded between one and zero, and then the average amount of hormones was calculated. The normal and natural ranges of the desired data are presented in Table 5 for each of these indicators.

In Table 6, descriptive statistics related to the level of Testosterone, T4 and TSH hormones are presented in Table 6. It can be seen that the average levels of Testosterone, T4 and TSH are 4.933, 1.976 and 2.341, respectively. Their standard deviation levels were 2.125, 0.499 and 1.173, respectively.

The results of the frequency distribution of risk-taking and optimism variables according to gender and in general are reported in Table 7 and these results show that 41.20% of the studied subjects were optimistic and 39.20% were risk-takers.

Structural equation modeling is also used in situations where there is more than one dependent variable. Due to the small size of the sample, in this research structural equation modeling was used using the partial least squares or pls method. Table 8 shows the R2 and Q2 indices related to the endogenous variables of all three models.

The results of Table 8 show that in the general model, 14.2% of changes in risk taking and 22.8% of changes in optimism are explained by the level of Testosterone, T4 and TSH hormones.

After examining the goodness of fit of the model and ensuring the appropriateness of the model, in this section, the relationship within the model and the significance of the paths are evaluated using the results of the model fit. The results of fitting the direct paths of the models and their significance test and the effect size of each path are presented in Table 9.

Table 9 shows the results the level of T4 and TSH hormones has no significant effect on the risk appetite of capital market investors ($P<0.05$). But the effect of Testosterone hormone level on risk taking has been significant ($P=0.000$) and since the standard coefficient of this path is estimated as 1.117, it can be said that Testosterone hormone level has had a positive and significant effect on capital market investors' risk taking. The effect size of Testosterone hormone level on risk taking is estimated at 0.424 and since three values of 0.02, 0.15 and 0.33 are considered as criteria for weak, medium and significant effect size. It can be claimed that the level of Testosterone hormone can have a positive effect on the risk-taking of capital market investors to a significant extent.

The results show that T4 and TSH levels do not have a significant effect on the optimism of capital market investors ($P<0.05$). But the effect of Testosterone hormone level on optimism has been significant ($P=0.000$) and since the standardized path coefficient of Testosterone hormone to optimism is estimated at 0.863, it can be said that Testosterone hormone level has had a positive and significant effect on the optimism of capital market investors. As mentioned, based on the results of T4 and TSH hormone levels, it had no effect on the optimism of capital market investors. But the effect size of Testosterone hormone level on optimism is estimated at 0.202 and it can be claimed that Testosterone hormone level can moderately affect the optimism of capital market investors.

Table 3. Distribution of respondents' demographic characteristics

		percentage	frequency			frequency	percentage
gender	man	74	57	**field of study**	economy	20	26
					Accounting and auditing	27	35.1
	woman	26	20		Financial management	26	33.8
					Other subjects	4	5.2
job	Investor and university professor	55.8	43	**Degree**	senior	32	41.6
					PhD. candidate	25	32.5
	Investor and employee	44.2	34		Ph.D	20	26

Table 4. Frequency distribution of respondents' age

	average	median	standard deviation	Min	Max	first quarter	third quarter
age	41.7	43.0	8.1	25.0	57.0	38.0	46.0
Capital market history	9.9	11.0	3.6	1.0	15.0	8.0	12.0
Work experience - year	13.5	13.0	6.1	2.0	26.0	9.0	18.0

Table 5. Normal range of indicators (normal range)

test	average	normal range
Testosterone	4.933	7.6-49 Nanomol- per liter
T4	1.976	0.35-4.95 million per ml
TSH	2.341	0.6-1.6 ng per ml

Table 6. Descriptive statistics results of measured hormone levels

	average	middle	standard deviation	min	max	first quarter	third quarter
Testosterone	4.933	5.2	2.125	0.600	8.200	3.300	6.126
T4	1.976	2.00	0.499	0.8	2.90	1.6	2.3
TSH	2.341	2.10	1.173	0.75	9.00	1.5	3.02

Table 7. Results of descriptive statistics of research variables

gender	Variable		Number of participants
overall	risk averse	number	46
		percentage	60.80%
	risk taking	number	31
		percentage	39.20%
	pessimism	number	44
		percentage	58.80%
	optimism	number	33
		percentage	41.20%
	total	number	77
		percentage	100.00%
men	risk averse	number	33
		percentage	58.10%
	risk taking	number	24
		percentage	41.90%
	pessimism	number	31
		percentage	54.80%
	optimism	number	26
		percentage	45.20%
	total	number	57

gender	Variable		Number of participants
	risk averse	percentage	100.00%
Women	risk averse	number	13
		percentage	65.00%
	risk taking	number	7
		percentage	35.00%
	pessimism	number	13
		percentage	65.00%
	optimism	number	7
		percentage	35.00%
	total	number	20
	risk averse	percentage	100.00%

Table 8. R2 and Q2 indices

Model	Endogenous variable	R2	Q2	GOF
total	risk taking	0.142	0.115	0.435
	optimism	0.228	0.163	

Table 9. The results of the significance check of the paths of the models

Model		Standard path coefficient	Standard error	T-value	p-value	Effect size F2
overall	Testosterone → risk taking	1.117	0.201	5.557	>0.001	0.424
	Testosterone → optimism	0.863	0.231	3.735	>0.001	0.202
	T4→ risk taking	-0.174	0.103	1.689	0.092	0.046
	T4→ optimism	-0.208	0.107	1.943	0.052	0.053
	TSH → risk taking	-0.024	0.138	0.173	0.835	0.001
	TSH → optimism	-0.029	0.115	0.252	0.831	0.001

Conclusion and discussion

According to the maps obtained from the VOSviewer software, according to Figure 2, the most active country in neurofinance research is the United States with an average of 6 articles published. Then India and Italy with 5 articles and Australia with 3 articles are in the next ranks. The thing to think about is that besides the fact that neurofinance is not the focus of Asian countries, no neurofinance record from Iran has been indexed in Scopus. From this figure, it can be concluded that in order to move in this direction, it is necessary to identify the leading countries and find a way for joint studies.

In figure 3. It identified the most used keywords and the co-occurrence graphic map of 15 words. According to this map, it can be seen that there are no blue circles between the words between 2006 and 2023, and all the circles tend to be green, green/yellow and yellow. In the interpretation of this situation, it can be stated that before 2017, there was no co-occurrence between the keywords, but from this year onwards, the words economy, finance, financial markets and profitability, due to the darker green color of the dedicated circles. They have been used by the authors in various articles.

The most cited article was introduced in the next section, which is Charlan Wu et al.'s article titled "Towards an effective financial account of 33 financial risk factors" which was published in 2012 and so far, 74 Citation has been received. Another highly cited article, "A Revolution in Finance?" It is called that Gippel wrote it in 2013 and it has been referred to this article 34 times 65 times. In 2018, Nadler et al. wrote an article titled "Wall Street Bulls: An Experimental Analysis of Testosterone and Asset Trading", which became one of the most cited neurofinance articles with 50 citations. According to the purpose of the research and the findings, it is suggested to study the most cited articles and use them in the theoretical literature for future research. Artificial intelligence should also be used to predict and present neurofinancial models. It is necessary to mention that

one of the most used keywords in the study of neurofinance is risk tolerance, uncertainty, and decision-making, which has been used by the most cited authors, so it is suggested should be studied and investigated as important variables. In addition, due to the fact that so far, no study has been done in the field of neurofinance between Iran and other countries, it is suggested to the authors to conduct a joint study with other countries in this regard.The results obtained from the second step of research showed that:

The results of Table 9 revealed that Testosterone is the only hormone that has a direct and significant effect on risk tolerance, that is, with the increase of this hormone, the risk tolerance and optimism of investors increases. The result obtained in this research is consistent with the research findings of Kamia et al. (2016) and Mills (2017) that there is a positive relationship between the level of Testosterone hormone and risk taking. 2016), Nouraei et al. (2020) and Mouszadeh et al. (2022) in their research achieved similar results to this research and stated that people with higher Testosterone levels bear more risk. It is also in line with the results of Payzan et al.'s research (2023) who believe that increasing the level of hormones causes more risk and making multiple transactions despite high price fluctuations.

Also, the findings of this research showed that T4 hormone has an inverse and significant effect on optimism and risk-taking, and the level of TSH hormone has no significant effect on the behavior of capital market investors. The analysis of this research confirms the results of studies by Frydman et al. (2014) and Asher et al. (2016).

We can point out the major limitations of this experimental and laboratory research, such as the costs of conducting tests and persuading the participants to provide blood tests and other variables affecting the participants. Also, the need to have financial expertise and experience at the same time as financial expertise is another limitation of this research. In addition, the answers given by the participants in the laboratory environment may be different from the answers given to the researcher in another place because in a laboratory environment, due to the awareness of the subjects, they will be involuntarily affected by the created conditions. Of course, this factor was beyond the researcher's control. In this research, the effect of hormones on people's choices showed that each person's hormone levels can affect their average risk-taking and optimism. The results of this research can be used in financial markets to predict the decisions of investors and portfolio managers. It is recommended that future studies of the model of financial behaviors and hormone levels be conducted in other conditions and with other control factors. The focus of most neurofinance studies is on financial behaviors, so it is suggested that other hormones and financial behaviors such as financial decisions and how people save should be investigated in future studies. It is recommended that researchers study the function of other parts of the brain with a focus on individual planning and optimal wealth management. Financial planning for retirement and current decision making of investors and portfolio managers should be monitored and analyzed.

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