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Neurotransmitters and the Behavior of Individual Investors: Exploratory and Confirmatory Factor Analysis

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Abstract

Neurotransmitters are the chemical messengers nerve cells use to transmit signals to target cells. Neurotransmitters affect the behavioral aspects of investors' performance. Therefore, this study investigated neurotransmitters' effect on individual investors' behavior by using structural equation modeling. To achieve this goal, exploratory and confirmatory factor analysis has been used. The study is applied research and utilizes a survey methodology. The required data were collected through the distribution of questionnaires among 315 individual investors. This study was done in the Tehran stock exchange's second and third seasons of 2023. According to the research, neurotransmitters through eight components of adrenaline or epinephrine, noradrenaline or norepinephrine, dopamine, serotonin, GABA (gamma-aminobutyric add), acetylcholine, glutamate, and endorphins affect the behavior of individual investors. Based on the second-order confirmatory factor analysis, the GABA component (0.39) has the highest impact, and adrenaline or epinephrine (0.25) has the least effect on the behavior of individual investors. The findings indicate the necessity of redefining rationality and considering its effects on investors' decisions and behavior.

Keywords: Neurotransmitters, Neurofinance, Behavioral Finance, Individual Investors

Introduction

To date, information processing in the human brain has been investigated from different perspectives. For example, many studies have been done on this issue in various disciplines, such as psychology, philosophy, economics, and cognitive neuroscience. In recent years, many studies have been done on the brain in different disciplines. One of their most crucial is using non-invasive techniques (not requiring surgery or invasive procedures). These techniques enable various fields of social sciences, such as neuroeconomics, neurofinance, neuro-marketing, and neuro-politics, to research and understand the decision-making process in the human mind (Mubarak, 2017). Therefore, investigating how other researchers process information in the human brain can help expand knowledge and technology in neuroscience. This issue allows for investigation of the physiology of neural circuits involved in people's choices. By focusing on the activity of the human brain, cognitive neuroscience can help to better understand the practical application of neuroscience in economic and financial decisions. In this sense, Ceravolo et al. (2019a) and Ceravolo et al. (2019b) conducted a quantitative study of brain activity regarding payment methods (such as cash, credit, and smartphone).

Among the studies related to neuroscience is the research work of Ceravolo et al. (2019a). These researchers investigated the eye-moving patterns while studying financial statements by focusing on the two characteristics of the color of financial statements and the impulsive personality of the subjects. These two factors are essential in attracting attention to financial information sources. Using innovative instruments and techniques makes it possible to note the brain modifications in the actual time. This method leads to a better understanding of the decision-making process (Peterson, 2007a). Srivastava et al. (2019) investigated the relationship between physiological mechanisms and economic behavior from an interdisciplinary perspective. Cognitive and affective biases affect people's decisions; therefore, understanding them is very important. Neurofinance can be used to achieve this goal.

Neurofinance is a new branch of behavioral finance. This branch studies how human brain activities affect financial behavior. This is done through interdisciplinary interaction, including finance, psychology, and neurology. Zhang et al. (2019), using event-related potentials (ERPs) based on electroencephalographic data, attempted to investigate how participants (for example, senior managers) make decisions regarding the settlement of their company in an industrial area. Electroencephalography is one of the non-invasive methods of recording brain signals. The human brain has three essential parts: the forebrain, the hindbrain, and the midbrain (Sahi, 2012). The forebrain consists of the limbic system and the cortex. Most of the brain consists of the forebrain. The neo-cortex, the most significant part of the cerebral cortex, is accountable for the neuronal computations of attention, thought, perception, and episodic memory (Morse, 2006). Another name for the limbic system is the "emotional brain. "This system has an influential role in processing emotions and memory storage. The limbic system provides the insula and nucleus accumbens (NAcc) and also plays a vital role in remembering and motivating (fear and thrill) (Peterson, 2007a). The Tectum and Tegmentum are placed in the central brain. This part of the brain includes vision, hearing, eye motion, and corporal movements. The hindbrain consists of the cerebellum, pons, and medulla and contains functions related to survival (Sahi, 2012).

The forebrain plays a vital role in economic decisions. The limbic system is a central part of the brain that has a significant role in processing emotions. The emotional brain is also another name for this part. The cognitive and primitive behaviors of different animal species are affected by the limbic system. However, this system is more active in humans. This part of the brain is called the higher brain (Morse, 2006). According to Kuhnen & Knutson (2005), neurotransmitters affect people's performance in economic and investment areas. Their research emphasized the role of neural bases in risk-taking. Due to the influence of neural signals on individuals' investment behavior, the neurofinance branch's importance is increasing constantly (Khan & Mubarik, 2022). Most research on applying neurotransmitters in the stock market has focused on the relationship between dopamine and serotonin in stock trading. Due to the more complicated activity in the capital markets, the importance of the concept of neurofinance as neurotransmitters is constantly increasing.

Neurotransmitters are chemical messengers that enable signal transmission to target cells (Blobe et al., 2000). Neurotransmitters (including dopamine, serotonin, epinephrine, and norepinephrine) affect the behavior of individual investors. Strong brain signals facilitate the process of confirming and acknowledging the behavior of individual investors. Friedman (2012) examined the function of dopamine, serotonin, epinephrine, and norepinephrine as neurotransmitters in the human central neural system. In other research, such as Kuhnen and Knutson (2005), neurotransmitters have been investigated as a neural circuit. These neural circuits can act as a data carrier for the brain. Neurotransmitters affect the investors' behavior, such as risk attitude, optimism, and confidence in the market. Activity in the capital market creates special psychological conditions, particularly in the investor's mind. In that respect, neurotransmitters are among those factors that cause investors to feel comfortable. This is done by shaping memory. According to Dornelles et al. (2007), the neurotransmitter epinephrine (adrenaline) affects the human remembrance process. Most neurotransmitter research has been done in the laboratory and under medical guidance. In these studies, the participants' reactions were different depending on the nature of the circumstance. Also, in such research, people's awareness of the nature of the research can affect their stress levels. This can increase people's desire to participate in the study. Therefore, this issue can affect the results of the study. Conducting such research requires a unique level of knowledge, which may require a remarkable degree.

Accordingly, the sample size of most of the research conducted in neurological finance is small and mainly includes students or patients. According to Peterson (2010), the findings of such studies may be different from real life and, therefore, can be misleading for decision-makers. Consequently, it is essential to carry out new studies about the participation of neurotransmitters in the processing of economic and financial information in making financial decisions. Similarly, it is essential to carefully examine how the brain plays a role in making financial decisions in real life. Most of the studies regarding the neurotransmitters, such as Braverman (2005), Kharrazian (2008), Tessler (2009), Colbert (2012), and Ross (2019), are related to designing the scales for measuring the functioning of these transmitters in various medical subjects. At the same time, a few studies, such as Ahmad (2018), are related to providing scales for measuring the functioning of neurotransmitters in financial and investment subjects. Some issues, such as lack of clarity about the formation of neurotransmitters and the absence of a valid scale to assess it, have caused little theoretical and empirical work to be done in the area of neurotransmitters.

According to the previous paragraphs, the primary aim of this study is to explore and confirm valid scales for evaluating the performance of eight significant neurotransmitters regarding how they affect financial investment choices. Therefore, this study is unique because it investigates the behavior of investors by using the capacity of disciplines such as neuroscience, psychology, economics, and finance. Also, this study investigates the role of neurofinance in individual investors' decision-making. For a long time, individual investors, financial institutions, and many researchers have realized that people's economic behavior is not rational based on the traditional economic approach. In this regard, the present study attempted to help financial institutions and individual investors by redefining rationality and reviewing how neurotransmitters affect investment behavior.

Literature Review

Traditional finance refers to various techniques that individual investors can use to make rational investment choices. According to Markowitz (1952), efficient portfolios (i.e., the balance between risk and return) are considered reasonable. In addition, each person's portfolio is formed according to risk tolerance. Thus, portfolio risk is affected by changes in expected returns. The following two theories can be mentioned: (1) Markowitz's standard mean–Variance theory (1952). Due to its alignment with the facts, this theory has different characteristics. Thus, the standard mean–variance theory of Markowitz (1952) provides a set of efficient portfolios, allowing the investor to choose the optimal portfolio from the set of portfolios according to the utility curve or the level of risk-taking. (2) Prospect theory of Kahneman & Tversky (1979). This theory is based on a condition in which people's decisions are based on existing risks and uncertainties. In other words, according to this theory, people's preferences in decision-making, especially in risky conditions, are different.

Behavioral finance is focused on the behavior of investors. However, on the other hand, neural finance seeks to understand business people's economic and financial behaviors through neuro-related technologies. There are differences between behavioral finance and neuroscience. Using the framework of financial decision-making systems and the basic principles of psychology, behavioral finance attempts to understand how people make financial decisions and communicate with others regarding the conditions they understand. On the other hand, neuroscience tries to identify and analyze people's behavior by observing their brains and hormones (Tseng, 2006). Risk-taking is essential to every economic model, showing people's willingness to take risks in other economic areas. Of course, this is achieved through people's choices. In general, the risk-taking of people in different economic conditions is disparate. This difference is partly due to heritage characteristics (Kuhnen & Chiao, 2009).

In finance, decisions include buying and selling opportunities. In recent years, neuroscience methods have played an essential role in better understanding financial decisions. For the first time in September 2005, a review of neurofinance was published under the title Neuron, which was in the form of brain imaging. Event-related FMRI (Functional magnetic resonance imaging) can identify structural deviation related to investment decisions and better understand the responsible brain processes in this connection (Kuhnen & Knutson, 2005). Kuhnen and Knutson (2005) highlighted the role of emotions in financial decisions. Fundamentally, two methods (NAcc1 and anterior insular 2) have a vital role in financial decisions based on FMRI. The NAcc releases two neurotransmitters, dopamine and inhibitory serotonin. Dopamine is a pleasurable chemical in the brain that deals with feelings and emotions. Consciousness and emotional feelings are related to the anterior insular and include pain, grief, happiness, disgust, fear, and aggression (Peterson, 2007a). Therefore, when people feel something like physical pain, aversive visual stimuli, dangerous decisions, and anxiety, their anterior insular is stimulated.

Conversely, the nucleus accumbens of the ventral striatum is triggered when people anticipate a benefit. According to Kuhnen & Knutson (2005), based on the componential perspective regarding risk-taking, the neural mechanisms predicting profit differ from those predicting loss. Neurons of the nucleus accumbens transmit dopamine through neurotransmitters (Peterson, 2007a). The genes governing these neurotransmitters affect the processing data related to reward and loss prevention, as well as personality traits such as extroversion, news, anxiety, and addiction (Kuhnen & Chiao, 2009).

Researchers such as Tseng (2006) and Schultz (2007) showed that neurotransmitters play an important role in financial decision-making. Cohen (2005) also found a positive correlation between individual differences in extroversion and brain compensation schemes. Furthermore, differentiated neural circuits such as the nucleus accumbens and anterior insular can be used in high-risk activities (e.g., gambling and speculation) and risk-inverse

[1]. The nucleus accumbens (NAcc) is a critical brain region for motivated behavior.

[2]. The anterior insular is responsible for emotional feelings, including maternal and romantic love, anger, fear, sadness, and happiness.

activities (e.g., purchasing insurance) (Kuhnen & Knutson, 2005). There is a consensus that activating the accumbens and insular nucleus in these two areas before the activation index could cause a change in risk preference (i.e., positive and negative predictive emotions). In addition, Kuhnen and Knutson (2005) showed that different neural circuits about forecasting effects can simplify decisions regarding various financial choices. Financial bias, which means unpredictable, asymmetric, and enormous consequences (such as winning the lottery or severe life-threatening disease), can also affect other brain parts (Knutson, 2011). Wu et al. (2011) showed that the effect on one brain area cannot be localized with a positive skewness versus a negative skewness.

In contrast, skewness can affect preferences. This is done through separate neural circuits previously involved in anticipatory effects. Rational decision-making can be affected by automatic feelings produced in a particular situation. Automatic feelings produced by a particular situation can help rational decision-making. This can be done by reducing the range of choices by opposing dangerous or supporting beneficial ones (Shiv et al., 2005).

The primitive part of the brain is responsible for risk perception, and its stimulation is directly related to people's risk aversion (Morse, 2006). According to Stenstrom and Saad (2011), people with high testosterone are most likely financially vulnerable to some impulsive pathologies. Shiv et al. (2005) found that compared to people with standard emotional circuitry, people with bad emotional circuitry are not superficial regarding risk aversion and, therefore, have more reasonable choices. Besides, persistent and stable focal lesions of the brain have not reacted to the consequences of previous investments. When faced with expected high-quality games and maximum observance of regulations in certain parts of the nervous system, they can make valuable decisions (Shiv et al., 2005). Therefore, in addition to increasing the speed of decision-making and improving adaptation, emotions can also provide a survival advantage. As a result, it maximizes interests by preventing the occurrence of emotional responses (normal and automatic) (Cohen, 2005). This situation occurs due to a lack of best interests resulting from those feelings or normal and automatic emotional responses (Kuhnen & Knutson, 2005). Lo et al. (2005) investigated the effect of emotions on decision-making. They discovered that traders react to both financial profit and loss, and they also judge risks and uncertainties based on the two stimuli of the brain's limbic system. Through studying the relationship between nerves and internal decision-making, Kenning et al. (2006) found a relationship between the amygdala-hippocampal behavior of the brain and general risk aversion.

Situations without the best interests of those emotions and the standard and automatic emotional responses can be impeded.

Knutson et al. (2008) studied whether incidental rewards affect financial risk-taking. According to this research, the desire to use a risky solution begins with positive reinforcement, and part of this behavioral change is also affected by the stimulation of the nucleus accumbens. Therefore, an accidental external stimulus can affect risk-taking, and the activation of a specific area of the brain controls this behavior. According to the traditional finance literature, sometimes people are not only risk-averse but also risk-taking. According to Coricelli et al. (2007), even if people are familiar with traditional financial concepts, they usually do not like to regret in the future. This led to choices that may contradict logical choices (theoretically). Regret is a powerful cognitively induced emotion and its prediction conflicts with the values considered by the benefit theory. Regret helps people to make the right and optimal choices. At the same time, decisions are made in the confrontational cortex based on the current situation (Coricelli et al., 2007).

To compensate for the deficiency of the mean-variance theory regarding the lack of attention to financial skewness, Wu et al. (2011) investigated this issue. They found that positive bias increases the activity of the nucleus accumbens, and participants prefer games (transactions) with positive bias. According to Preuschoff et al. (2006), the activation of the subcortical structures of the human brain is related to the expected return and risk. This shows that the aspects of return and risk, which are the primary inputs of the mean-variance theory (Markowitz, 1952), are linked to at least one brain area. According to Pompian (2007), the effect of dopamine on investors' behavior, such as optimism, overconfidence, and risk aversion, can be caused by low serotonin levels. Preuschoff et al. (2006) showed that dopamine is related to returns and risk, and people's risk tolerance is also different. According to Kuhnen and Chiao (2009), the neurotransmitters dopamine and serotonin are among the factors influencing people's risk-taking in investment decisions. The neurotransmitters dopamine and serotonin help people to process events, analyze financial data, and prevent losses. Besides, Roe et al. (2009) showed a relationship between the neurotransmitters (dopamine and serotonin) and attitudes toward risk. According to Pompian (2007), most individual investors gain when the stock market is in a state of fight or flight.

Cohen and Hamrick (2003) showed that neurotransmitters norepinephrine and epinephrine are vital in the continuity or discontinuity of a specific activity (e.g., economic activity). According to Kuhnen et al. (2013), little serotonin specifies people's low participation in the stock market and limited company borrowing capacity. In financial systems based on a free economy, neurotransmitters are influential in obtaining real profits. This is in line with neurofinance goals. Jin et al. (2019) modulated the dorsolateral prefrontal cortex (DLPFC) using transcranial direct current stimulation (TDCS). The causal relationship between DLPFC and asset bubble was investigated and tested in their research through classic learning experiments for prediction. If neurotransmitters increase stock value, then this competitive advantage may be expected. Krugel et al. (2009) found that dopamine affects behaviors such as thrill-seeking. According to Anderson et al. (2015), a relationship exists between neurotransmitters (i.e., dopamine and serotonin) and behavioral aspects of investment, such as risk aversion and financial risk.

Mccormick et al. (2019) raised the following two main themes. (1) Interactive relationships: Activation/connection in the default mode of the network (DMN) has reduced cognitive control capacity and increased emotional or reward-oriented response to decisions, which, in turn, can lead to increased decision-making. (2) Alternative DMN behavior, Mental and internal representation through the combination of prejudices based on Gist (the principle of the event) and DM to consider the element of two normal processes. Therefore, based on the research on understanding the role of critical neural mechanisms in financial decisions, different brain parts affect financial decisions.

Research Methodology

According to Ahmad (2018), it is better to use survey research (such as explicit psychometric tools) and not laboratory research in neurofinance . In survey research, questionnaires are often used to collect data. In survey research, validity and reliability are among the serious issues that can sometimes lead to complexity in interpreting the results (Schriesheim et al., 1993). Therefore, developing a valid measurement scale is very important. The primary goal of designing a questionnaire is to properly evaluate the subject to be measured (Clark & Watson, 1995). According to Khan and Mubarak (2022), the essential part of all studies is using a reliable measurement scale.

Until now, in the field of neurofinance, appropriate measurement tools, especially regarding dopamine, serotonin, epinephrine, norepinephrine, gamma-aminobutyric acid (GABA), acetylcholine, glutamate, and endorphin, have not been given serious attention. Therefore, designing and evaluating a comprehensive and complete measurement tool is necessary for neurofinance .

The current research is a descriptive study of exploratory and confirmatory types. The population of this study was individual investors of the Tehran stock exchange, who were selected by convenient sampling method. The current research period is the second and third seasons of 2023. Due to the large population, we used Cochran's formula to determine the sample size (Equation 1). The related calculations are as follows:

$$n = \frac{(Z_{1+\alpha_2})2 * p * (1-P)}{d^2} = \frac{(1.96)^2 * .5 * .5}{.05^2} = 385 \quad (1)$$

Description of the above formula:

$Z_{1+\alpha_2}$	desired level of confidence
p	Proportion of possessing the desired attribute
q	the proportion of not possessing the desired attribute
d	permissible error

Generally, 315 usable questionnaires were collected. Therefore, the ratio of usable questionnaires to total questionnaires is 82%. This ratio exceeds the accepted rate of 33% (Pennings et al., 2002). Before the analysis, outliers were identified and removed. The skewness and kurtosis of the questions were less than 2, which indicates their normality. Hypotheses were tested using structural equation modeling based on SPSS version 26 and Amos version 24.

Tables 5 to 12 show the items of the questionnaire. Each of the tables includes the items of each variable. Developing questionnaire items was done in the following two steps:

First step: Through reviewing the literature, especially the work of Khan and Mubarak (2022), questions were designed for each construct. Then, the necessary analyses were done on the questions to obtain a final version.

Second step: In this step, the questions extracted from the previous step were re-evaluated by experts to ensure whether these questions have the necessary capability to measure the research objectives. For this purpose, to ensure the validity of the research tool, the initial questionnaire was distributed among experts such as psychiatrists, neurologists, and stock brokers. In this way, the content and face validity of the questionnaire was confirmed. Using Cronbach's alpha coefficient, the reliability of the questionnaire was determined as 0.841. Therefore, the reliability of the research tool is high.

The questionnaire had closed-ended questions scored using a five-point Likert scale. The five scales were: "strongly agree," "agree," "neutral," "disagree," or "strongly disagree." The final questionnaire included the following two parts: (1) respondents' Demographic information, which included three questions. (2) Questions related to research constructs, which included 47 questions. Questionnaires were distributed online and offline among the members of the statistical population.

Therefore, in the second step, to ensure the correctness of the first step process and to observe any possible changes, exploratory factor analysis was performed without any initial classification for the extracted factors from the first step.

In our study, the reliability of the measurement tool was measured using two indexes of composite reliability1 (CR) and average Variance extracted2 (AVE), the validity of the measurement tool was measured using two indexes: convergent validity and divergent validity. Besides, indices such as incremental fit (IFI), comparative fit (CFI), goodness of fit (GFI), and root mean square error of approximation (RMSEA) are used to test the model fit.

In data analysis, exploratory factor analysis (through SPSS software, version 26) and confirmatory factor analysis (through Amos software, version 24) were used. This means that first, through exploratory factor analysis, the primary constructs of the research were identified. Then, the significance of the relationship between the latent variables and the items was checked from the first-order confirmatory factor analysis. Then, using the second-order factor analysis, the identified latent variables were ranked based on their impact on forming the primary construct (neurotransmitters' effect on individual investors' behavior).

A normality test: Before the data analysis, assessing the normality of the data is necessary. Based on the central limit theorem, if the sample size is more than 200, the data is considered to have a normal distribution (Demir, 2022). Since the sample size of the present study is 315, the data are supposed to be expected.

Results

This section presents descriptive statistics first, then hypotheses are tested, and finally, the findings are analyzed.

[1]. Composite reliability (CR) measures internal consistency in scale items.

[2]. Average Variance Extracted (AVE) is commonly used to validate constructs.

Table 1. Demographic Description of the Survey Sample

Variable	Category	%	Variable	Category	%
Age	Under 25 years old	8.9	Degree of Education	High school diploma	9.5
	25 – 30 years old	23.2		Associate degree	10.2
	30-40 years old	40.6		Bachelor’s degree	39.7
	40-50 years old	15.9		Master’s degree	32.7
	Above 40 years old	11.4		Doctoral degree	7.9
Gender	Male	73.7			
	Female	26.3			

Table 1 shows that about 74% of the respondents were male and 26% female. Most respondents' age and education degrees were between 30 and 40 years old (40.6 percent) and bachelor's degrees (39.7 percent), respectively.

In the following paragraphs, the findings of the research are analyzed.

Exploratory factor analysis: Before the exploratory factor analysis, it is necessary to ensure the adequacy of the sample size and the adequacy of the correlation matrix (the Sphericity of the variables). For this purpose, Kaiser-Meyer-Olkin (KMO) and Bartlett tests were used. According to Table 3, the KMO value is more than 0.7 (i.e., 0.824). Therefore, the sample size is sufficient to perform exploratory factor analysis. Since the significance level of Bartlett's test is less than 0.05 (i.e., 0.000); Therefore, the data are correlated with each other, and as a result, it is possible to identify and define new factors based on the correlation between the variables. Therefore, factor analysis is suitable for identifying the underlying relationships between measured variables.

Table 2. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.824
Bartlett's Test of Sphericity	Approx. Chi-Square	7015.208
	df	1081
	Sig.	0.000

Table 3 shows the extraction communalities. The more significant the number of these types of commonalities, the more extracted factors can explain the variables adequately. The commonalities in Table 3 are all above 0.5. Therefore, the extracted components represent the variables well. However, there are differences between the community amounts. For example, the communality amount related to the fourth question equals 0.638, and the thirty-second question equals 0.681.

Table 3. Communalities

Q	Extraction	Q	Extraction	Q	Extraction	Q	Extraction
1	0.629	13	0.510	25	0.666	37	0.622
2	0.562	14	0.659	26	0.582	38	0.591
3	0.572	15	0.695	27	0.638	39	0.628
4	0.638	16	0.596	28	0.575	40	0.462
5	0.604	17	0.628	29	0.643	41	0.549
6	0.625	18	0.659	30	0.620	42	0.577
7	0.628	19	0.701	31	0.539	43	0.597
8	0.648	20	0.690	32	0.681	44	0.630
9	0.569	21	0526	33	0.632	45	0.622
10	0.606	22	0.545	34	0.585	46	0.599
11	0.690	23	0.621	35	0.674	47	0.701
12	0.598	24	0.718	36	0.589		

Note: Extraction Method is Principal Component Analysis. Initial Communalities of all items is equal to one.

According to Table 4, the final factor analysis led to the extraction of eight factors. These factors explain 61.539% of the total Variance. This means that eight components of adrenaline (epinephrine), noradrenaline (norepinephrine), dopamine, serotonin, GABA (gamma-aminobutyric add), acetylcholine, glutamate, and endorphins could explain about 61.5% of the changes in the behavior of individual investors. In this analysis, to simplify the interpretation of results, the data were rotated using the varimax method, the results of which are reflected in Table 4. This technique minimizes the number of variables with high loadings on each factor. Unlike the method without rotation, in which the first factor determines a higher percentage of changes (12.510 percent), in the rotation method, the contribution of the factors in explaining the changes is adjusted. Due to this feature, the varimax rotation can uniformly distribute the changes among the factors.

Table 4. Total Variance Explained

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% Of Variance	Cumulative %	Total	% Of Variance	Cumulative %
1	5.880	12.510	12.510	4.713	10.029	10.029
2	4.431	9.427	21.937	4.252	9.047	19.076
3	3.972	8.451	30.388	4.232	9.003	28.079
4	3.333	7.091	37.479	3.206	8.821	34.900
5	2.966	6.310	43.789	3.160	7.724	41.624
6	2.847	6.058	49.848	3.160	6.723	48.347
7	2.833	6.028	55.875	3.108	6.613	54.960

8	2.662	5.664	61.539	3.092	6.579	61.539

Tables 5 to 12 include the factor loadings of each variable and the estimated components. Factor loadings[1] Higher than 0.4 are considered to assign each item to one variable (Guadagnoli & Velicer, 1988). Cronbach's alpha coefficient of all components/variables is higher than 0.7 (Tables 5 to 12). Therefore, the reliability of the questions of each variable is at an optimal level (i.e., there is an acceptable internal consistency between them). In addition, Cronbach's alpha value of the entire questionnaire was calculated as 0.841, which shows that the reliability of the whole questionnaire is at a favorable level.

Table 5. Rotated Matrix of First Component [Glutamate (Memory)]

Q	Lodgings	α	Title of question
1	0.803	0.894	Inability to do things like choosing and organizing holidays
2	0.784		Inability to remember sequences of numbers such as a phone number
3	0.773		Not having the necessary concentration in simultaneous conversations with several people
4	0.765		Inability to remember the names of recently met people
5	0.756		Inability to remember newly read topics
6	0.751		Hesitation to receive the rest of the money during cash purchases
7	0.716		Inability to properly understand the user's guide of an electrical device
8	0.674		Inability to do things in noisy environments

Table 6. Rotated Matrix of second Component [Adrenaline or epinephrine (Fight or Flight)]

Q	Lodgings	α	Title of question
1	0.782	0.885	Feeling overcautious or hyper-vigilant most of the time
2	0.778		Feeling impatient at times
3	0.775		Emotional reaction to various issues, instead of thoughtfully responding
4	0.768		Having trouble getting a good night's sleep
5	0.762		Feeling frequent headaches at times
6	0.750		Feeling severe headaches at times
7	0.738		Feeling chronic physical pains at times

[1]. The factor loading is the correlation between the item and the factor. According to Stevens (1992), factor loading should be more than 0.40.

Table 7. Rotated Matrix of third component [Noradrenaline or Norepinephrine (Concentration)]

Q	Lodgings	α	Title of question
1	0.827	0.887	Feeling tired and run down most of the time
2	0.794		Not having enough motivation and energy to do tasks
3	0.787		Feeling exhausted after doing everything
4	0.770		Feeling tired when you wake up
5	0.763		Feeling tired so quickly in the afternoons and needing a short break
6	0.716		Inability to be conscious and concentrate most of the time
7	0.704		Feeling unable to do things in the morning

Table 8. Rotated Matrix of fourth component [Dopamine (Pleasure)]

Q	Lodgings	α	Title of question
1	0.824	0.850	The feeling of hopelessness at times
2	0.803		feeling of worthlessness at times
3	0.778		Inability to feel pleasure at times
4	0.763		Feeling depressed and not interested in life at times
5	0.749		Feeling tired after a long sleep

Table 9. Rotated Matrix of the fifth component [CABA (gamma-amino butyric add) (Calming)]

Q	Lodgings	α	Title of question
1	0.802	0.841	Feeling anxiety and depression at times
2	0.789		Feeling guilty and regretting some everyday decisions
3	0.773		Sensitivity to bright light, noise, and polluted environments
4	0.755		Feeling knots in your stomach at times
5	0.747		Inability to tolerate skip meals or go too long without eating

Table 10. Rotated Matrix of the sixth component [Serotonin (Mood)]

Q	Lodgings	α	Title of question
1	0.836	0.835	Being negative and seeing the glass as half-empty instead of half-full
2	0.822		Having mostly pessimistic and dark thoughts most of the time
3	0.773		Being worried and anxious most of the time
4	0.708		Feeling low self-esteem and low self-confidence most of the time
5	0.697		Bing is so structured and needs more flexibility at times.

Table 11. Rotated Matrix of the seventh component [Acetylcholine (Learning)]

Q	Lodgings	α	Title of question
1	0.814	0.837	Feeling problems with visual memory (shapes images)
2	0.786		Feeling problems with verbal memory
3	0.782		Feeling a lapse in memory
4	0.756		Feelings of difficulty with creativity
5	0.716		The feeling of experiencing a slower mental response

Table 12. Rotated Matrix of the eighth component [Endorphins (Euphoria)]

Q	Lodgings	α	Title of question
1	0.798	0.833	Being sensitive to different issues from one's own or others' point of view
2	0.789		Feeling emotional or physical pain at times
3	0.784		Feeling tear up or cry easily; For example, when watching a movie
4	0.748		Avoiding dealing with painful issues
5	0.717		Inability to get over losses or get through grieving

The data were summarized using the exploratory factor analysis method, and then the eight constructs (variables) were identified. Theoretically, latent variables (constructs) represent the underlying causes of the measured variables. This method can reduce many variables into a few meaningful ones. After this stage, it is time for confirmatory factor analysis1 (CFA). CFA verifies the factor structure of a set of observed variables.

First-order confirmatory factor analysis: To study neurotransmitters' effect on individual investors' behavior, the identified latent variables (exploratory factor analysis stage) were analyzed through confirmatory factor analysis. The results are reflected in Figure 1 and Tables 13 and 14. Considering that the factor loadings of all observed variables are higher than 0.5, the Variance between the constructs and related items is greater than the Variance of their measurement error. As a result, the reliability of the research model is acceptable (Figure 1).

The purpose of first-order confirmatory factor analysis is to measure the relationship between construct(s) (latent variables) and items (observable variables). Therefore, the relationship between latent variables needs to be studied using this method. As a result, this method only ensures the correct measurement of latent variables.

[1]. The primary goal of CFA is to confirm whether the data fits a hypothesized measurement model based on theory or prior research.

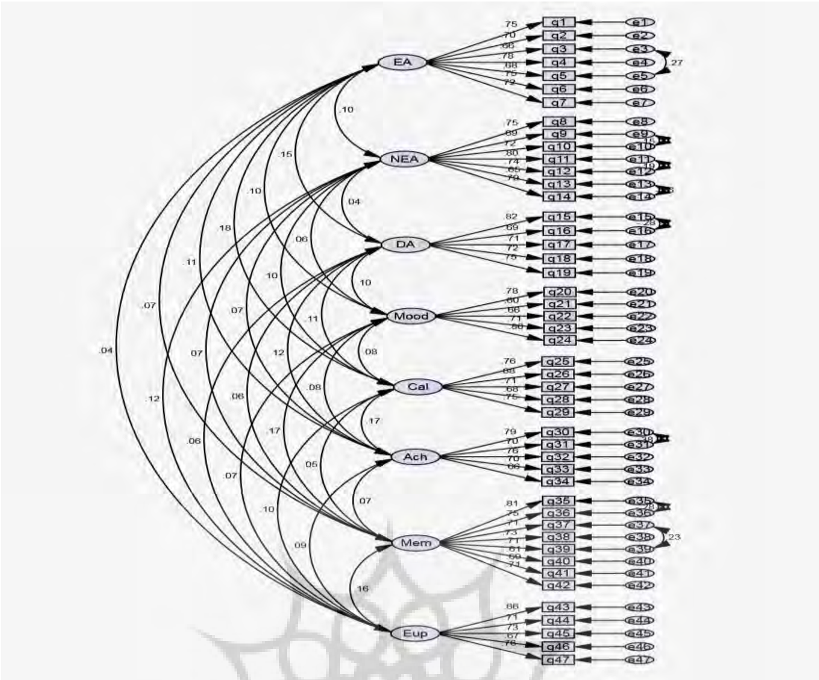

Figure 1. Fitted Measurement Model based on Standard Coefficients (CFA First Order)

In Figure 1, the big circles (octet) represent the latent variables, and the rectangles represent the items. The two-way arrows show the correlation between the latent variables. The one-way arrows drawn from the side of the big circles (octet) towards the rectangles indicate the factor load of each of the items. Besides, the numbers listed indicate the items' correlation coefficient with each of the related latent variables.

Table 13. Research variables and their symbols

Variable	Symbol	Variable	Symbol
Adrenaline	EA	CABA (gamma-amino butyric add)	Cal
Noradrenaline	NEA	Acetylcholine	Ach
Dopamine	DA	Glutamate	Mem
Serotonin	Mood	Endorphins	Eup

The reliability and validity test of the measurement instrument (questionnaire) is described in Table 14.

Table 14. Reliability and Validity of Model

	CR	AVE	MSV	ASV	EA	Mem	Eup	Ach	Cal	Mood	DA	NEA
EA	0.883	0.519	0.032	0.013	0.721							
Mem	0.894	0.514	0.028	0.011	0.068	0.717						
Eup	0.835	0.503	0.025	0.010	0.037	0.158	0.709					
Ach	0.846	0.524	0.030	0.011	0.108	0.070	0.090	0.724				
Cal	0.841	0.515	0.032	0.015	0.178	0.049	0.103	0.173	0.718			
Mood	0.838	0.511	0.028	0.010	0.103	0.167	.074	0.078	0.76	0.715		
DA	0.857	0.545	0.023	0.010	0.153	0.063	0.060	0.120	0.114	0.097	0.738	
NEA	0.892	0.542	0.014	0.007	0.100	0.071	0.118	0.073	0.096	0.058	0.043	0.736

Table 15. Minimum Requirements for Model Reliability and Validity

	Threshold Value
Reliability Condition	CR>0.7
Convergent Validity Condition	AVE>0.5 ، CR>AVE
Divergent Validity Condition	MSV < AVE ، ASV < AVE

Based on the results in Table 14, the obtained values are more than the threshold values (Table 15), so the research model has good reliability and validity. For example, all composite reliability (C.R.) values are higher than 0.7, or all average Variance extracted (AVE) values are higher than 0.5. Also, the maximum shared Variance (MSV) and average shared Variance (ASV) are smaller than the average Variance extracted.

The model fit test and the relevant indicators are shown in Table 16. The research model fits well if at least 3 to 4 of the calculated indicators are favorable. (Hair et al., 2010).

Table 16. Goodness of Fit with Different Indicators of Fitness

Indicator	$\frac{X^2}{df}$	RMSEA	GFI	CFI	NFI	IFI
Criterion	≤ 3	≤ 0.08	0.90 ≤	0.90 ≤	0.90 ≤	0.90 ≤
Calculated	1.372	0.034	0.849	0.941	0.815	0.942
Interpretation	good	good	acceptable	good	acceptable	good

Second-order confirmatory factor analysis: In this method, the relationship between the latent and observable variables and the relevant main structure is investigated. Figure 2 and Table 17 show the second-order confirmatory factor analysis results.

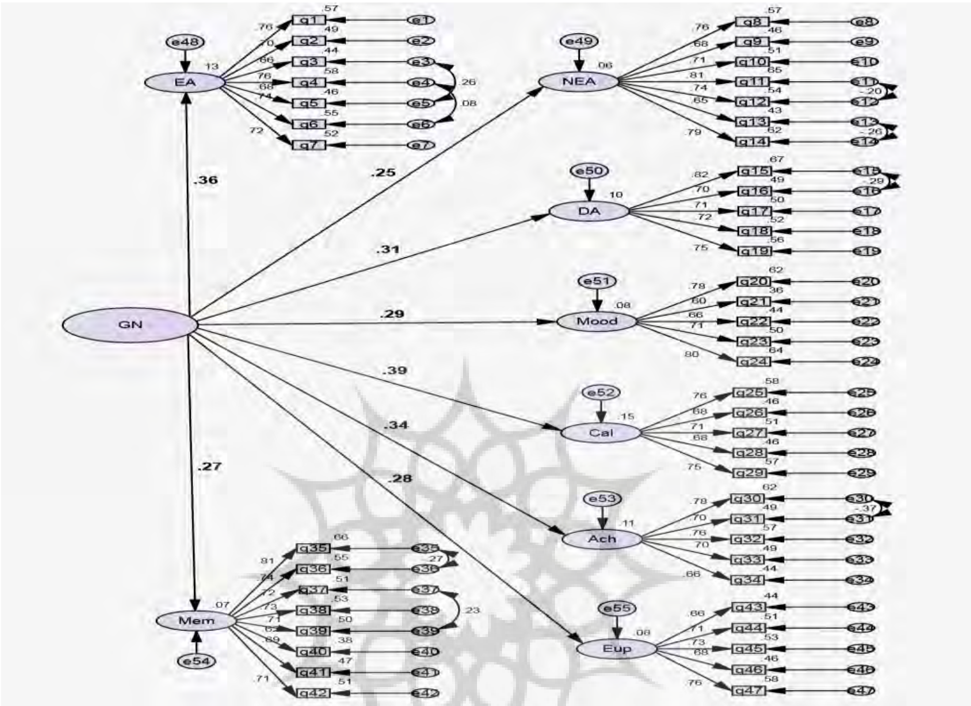

Figure 2. Fitted Measurement Model Based on Standard Coefficients (CFA Second Order)

Like the first-order factor analysis, all fitness indexes have achieved the required level. The results showed that neurotransmitters load well on its eight sub-constructs. The highest and lowest neurotransmitter factor loads are related to constructs Cal (0.39) and NEA (0.25).

Table 17. The Result of Second-Order CFA

	Relationship			B	Beta	C.R.	P
1	NEA	⟶	GN	0.092	0.245	2.651	0.008
2	DA	⟶	GN	0.126	0.311	2.263	0.001
3	Mood	⟶	GN	0.113	0.291	3.016	0.003
4	Cal	⟶	GN	0.149	0.387	3.852	0.000
5	Ach	⟶	GN	0.133	0.338	3.500	0.000
6	Eup	⟶	GN	0.090	0.277	2.835	0.005
7	EA	⟶	GN	0.135	0.357	2.659	0.000
8	Mem	⟶	GN	0.109	0.270	2.907	0.004

Table 17 shows that the effect of neurotransmitters (primary construct) on all sub-constructs is significant. Besides, the critical ratio (C.R.) calculated for all eight variables is more than 2.58; therefore, each of these variables contributes to the formation of the primary research construct of "The effect of neurotransmitters on the behavior of individual investors". In other words, the theory that the primary construct consists of eight subconstructs is well supported. Based on the standard coefficients (Beta), the order of influence of sub-constructs in the formation of the primary construct are as follows: CABA (gamma-amino butyric add), adrenaline, acetylcholine, dopamine, serotonin, endorphins, glutamate, and noradrenaline.

Discussion and Conclusion

In most neurofinance research, biological tools, which are mainly related to the area of medicine, have been used. For example, we can mention how neurotransmitters play a role in diet and measure the effect of neurotransmitters' unbalancing on health and medicine experiments (Khan & Mubarak, 2022). So far, few studies have been conducted regarding the different dimensions of neurofinance. Besides, there is little empirical evidence regarding exploratory and confirmatory factor analysis of neurotransmitter measurement scales despite their great importance in financial decisions. According to Njegovanović (2020), using the mind and behavioral sciences in financial decisions is essential. Because complex mathematical and econometrical models can never correctly predict economic phenomena without the intervention of agent-based modeling (i.e., the human brain), in this regard, it seems that neurofinance , as an essential and emerging field, is trying to connect brain processes to investment behavior. Neurotransmitters are chemical messengers that attempt to transmit signals from a neuron to other neurons, muscle cells, and gland cells through chemical synapses. In this study, eight neurotransmitter constructs identified in neuroscience were confirmed. These neurotransmitters include dopamine, serotonin, epinephrine, norepinephrine, gamma-aminobutyric add (GABA), acetylcholine, glutamate, and endorphin. These eight neurotransmitters are responsible for tension, attention, mood, claiming, learning, memory recall, and happiness (pain and positive sensations). These neurotransmitters influence the behavior of investors.

Therefore, when the predictions made by investors have profit and loss consequences, they can cause an increase or decrease in the level of these neurotransmitters. A change in the number of neurotransmitters causes situations such as herd behavior, overconfidence, anxiety, depression, appetite, weak memory, sleeping disorders, fight or flight behavior, and optimism. This type of behavior plays an essential role in financial decisions. For example, when investors are more depressed or overconfident, they may make inefficient decisions.

The aim of this study was exploratory and confirmatory factor analysis of neurotransmitter measurement scales. In this regard, different scales were identified and assessed. Also, the internal consistency of the measurement model was evaluated. This study tested 47 items related to eight neurotransmitters through exploratory and confirmatory factor analysis. In other words, the research aimed to discover and confirm the effects of eight neurotransmitters (adrenaline, noradrenaline, dopamine, serotonin, GABA, acetylcholine, glutamate, and endorphin) on the behavior of individual investors. The scales identified and confirmed in this study have the necessary validity for future studies. This study showed that the human mind is inconsistent with the concept of traditional economy. Therefore, the results can help investors and brokerage firms to make appropriate financial decisions by redefining rationality. For example, recognizing personal biases in reading and understanding financial statements and their background changes can make individual investors' expectations more reasonable. This means that the results of this research can help individual investors to make more informed investment decisions (for example, in small transactions) without over-relying on financial advisors.

The research findings can be used to understand and use better neurotransmitters in financial decisions. Also, this study can promote the neurotransmitters literature due to its exploratory and confirmatory nature. Finally, the identified scales for the eight dimensions of neurotransmitters may make people financial and investment decisions more rational.

Declaration of Conflicting Interests

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References

Ahmad, M. (2018). Construction and validation of neurotransmitters scale. *Global Social Sciences Review*, 3, 219–244.

Anderson, A., Dreber, A., & Vestman, R. (2015). Risk taking, behavioral biases and genes: Results from 149 active investors. *Journal of Behavioral and Experimental Finance*, 6, 93–100.

Blobe, G. C., Schiemann, W. P., & Lodish, H. F. (2000). Role of transforming growth factor β in human disease. *New England Journal of Medicine*, 342(18), 1350–1358.

Ceravolo, M. G., Cerroni, R., Farina, V., Fattobene, L., Leonelli, L., Mercuri, N. B., & Raggetti, G. (2019a). Attention allocation to financial information: The role of color and impulsivity personality trait. *Frontiers in Neuroscience*, 13, 818.

Ceravolo, M. G., Fabri, M., Fattobene, L., Polonara, G& ,. Raggetti, G. (2019b). Cash, card or smartphone: The neural correlates of payment methods. *Frontiers in Neuroscience*, 13, 1–9

Clark, L. A., & Watson, D. (1995). Constructing validity: Basic issues in objective scale development. *Psychological Assessment*, 7(3), 309–319.

Cohen, J. D. (2005). The vulcanization of the human brain: A neural perspective on interactions between cognition and emotion. *Journal of Economic Perspectives*, 19(4), 3–24.

Cohen, S., & Hamrick, N. (2003). Stable individual differences in physiological response to stressors: Implications for stress-elicited changes in immune-related health. *Brain, Behavior, and Immunity*, 17(6), 407–414.

Colbert (2012*). “Ianc dthis” idt: New edical breakthroughs that use the power of your brain and body chemistry to help you lose weight and keep it off for life*, New York Times. In The Seven Pillers of Health. Thomas Nelson, Inc. Publishers.

Coricelli, G., Dolan, R. J., & Sirigu, A. (2007). Brain, emotion and decision making: The paradigmatic example of regret. *Trends in Cognitive Sciences*, 11(6), 258–265.

Demir, S. (2022). Comparison of normality tests in terms of sample sizes under different skewness and kurtosis coefficients. *International Journal of Assessment Tools in Education*, 9(2), 397-409.

Dornelles, A., de Lima, M. N. M., Grazziotin, M., PrestiTorres, J., Garcia, V. A., Scalco, F. S., & Schröder, N. (2007). Adrenergic enhancement of consolidation of object recognition memory. *Neurobiology of Learning and Memory*, 88(1), 137–142.

Frydman, C. D. (2012). *Essays in neurofinance* (Doctoral dissertation, California Institute of Technology).

Guadagnoli, E., & Velicer, W. F. (1988). Relation of sample size to the stability of component patterns. *Psychological bulletin*, 103(2), 265.

Hair, J., Black, C., Babin, J. & Anderson, E. (2010). *Multivariate data analysis*. Prentice Hall Publisher, USA, p.816.

Jin, X., Chen, C., Zhou, X., & Yang, X. (2019). Stimulating the dorsolateral prefrontal cortex decreases the asset bubble: A tDCS study. *Frontiers in Psychology*, 10, 1031.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision making under risk. *Econometrica*, 47(2), 263.

Kenning, P., Mohr, P., Erk, S., Walter, H., & Plassmann, H. (2006). The role of fear in home-biased decision making: First insights from neuroeconomics. MPRA Paper.

Khan, A., & Mubarik, M. S. (2022). Measuring the role of neurotransmitters in investment decision: A proposed constructs. *International Journal of Finance & Economics*, 27(1), 258-274.

Kharrazian, D. (2013). Toxicant loss of immune tolerance, neurologic disease, and nutritional strategies. *Functional Neurology, Rehabilitation, and Ergonomics*, 3(2/3), 203.

Knutson, B., Wimmer, G. E., Kuhnen, C. M., & Winkielman, P. (2008). Nucleus accumbens activation mediates the influence of reward cues on financial risk taking. *NeuroReport*, 19(5), 509-513.

Krugel, L. K., Biele, G., Mohr, P. N., Li, S. C., & Heekeren, H. R. (2009). Genetic variation in dopaminergic neuro-modulation influences the ability to rapidly and flexibly adapt decisions. *Proceedings of the National Academy of Sciences*, 106(42), 17951–17956.

Kuhnen, C. M., & Knutson, B. (2005). The neural basis of financial risk-taking. Neuron, 47, 763–770.

Lo, A. W., Repin, D. V., & Steenbarger, B. N. (2005). Fear and greed in financial markets: A clinical study of day-traders. *Cognitive Neuroscientific Foundations of Behavior*, 95(2), 352–359.

Kuhnen, C. M., & Chiao, J. Y. (2009). Genetic determinants of financial risk taking. *PLoS One*, 4(2), 3–6.

Kuhnen, C. M., Samanez-Larkin, G. R., & Knutson, B. (2013). Serotonergic genotypes, neuroticism, and financial choices. *PLoS One*, 8(1), e54632

Markowitz, H. (1952). Portfolio selection. *Journal of Finance*, 7(1), 77–91.

Mccormick, M., Reyna, V. F., Ball, K., Katz, J., & Deshpande, G. (2009). Neural underpinnings of financial decision bias in older adults: Putative theoretical models and a way to reconcile them. *Frontiers in Neuroscience*, 13, 184.

Morse, G. (2006). Decisions and desire. Harvard Business Review, 84(1), 42–44.

Mubarik, M. S. (2017). The end of theory: Financial crises, the failure of economics and the sweep of human interaction. *Institutions and Economies*, 9(4), 113–115.

Njegovanović, A. (2020). Mind Theory and the Role of Financial Decision and Process Role of Optogenetics. *Financial Markets, Institutions and Risks*, 4(1), 40-50.

Roe, B. E., Tilley, M. R., Gu, H. H., Beversdorf, D. Q., Sadee, W., Haab, T. C., & Papp, A. C. (2009). Financial and psychological risk attitudes associated with two single nucleotide polymorphisms in the nicotine receptor (CHRNA4) gene. *PloS one*, 4(8), e6704.

Pennings, J.M.E., Scott, H.I., Good, D.L. (2002). Surveying farmers: a case study. *Review of Agricultural Economics*, 24(1), 266–277.

Peterson, R. L. (2007). Affect and financial decision-making: How neuroscience can inform market participants. *Journal of Behavioral Finance*, 8(2), 70–78.

Peterson, R. L. (2010). Neuroeconomics and neurofinance. In H. K. Baker & J. R. Nofsinger (Eds.), *Behavioral finance: Investors, corporations, and markets* (pp. 73–94). John Wiley & Sons, Inc.

Pompian, M. (2007). Behavioral finance and wealth management-How to build optimal portfolios that account for investor biases (p. 21). Springer: Financial Markets and Portfolio Management

Preuschoff, K., Bossaerts, P., & Quartz, S. R. (2006). Neural differentiation of expected reward and risk in human subcortical structures. *Neuron*, 51(3), 381–390.

Ross, J. G., & Burrell, S. A. (2019). Nursing students' attitudes toward research: An integrative review. *Nurse Education Today*, pp. 82, 79–87.

Sahi, S. K. (2012). Neurofinance and investment behavior. *Studies in Economics and Finance*, 29(4), 246–267.

Schriesheim, C. A., Powers, K. J., Scandura, T. A., Gardiner, C. C., & Lankau, M. J. (1993). Improving construct measurement in management research: Comments and a quantitative approach for assessing the theoretical content adequacy of paper-and-pencil survey-type instruments. *Journal of Management*, 19(2), 385–417.

Schultz, W. (2007). Behavioral dopamine signals. *Trends in neurosciences*, 30(5), 203–210.

Shiv, B., Loewenstein, G., Bechara, A., Damasio, H., & Damasio, A. R. (2005).

Investment behavior and the negative side of emotion. *Psychological Science*, 16(2), 435–439.

Srivastava, M., Sharma, G., & Srivastava, A. (2019). Human brain and financial behavior: A neurofinance perspective. *International Journal of Ethics and Systems*, 35(4), 485–503.

Stenstrom, E., & Saad, G. (2011). Testosterone, financial risk-taking, and pathological, testosterone, financial risk-taking, and pathological gambling. *Journal of Neuroscience, Psychology, and Economics*, 4(4), 254–266.

Stevens, J.P. (1992). *Applied multivariate statistics for the social sciences (2nd edition)*. Hillsdale, NJ:Erlbaum.

Tseng, K. C. (2006). Behavioral finance, bounded rationality, neurofinance, and traditional finance. *Investment Management and Financial Innovations*, 3(4), 7–18.

Tessler, D. M. S. (2009). The fight or flight of a kinase. Science Signaling, 2(66), 130.

Wu, C. C., Bossaerts, P., & Knutson, B. (2011). The affective impact of financial skewness on neural activity and choice. *PLoS One*, 6(2), e16838

Zhang, W., Yang, D., Jin, J., Diao, L., & Ma, Q. (2019). The neural basis of herding decisions in Enterprise clustering: An event-related potential study. *Frontiers in Neuroscience*, p. 13, 1175.

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