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FROM CORTEX TO CAPITAL: A BIBLIOMETRIC EXPLORATION OF NEUROFINANCE

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Abstract

Purpose: *This paper provides a comprehensive bibliometric overview of the new, emerging multidisciplinary field of Neurofinance, which covers cognitive and neurological mechanisms involved in the process of making financial decisions.*

Design/Methodology/Approach: *To extract the publication trends, keyword network, and to formulate thematic clusters, a bibliometric analysis of 157 Scopus-indexed publications (2000–2024) was conducted using Bibliometrix, VOSviewer, and SciMAT.*

Findings: *The findings revealed the role of significant biological structures on the change and impact in investors' behaviour, which include the Hippocampus, the Amygdala, the Prefrontal Cortex, and even chemicals such as Dopamine and Cortisol. Thematic mapping identified the key themes associated with trading, processes of cognitive functioning, emerging themes across Neuroeconomics and hormone regulation as well as important motor motifs for human-centred experimental mapping.*

Research Limitations/Implications*:As the study has relied only on Scopus-indexed and English-language publications, the forthcoming research may include cross-cultural samples and other multimodal neuroscientific dimensions.*

Originality/Value: *The study is one of the novel studies to provide an insight into the investor behaviour by developing a comprehensive mapping of Neurofinance research, thereby recommending a Neurofinance Emotional-Cognitive Model to explain investor behaviour.*

Keywords: *Bibliometric Analysis; Brain Regions; Decision Neuroscience; Dopamine; Dual-Process Theory; Emotional-Cognitive Model, fMRI, Investment Decisions.*

1. INTRODUCTION

Over the past few years, a new interdisciplinary discipline has emerged- Neurofinance, a discipline that attempts to understand the role that neurological processes play in financial decision-making (Lo & Repin, 2002; Camerer et al., 2005). In the past few decades, the theories of traditional finance with their underlying assumptions of rational choice and efficient markets have increasingly been called into question by empirical studies that suggest that emotion, cognitive biases and neurological patterns have a major impact on investor behaviour (Kahneman & Tversky, 1979; Thaler, 2000).

Understanding the neural underpinnings of decision-making has become even more critical as world financial systems become more complex and volatile. Neurofinance is the exploration of brain anatomy, hormones, and physiological responses affecting financial decisions, from investing in a volatile market to how the brain responds when stressed (Sapienza, Zingales, & Maestripieri, 2009).

Technologies such as fMRI and EEG are uncovering the Amygdala, Prefrontal Cortex and Dopaminergic systems' response to market stimuli (Knutson et al., 2005; Lo, 2011).

Research on the given discipline is extremely fragmented and developing, thus, a thorough bibliometric study is needed to develop a research landscape overview. This study provides a structured view of the intersection of 'biology meets behaviour' in the field of financial decisions by exploring relevant subjects, citing trends, co-occurrence graphs and research clusters of Neurofinance.

At the center of this research is the Prefrontal Cortex (PFC), Ventromedial PFC (vmPFC) and Dorsolateral PFC (DLPFC). These areas are related to executive functions such as planning, regulating impulses, calculating risks and optimizing long-term reward (Bechara et al., 1999; Fuster, 2008). In these areas economic decisions are made very important because they help to prevent instantaneous responses and encourage rational profits.

Neuroimaging studies show that the activity in the DLPFC is correlated with calculated risk-taking in investment tasks that involve either uncertainty about the probability of the investment or delay of consequences (Knoch et al., 2006; Paulus, 2007). The vmPFC, however, has a more internal role functioning as a biological integration between the emotional value signals and logical predictiveness (Rangel, Camerer, & Montague, 2008).

In times of turbulent conditions, the intentions that involve the brain's ability to "read" the situation and its handling can be beaten back by the limbic system, the subcortical way for emotions, recollections, and arousal to assume control. In a market crash, processing fear and loss aversion or risk detection, by the Amygdala, which is an important structure that is at work in this system, may lead to panic selling or herd behaviour (Wright et al., 2003; Shiv et al., 2005). Studies have also shown that investment decisions are made more conservatively and that there is increased sensitivity to financial losses with greater activation in the Amygdala region (Kuhnen & Knutson, 2005).

The Hippocampus is also involved in the investor's behavior and its function, the formation and remembrance of financial memories. When dealing with risky market situations, investors will often turn to their past experiences, which are housed in the Hippocampus. This might result in irrational or pattern-based forecasts (Shohamy & Adcock, 2010).

The hypothalamus, which regulates the body's response to stress, affects risk perception and tolerance through its control of the hormone Cortisol. Acute stress results in an increase in Cortisol which often increases avarice and subsequently disturbs the information processing system (Coates & Herbert, 2008). Under such circumstances, there can be continuous activation of the brain's limbic system, which can affect judgment and lead to unpredictable or impulsive spending, such as shopping and gambling (Peters et al., 2011).

Neurofinance is an examination of prefrontal rationality, limbic emotionality and neurochemical dynamics, investigating how these are interrelated systems in terms of a biopsychological understanding of the actual investor's behaviour. Neurological constraints and evolutionary forces that shape our financial life are hard to describe in a traditional economic model that assumes an agent who maximizes her utility and is rational (Kahneman, 2011; Lo, 2011).

To detect relevant trends, clusters and gaps within the literature, this study implements a bibliometric approach to explore the intellectual structure and development of Neurofinance studies. In this context, our purpose is to lay out a theory-based, physiology-grounded model of investor behavior that enrols the economic, emotional and brain response.

In addition to providing an overview of the development of Neurofinance, this study provides a conceptual framework that brings together the various disciplines of decision science, behavioural finance and neuroscience. This study complements a more comprehensive Physiological compile of investor's uncertainty absorption, risk appraisal and financial choices, with bibliometric data and theories from the Neurosciences domain. The structured lens of the proposed Neurofinance Emotional-Cognitive Model can be used in future empirical research to investigate the functional relationship among limbic activity, hormonal system modulation and executive functioning of the brain when confronted with financial situations. The study highlights some methodological and theoretical limitations, including cross-cultural validation and overreliance on homogeneity in the samples studied, as well as difficulties in applying multimodal neurophysiology techniques (e.g., EEG + fMRI).

This book contributes to the theories in behavioural finance and cognitive sciences by presenting the theory that investors make decisions that are not only rational but also embedded in the biological, emotional and cognitive systems, shaped by experience and evolution.

2. REVIEW OF LITERATURE

In the early 2000s, behavioural finance was born and researchers started using techniques derived from neuroscience in economic studies, thus giving the appearance of the "official" beginning of Neurofinance. Lo and Repin (2002) found significant physiological basis and psychogenic factors involved in the financial decisions, which was one of first studies to obtain such data from traders.

The Prefrontal Cortex has been connected to executional functions and long-term planning, in clinical terms particularly important for the assessment of risk and their portfolio management. Risk aversion, fear and reward anticipation are associated with emotion-related brain regions (Insula, Amygdala) in the meantime (Kuhnen & Knutson, 2005). Additional studies show that there is a strong effect of hormones on risk-taking, particularly of Cortisol and Testosterone. Excessive Cortisol has been linked to a lack of risk taking in the volatile markets, while high levels of Testosterone have been linked to overconfidence on traders, in the case of the markets (Coates & Herbert, 2008).

Advances in fMRI and electroencephalography (EEG) have made it possible for researchers to study decision-making in real time. Research indicates that patterns of EEG activity can forecast an individual's investment decisions, especially when the stakes are high (Peterson, 2007; Camerer & Yoon, 2015). Using fMRI to monitor the brain activity of retail investors while they evaluated actual stocks, Webb et al. (2024) demonstrated recent advances in Neurofinance by positing that, even after controlling for traditional financial indicators, activation in the striatum and nucleus accumbens accurately predicted future stock outperformance. This innovative study demonstrated the predictive ability of reward-system stimulation in actual trading decisions by combining neural predictors with market returns. To examine the impact of neurotransmitters on investment behaviour, Babu et al. carried out a comprehensive synthesis of EEG, fMRI, and biomarker analyses in 2021. They also analysed cross-sectional surveys using PLS-SEM. They discovered that Dopamine and adrenaline regularly alter risk preferences, providing a strong neurochemical explanation for a sizable portion of investor choice diversity. An Activation Likelihood Estimation (ALE) meta-analysis of sixteen fMRI investigations from 2005 to 2018 was previously carried out by Miendlarzewska, Kometer, and Preuschoff (2019). Their findings supported a shared brain network in charge of value processing and risk assessment across studies by confirming that the vmPFC, dlPFC, insula, anterior cingulate cortex (ACC), and striatum were frequently engaged during investing decisions.

In a previous seminal study by Knutson and Kuhnen (2005), subjects were given a series of financial decisions to make involving both safe and risky financial choices in an fMRI experiment. The study revealed a brain mapping of conflicting impulses during the process of making financial decisions: Risk-taking was related to activity in the nucleus accumbens in the predecisional phase, while activity in the insula was associated with risk aversion. In support, Yu and Zhou (2009) studied the error related negativity (ERN) in an investment task using EEG. They found that the amplitudes of ERN evoked by the ACC indicated the level of financial conflict for incurring the risk, and thus the early stages of neural monitoring for uncertain decision making. The story these studies tell is a powerful one: neurotransmitters drive individual risk appetites; remarkably consistent brain networks drive uncertainty and valuation; reward anticipation mechanisms in the striatum underlie professional trading; and fast error-detection mechanisms in the brain watch for new financial conflicts.

Neuroeconomics is a sister field of Neurofinance, and provides tools to analyze choice architecture, reward systems, and utility (Glimcher & Rustichini, 2004). However, neuromarketing and Neurofinance often overlap and are largely relevant to the understanding of consumer perceptions and choices of financial products.

3. RESEARCH OBJECTIVES AND HYPOTHESES

With an emphasis on how biological, neurological, and psychological processes affect financial decision-making, this study attempts to perform a thorough bibliometric assessment of the multidisciplinary subject of Neurofinance. From the inception to the present, the study aims to map the intellectual structure, pinpoint topic evolution, and identify important research clusters in the Neurofinance literature. To reveal the scientific landscape, identify prominent theoretical approaches, and uncover gaps that require more research, this study blends bibliometric methodologies and draws on neurobiological constructs such as limbic system activity, Prefrontal Cortex regulation, and neurochemical signalling.

The objectives of the study are as follows:

1. To map keyword co-occurrence networks and strategy diagrams to identify new, foundational, motor, and declining topics, thereby investigating the thematic evolution of Neurofinance research over time.
2. To evaluate the core biological concepts discussed in the literature and their relevance to investing behaviour, including brain regions (such as the Prefrontal Cortex and Amygdala), neurochemical agents (such as Dopamine and Cortisol), and cognitive-emotional processes.
3. To develop a conceptual framework for dual-process theory-based neurobiological decision-making in finance, enhanced by neuroscientific data.
4. To identify methodological and theoretical shortcomings in Neurofinance literature that hinder its full integration into behavioural economics and finance.

The following theories are put forth for empirical validation using bibliometric and content analysis methods considering the multidisciplinary character of Neurofinance and the clustering patterns seen in keyword and citation networks:

H1 (Thematic Evolution Hypothesis): By identifying unique thematic categories in the Neurofinance literature, such as well-established motor themes (like decision neuroscience), fundamental but undeveloped fields (like hormonal modulation), and new subjects (like machine learning applications in Neurofinance), the keyword co-occurrence network and strategic diagram analysis will show a dynamic thematic evolution over time.

H2 (Biological Relevance Hypothesis): Important behavioural constructs like risk preference, loss aversion, and decision uncertainty are positively connected with core biological constructs, especially activity in the Prefrontal Cortex and Amygdala, as well as neurochemical agents like Dopamine and Cortisol, which are highly represented in high-impact Neurofinance studies.

H3 (Conceptual Integration Hypothesis): The body of research backs up the creation of an integrated conceptual framework that blends dual-process theory with neurobiological data, showing that during investment decisions, distinguishable neural circuits and hormonal reactions influence the interplay between automatic emotional reactions (System 1) and rational executive control (System 2).

H4 (Methodological Gap Hypothesis): The full integration of Neurofinance into mainstream behavioural finance theory is hampered by a number of methodological and theoretical fragmentations, such as an excessive reliance on single-modality data (e.g., fMRI-only studies), a lack of longitudinal designs, and a limited integration of cross-disciplinary models, which are revealed by bibliometric and content analysis of the Neurofinance literature.

4. RESEARCH METHODOLOGY AND PARADIGM

This study employs bibliometric analysis and a quantitative, exploratory research design to investigate the thematic and intellectual development of the Neurofinance discipline. Based on positivist epistemology and scientific realism, the study measures trends in published literature to draw conclusions regarding scholarly influence and theoretical advancement (Donthu et al., 2021).

4.1. Data Source and Retrieval Strategy:

Since the Scopus database covers a wide range of high-impact, peer-reviewed literature in the fields of finance, psychology, neuroscience, and economics, it was chosen as the main source. Terms including "Neurofinance," "financial decision-making," "Neuroeconomics," "investment behaviour," "EEG," "fMRI," "Amygdala," "Dopamine," and "cognitive bias" were used in a structured keyword search.

Database: Scopus

Time Frame: 2000–2024

Document Types: Articles, conference papers, reviews

Language: English

The study was conducted in four stages: The first two stages aimed at selection of literature, the third stage consisted of development of domain visualization and analyzing associated scientometric networks and final stage was conclusion of objective, advancing emerging research areas. Records that were not neurologically or financially-oriented were excluded as well as duplicates and records in languages other than English. After refinement, 157 articles were selected for the study.

We used three special tools in the bibliometric analysis, which were selected for their capability in conducting specific research work as described below:

The Bibliometrix R Package (Aria & Cuccurullo, 2017) was used for the performance analysis, descriptive statistics and data preprocessing. All of these productivity measures, author impact (h-index) and publishing patterns over time were extracted. Further, the output files from Scopus can be converted to an analytical format by Bibliometrix, which was useful for further processing.

VOS viewer (van Eck & Waltman, 2010) was used to create the co-occurrence network visualisation used in the analysis. Normalized association strength and co-word frequency was used to create the visual map, with associated keyword nodes interlinked. The terms "decision making", "emotion" and "financial markets" are good examples of how keywords were clustered into coloured theme groups, based on their semantic proximity, using the layout algorithm of VOSviewer.

The strategic diagram (density versus centrality) was created using SciMAT (Cobo et al., 2012) that classifies themes into four groups: motor themes, basic themes, niche themes, and emerging or declining topics. This 2D mapping illustrated the maturity and applicability of the subtopics of Neurofinance and identified this as an emerging theme (motor theme) in addition to the theme that was already established as a subtopic (human theme).

These methods enabled a comprehensive and multidimensional analysis of the Neurofinance research field, revealing the theme dynamics and disunity of the field as well as its intellectual structure.

4.3. Analytical Technique:

To achieve the aim of this study, a multi-layered bibliometric analysis of the same research was performed, along with performance assessment, network based keyword analysis and the tracking of the thematic evolution of the research. The first step was to perform a bibliometric analysis on the most cited and highest-publishing authors, journals, institutions and publications in the Neurofinance literature to get an idea about the research output and impact of the field. This facilitated the identification of major channels of knowledge dissemination as well as key leadership, a structural base of the discipline. Then, the semantic and conceptual connections among the frequently used keywords were explored in a co-word analysis. It enabled the development of sets of words, corresponding to certain themes, resulting from the analysis of the thematic affinity of these words, and was inspired by the principles of co-occurrence frequency and normalised association strength (Callon, Courtial & Laville, 1991).

The resulting co-occurrence network visualisation was generated using VOSviewer which enabled an accurate mapping of the knowledge structure and demonstrated how financial psychology and economic and biological constructs appear in the literature.Additionally, a thematic mapping process was used with SciMAT to produce a strategic diagram based on two fundamental parameters: density, which depicts the internal growth and coherence of a thematic cluster, and centrality, which gauges the degree of external connectivity or relevance of a theme within the global network.

Using this method, the themes that emerged were divided into four different quadrants: Several themes demonstrated both profound importance and development, such as "human," "male," and "article"; Emerging or Declining Themes: "Neurofinance" and "Neuroeconomics" showed low density and centrality, indicating either a nascent or diminishing scholarly focus; Basic Themes: "brain," "commerce," and "decision makings" are central but relatively underdeveloped; Niche Themes: "EEG," "emotion," and "decision making" are internally specialized but less integrated into the larger discourse. Lastly, to monitor the theme clusters' alteration and temporal progression over several time slices, a thematic evolution analysis was carried out.

The table below summarises the research design and paradigm adopted for the study:

Component	**Specification**
Research Type	Quantitative, bibliometric
Design	Exploratory–descriptive
Data Source	Scopus
Software Tools	Bibliometrix (R), VOS viewer, SciMAT
Unit of Analysis	Peer-reviewed scholarly articles
Period Covered	2000–2024
Sampling	Purposive, keyword-based
Data Processing	Co-word analysis, clustering, strategic mapping

Table 1: Research Design Framework (Author's Own Compilation)

5. RESULTS AND CONCLUSION

The result and conclusion of the study have been thoroughly discussed in the following section:

5.1 Thematic Structure:

This is a basic schematic of the framework of Neurofinance research as depicted in the strategic diagram. The methodological anchoring with human subject experiments was expressed by the motor theme cluster "Human", "Male" and "Article" which have high centrality score and density. These were the specialized issues with high development and low related inter-disciplinary connectedness defined as "decision making", "emotion" and "EEG". On the other hand, the themes of 'brain', 'commerce' and 'decision making' were all present and yet had the impression that they were somehow undeveloped and/or fundamental; that is, fundamental subjects requiring deeper scholarly study. Density and centrality were both determined to be low; the “Neurofinance” and “Neuroeconomics” were identified as emerging themes, which are still being developed but in more fragmented ways

(Figure 1).Co-occurrence Network Insights:
Three prominent clusters were identified by the keyword network:

Red cluster: "Decision making," "financial markets," and "Neurofinance," all of which are related to issues of real-world application.

The "Emotion," "EEG," and "physiology" green clusters represent the biological underpinnings of investor behaviour.

The blue clusters "human," "male," and "experiment" denote methodological pillars and demographic emphasis in empirical research.

This pattern is consistent with research by Kuhnen and Knutson (2005) and Lo and Repin (2002), which shows the convergence of investment physiology and decision neurobiology (Figure 2).

5.2 Productivity Trends:

A literature analysis of the Neurofinance field, which was carried out by its productivity, reveals a small number of founding academics with a significant amount of work in the literature. Some of the most cited writers include Andrew W. Lo, Colin F. Camerer and John M. Coates, who have made a multidisciplinary impact on the theoretical and empirical trajectory of the field. Camerer's research has brought together behavioural economics and Neuroeconomics as a way of looking at the valuation process and choice under risk using neuroimaging; Lo's pioneering work led to the development of adaptive market hypotheses and the introduction of physiological measures into market analysis (Lo & Repin, 2002). Coates, however, from a different perspective, provided an innovative perspective from the trading floors of professionals, using hormonal tests to correlate levels of testosterone and Cortisol with trading performance and market volatility (Coates & Herbert, 2008). A study of the trends in publications over time reveals two areas of major academic production.

The first important wave occurred from 2010-2015, when the use of functional magnetic resonance imaging (fMRI) and the field of Neuroeconomics was growing. This stage marked more than just a shift from theory to data because empirical studies with neuroimaging, electroencephalography (EEG), and psychophysiological assessment instruments became more common. Following 2020, there is another increase in the number of publications, likely attributable to new advances in neuroimaging technology, as well as to a renewed interest in the neurological mechanisms underlying the decision-making process under times of economic instability such as the Covid-19 pandemic and its aftermath.

Several important publications have become the primary publication platforms for Neurofinance research in terms of scholarly dissemination. Among these are the Journal of Neuroscience, which frequently publishes neuroscientific research on valuation and decision-making; Neuroeconomics, a specialized publication that focuses on the neural underpinnings of economic behaviour; and the Journal of Behavioural Finance, which has emerged as a vital link between behavioural science and financial economics. Given the prominence and influence of these journals, it appears that Neurofinance is still a very interdisciplinary field that sits at the intersection of behavioural economics, psychology, neuroscience, and finance.

This bibliometric analysis confirmed that Neurofinance is a rapidly developing yet theoretically fragmented topic by methodically mapping its intellectual terrain. The frequent use of ideas like Dopamine signalling, prefrontal decision control, and emotional modulation through the Amygdala and Cortisol demonstrates how neuroscience and finance are intertwined. The strategy map, however, highlights a lack of coherence in the development of underlying topics, with important concepts like Neuroeconomics and hormone regulation remaining little understood. The co-occurrence network emphasizes the overrepresentation of specific demographic features (such as "male" and "human") in experimental investigations, but it also supports the increasing multidisciplinary convergence.

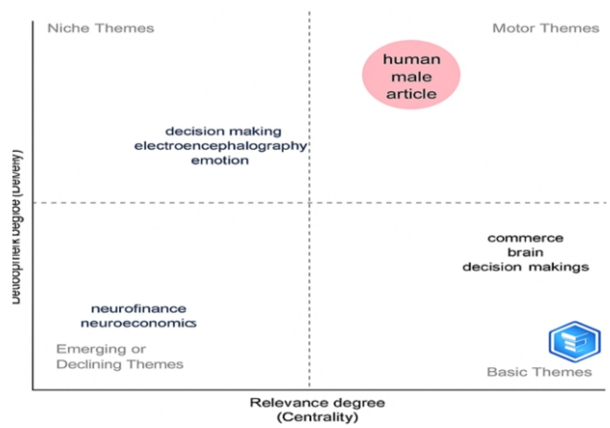

Figure 1: Figure showing Neurofinance themes (Authors' Own Compilation)

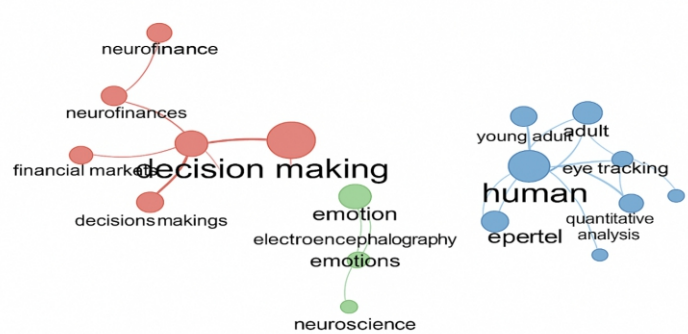

Figure 2: Figure showing Co-Occurance Network Insights (Authors' Own Compilation)

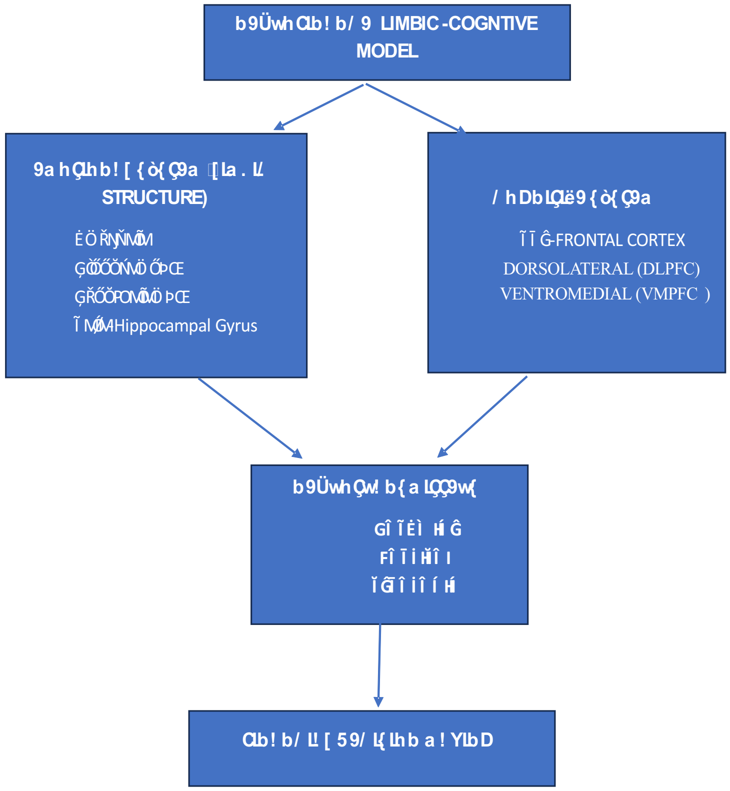

Figure 3: Neurofinance Limbic-Cognitive Model (Authors' Research Model)

Through a thorough bibliometric examination of the Neurofinance literature, this study aimed to investigate the relationship between neurology and financial decision-making. This study provides an integrative perspective on how biological mechanisms impact investment behaviour and how the field of Neurofinance has changed over the past 20 years by methodically analysing patterns in scholarly output, thematic clusters and conceptual linkages acrosspublications.

Using VOS viewer and SciMAT, the first goal—mapping strategic diagrams and keyword co-occurrence networks—was effectively accomplished. The strategic diagram divided the topic concentrations into four categories: Emerging Themes ("Neurofinance", "Neuroeconomics"), Niche Themes ("electroencephalography", "emotion", "decision making"), Basic Themes ("commerce", "brain", "decision makings"), and Motor Themes (e.g., "human", "male", "article"). This thematic taxonomy reflects a maturing but still unevenly developed research landscape (Cobo et al., 2012; van Eck & Waltman, 2010).

The second objective was to assess fundamental biological ideas that were present in the literature. The findings support the importance of limbic structures, especially the Hippocampus and Amygdala, in encoding emotional reactivity and memory during financial decision-making (Kuhnen & Knutson, 2005; Shiv et al., 2005), as well as the Prefrontal Cortex's pivotal role in cognitive regulation and strategic control (Bechara et al., 1999; Fuster, 2008). Additionally, it has been frequently shown that neurochemical mediators of reward sensitivity and stress-related risk aversion include Dopamine and Cortisol (Coates & Herbert, 2008; Frydman et al., 2014).

Based on dual-process theory, this work developed and illustrated a unique Neurofinance Emotional-Cognitive Model in accordance with the third goal (Evans, 2008; Kahneman, 2011). Through neurological substrates, this concept outlines the interactions between System 1 (slow, deliberative) and System 2 (fast, emotive) activities. The concept creates a dynamic system that controls investment decisions by combining prefrontal executive oversight with limbic-driven emotional inputs that are controlled by neurotransmitters like Dopamine. The model offers a single lens through which to evaluate actual financial behaviours by fusing behavioural finance theory with neuroscientific accuracy.

Identifying theoretical and methodological gaps, the fourth and final goal, showed a great deal of fragmentation in the literature. The bibliometric density and thematic placement of "Neurofinance" and "Neuroeconomics" in the strategic map imply that these fields are still immature and, on the periphery, even though the co-occurrence network identifies intriguing interdisciplinary linkages. Furthermore, the "human-male-article" cluster's preponderance of male, Western subject samples indicate a methodological homogeneity that restricts the generalizability of current findings (Bossaerts, 2009; Sapienza et al., 2009).

The field's evolutionary trend is further shown by this study, which shows that output peaked between 2010 and 2015 and then increased beyond 2020, due to developments in neuroimaging and growing interest in making decisions in the face of uncertainty. According to citations and influence, leading academics like Lo (2002), Camerer (2005), and Coates (2008) continue to be at the vanguard, indicating a comparatively focused intellectual core within an otherwise diverse area.

To sum up, this study can make a conceptual contribution by proposing a model to bridge the emotional-cognitive gap in the psyche of investors, as well as through a comprehensive bibliometric analysis of Neurofinance. Future studies should seek to build on the promise of the study by introducing more diverse methodologies, cross-validating with other ethnic groups, and multi-modal datasets (electroencephalograms, functional MRI and hormone assays).

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