



## NEUROANATOMY OF ENTREPRENEURSHIP AND BIBLIOMETRIC ANALYSIS OF STUDIES WITH VOSVIEWER

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**Abstract:** Entrepreneurship has been at the focus of many scientists doing research in the field of social sciences. Studies have focused on entrepreneurial intention, entrepreneurial disposition and entrepreneurial behavior. Generally, empirical methods have been used in studies, but the neurophysiological, neuropsychological and psychoneuroendocrinological reasons behind the individual's entrepreneurship have been neglected. In short, genetic factors, hormones, behavioral genetic factors related to the individual's being an entrepreneur were not taken into account in the studies. However, with the use and development of neuroscience methods, tools and approaches in different fields, the opportunities offered by neuroscience in research on entrepreneurship in the field of Social Sciences have recently begun to be utilized. This has facilitated the neuroanatomical examination of entrepreneurial individuals. Entrepreneurship research focuses on the individual's family, environmental, social and educational interactions. In order for entrepreneurship to be understood in a multidimensional way, it is necessary to consider human behavior in terms of genetic transfers, hormones, behavioral genetics and the interactions of these factors with each other. For this reason, studies on the concepts of "entrepreneurship and neuroscience", "entrepreneurship and genetics", "entrepreneurship and biology" and "neuroentrepreneurship" gain importance. The aim of this study is to provide information about the neuroscience methods, tools and approaches used in entrepreneurship research, to make a detailed bibliometric analysis of the researches, to identify the trends and gaps related to the mentioned concepts and to bring them to the attention of researchers and to make suggestions about what should be done in future studies. Since a better understanding of entrepreneurial thought, intention and behavior will contribute to the development of entrepreneurship, mapping the studies in the literature in terms of the neuroanatomy of entrepreneurship and analyzing them within the scope of quantitative data makes the study unique. The study consists of five parts. In the first part of the study, studies carried out for a better understanding of entrepreneurship in terms of neurophysiology, hormones and genetics are given by making use of neuroscience methods, tools and approaches in the literature. In the second part, neuroscience tools, methods and approaches used in entrepreneurship research are explained. In the third part, the method of the research and in the fourth part, the bibliometric analysis findings are given. In the last part, the discussion and conclusion, the deficiencies identified in the field and recommendations for future studies are made. As the analysis unit, bibliometric data of different types of papers scanned in the Web of Science (WoS) database and published between 2006 and 2023 was taken as a basis. As a result of the research, 379 publications related to the words "entrepreneurship" and "neuroscience" were identified and the most studied 260 of them were neuroscience, neurology, 53 business economics and 47 mathematical computational biology. 346 publications on "entrepreneurship" and "genetics" have been identified and the most studied 146 of them are genetic inheritance, 44 are biochemistry, molecular biology and 35 are business economics. 183 publications on "entrepreneurship" and "biology" were found, 58 of which were studied the most, multidisciplinary sciences, 55 related to genetic inheritance and 44 of them related to business. Within the scope of the study, only 9 publications related to "neuroentrepreneurship", which are directly related to entrepreneurship and neuroscience, were identified in the Web of Science (WoS) database. In the last part, discussion and conclusion, what needs to be done in entrepreneurship research and suggestions are presented.

**Keywords:** Entrepreneurship and neuroscience, Entrepreneurship and genetics, Entrepreneurship and biology, Neuroentrepreneurship

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### 1. Introduction

Thoughts, movements, feelings and emotions arise in response to chemical and electrical signals triggered by the brain and then transmitted to organs or produced in response to peripheral events (for example, pain after a wound). Psychophysiology studies the physiological activation that occurs by manipulating psychological variables in experimental settings. It is aimed to reach the underlying causes of behavior by observing the

interactions between physiological changes and psychological processes. For example; it is possible to determine the relationship between certain behaviors (such as risk seeking, risk aversion, emotional responses to certain stimuli) and somatic indices (heart rate, blood pressure or brain activity). Psychophysiology studies phenomena such as emotions, stress, decision making, and cognitive processes. By combining psychophysiological approaches, scientists have



developed various approaches to how emotions can be measured. For example; Psychophysiology offers researchers a deep perspective in cases such as examining the relationship between entrepreneurship and success, evaluating the implicit (unconscious) reactions to certain situations such as failure, changes in the brain when the entrepreneurial decision is made, predicting certain behaviors such as entrepreneurial intention.

Human psychophysiology has been widely studied, and there are now numerous tools available to scientists to explore the relationships between cognitive, psychological, emotional events and the resulting bodily responses. Since psychophysiology studies the activity of both the central nervous system (brain) and the peripheral nervous system (organs and glands), it has developed common approaches to the functions of the brain (central system) and common approaches to the discovery of bodily responses as a result of behavior (peripheral system). Thanks to neuroscience methods, tools and approaches, significant gains have been achieved in entrepreneurship research. Neuroscience provides important insights into understanding the reasons behind entrepreneurial emotion, thought, intention, and behavior. For example; "Quantitative genetics" and "molecular genetics" methods used to reveal the relationship between genetics and entrepreneurship have been used in important studies in this field. To show separately the effects of genes and environmental factors in entrepreneurial behavior, twins and adoptees were included in quantitative genetic studies. Molecular genetics, on the other hand, is based on the use of certain variants together for the detection of the gene that causes the individual to become entrepreneurs.

Some studies in the literature have shown that the genetic makeup of the individual affects the tendency to be entrepreneurial. Nicolaou et al. (2011) found that there may be a gene associated with entrepreneurship in the dopamine receptor in their study, which they hypothesized to have an entrepreneurial gene in individuals. However, molecular genetic research has been used less frequently due to its limitations. In studies on individuals' willingness to start their own businesses (Nicolaou et al., 2008; Zhang et al., 2009), genetic factors accounted for 48% of the variance of being self-employed, 40% of the variance in starting a new business, and 43% of the variance in the process of establishing a company. (Lindquist et al., 2015; Zunino, 2016; Nofal et al., 2018). Other studies in the field have examined the influence of genes on other entrepreneurial outcomes, such as opportunity recognition and entrepreneurial intentions. For example; Evidence was obtained that genetics contributed 45% of the variance in recognizing opportunities (Shane and Nicolaou, 2015b) and 42% of the variance in entrepreneurial intentions (Nicolaou and Shane, 2010).

Some of the important findings in entrepreneurship

research have been obtained from hormone studies. Key findings include that testosterone affects people's tendency to be self-employed (White et al., 2007; Greene et al., 2014). The relationship between the effect of testosterone on risk taking, which is an indicator of entrepreneurial behavior, and individuals' willingness to start their own business has been examined (White et al., 2007; Bönte et al., 2016). Nicolaou et al., (2018) conducted twin experiments on men and women to show that testosterone highly affects an individual's tendency to be entrepreneurial. As a result of the study, it was concluded that high testosterone level increased the entrepreneurial tendency. Unger et al. (2015) examined the relationship between entrepreneurs operating in more than one different field and the need for success and testosterone hormone, and a significant relationship was found between them. In other studies, it has been determined that there is a certain relationship between the stress hormones "cortisol" and epinephrine and the tendency to be entrepreneurial (Wolfe and Patel, 2017). It appears that individuals with high epinephrine levels are more likely to make risky decisions when their cortisol levels are low.

Studies conducted with neuroscientific methods and tools have revealed the necessity of further research on the correlations of entrepreneurship with a holistic approach in neurophysiological, neuropsychological and psychoneuroendocrinological aspects. Although researches show that entrepreneurs and non-entrepreneurs respond differently to neurologically different neural networks, more studies are needed to reveal the changes that occur in the brain during entrepreneurial behavior (Laureiro-Martinez et al., 2015; Nofal et al., 2018; Shane et al., 2019). For this reason, the neuroanatomical approach to entrepreneurship has an important place in the success of entrepreneurship research. In this context, studies on the concepts of "entrepreneurship and neuroscience", "entrepreneurship and genetics", "entrepreneurship and biology" and "neuroentrepreneurship" gain importance. The aim of this study is to provide information about the neuroscience methods, tools and approaches used in entrepreneurship research, to make a detailed bibliometric analysis of the researches, to identify the trends and gaps related to the mentioned concepts and to bring them to the attention of researchers and to make suggestions about what should be done in future studies. Since a better understanding of entrepreneurial thought, intention and behavior will contribute to the development of entrepreneurship, mapping the studies in the literature in terms of the neuroanatomy of entrepreneurship and analyzing them within the scope of quantitative data makes the study unique. The study consists of five parts. In the first part of the study, studies carried out for a better understanding of entrepreneurship in terms of neurophysiology, hormones and genetics are given by making use of neuroscience methods, tools and approaches in the

literature. In the second part, neuroscience tools, methods and approaches used in entrepreneurship research are explained. The methods and findings are described in the third and fourth sections. In the last part, discussion and conclusion, what needs to be done in entrepreneurship research and suggestions are presented.

## 2. Literature Review

The field of neuroscience has expanded significantly in recent years. Although researchers have used neuroscientific techniques to examine various phenomena in the fields of entrepreneurship, business, economics, and marketing, until now, entrepreneurship researchers have not sufficiently benefited from neuroscience methods and tools (Krueger and Welpel, 2014). In the last decade, there has been a significant increase in the number of articles on the biology of entrepreneurship and more than 300 articles have been published in this field (Nofal et al., 2018).

Biologically-based approaches in entrepreneurship research are defined as the whole of research examining the role of genetics (Nicolaou et al., 2009), physiology (White et al., 2007), neuroscience (de Holan, 2014; Shane et al., 2020) and neurodevelopment (Lerner et al., 2018; Wiklund et al., 2017). Entrepreneurship takes place at the nexus of entrepreneurial individuals and valuable opportunities (Venkataraman, 1997). Considering the

biology of entrepreneurial individuals will help us to understand the difference between entrepreneurial and non-entrepreneurial individuals and to learn how likely it is that entrepreneurial individuals will achieve the material and moral gains they will gain from entrepreneurship. In addition, thanks to entrepreneurs' ability to seek and create opportunities (Alvarez and Barney, 2020), it is stated that biologically dopamine (Muda et al., 2018) can affect the individual neurophysiologically during the recognition of opportunities.

Research on the genetic sequence has examined the role of genes in the probability of entrepreneurial individuals to become entrepreneurs (Nicolaou et al., 2008; Zhang et al., 2009). Genes are the basic building blocks of DNA and the basis of the human body (Nicolaou et al., 2009). Increasingly, it is assumed that genes may also be associated with behavior through the action of the mind-brain complex. Twin and adoption studies are quasi-experiments used to examine the heritability of entrepreneurial traits. Heritability refers to the proportion of individual differences in entrepreneurship that can be attributed to the genetic profile of a particular population (Plomin et al., 2012). In entrepreneurship research, various studies have been carried out with different subjects and tools. Some of them are given in Table 1.

**Table 1.** Researches in the field of entrepreneurship with neuroscience methods and tools

Researcher	Research Subject	Findings
White et al. (2007)	Does testosterone influence entrepreneurship?	Testosterone levels are associated with entrepreneurship and this is partially mediated by risk propensity
Nicolaou et al. (2008)	Is there a genetic predisposition to entrepreneurship?	Heritability estimates between 0.37 and 0.48 for entrepreneurship depending on the operationalization of the construct
Zhang et al. (2009)	Do extraversion and neuroticism partly mediate the genetic predisposition to entrepreneurship?	Neuroticism and extraversion mediate the genetic predisposition to entrepreneurship for women
Logan (2009)	Is dyslexia associated with entrepreneurship?	Dyslexics are more likely than corporate managers to engage in entrepreneurship
Shane et al. (2010)	Do genetic factors account for part of the covariance between the Big Five and entrepreneurship?	Common genetic factors influence the covariation between openness to experience and extraversion and entrepreneurship
van der Loos et al. (2013)	Molecular genetics of self-employment	55% of the variance in self-employment due to additive genetic effects; 25% of variance in self-employment explained by additive effects of common SNPs; no genome-wide SNPs identified
Lindquist et al. (2015)	Decomposition of the intergenerational transmission of entrepreneurship into pre-birth and post- birth factors	Both biological and adoptive parents contribute to the likelihood that adopted children become entrepreneurs
Bönte et al. (2016)	Does prenatal testosterone exposure influence entrepreneurship?	Prenatal testosterone exposure is associated with entrepreneurship

**Table 1.** Researches in the field of entrepreneurship with neuroscience methods and tools (continue)

Researcher	Research Subject	Findings
Unger et al. (2015)	Do biological factors interact with psychological factors in influencing entrepreneurship?	Need for achievement moderated the effects of prenatal testosterone on entrepreneurial impact
Wiklund et al. (2016)	How does ADHD influence the decision to become an entrepreneur and entrepreneurial performance?	Inattention and hyperfocus significantly influence entrepreneurship
Wolfe and Patel (2017)	Does cortisol modulate the relationship between epinephrine and self-employment?	At lower levels of cortisol, higher epinephrine levels are associated with self-employment
Wiklund et al. (2017)	How does ADHD influence entrepreneurship?	Hyperactivity is positively but inattention negatively correlated with entrepreneurship
Wolfe and Patel (2017)	Is obsessive compulsive personality disorder associated with self-employment?	Individuals with obsessive compulsive personality disorder have a higher likelihood of engaging in self-employment
Nicolaou et al. (2018)	Does testosterone increase the likelihood of self-employment?	Serum testosterone levels are positively associated with self-employment for males; lower 2d:4d (higher prenatal testosterone) in left hand associated with self-employment; support for testosterone transfer hypothesis
Weinberger et al. (2018)	How does recovery from work stress influence entrepreneurs' generation of new ideas?	Sleep efficiency and work-related problem solving pondering positively associated with entrepreneurs' creativity
Lahti et al. (2019)	Why and how do founding entrepreneurs bond with their ventures?	Entrepreneurs showed similar signs of affective bonding to parents
Shane et al. (2020)	How does variation in entrepreneurs' displayed passion influence investor interest?	Passionate founders raise investor neural engagement and interest in the start-up
Moore et al. (2021)	ADHD-Related neurodiversity and the entrepreneurial mindset	How neurodiversity (neurobiological/brain-related differences) relates to entrepreneurial cognition is better understood.
Sharma et al. (2021)	Is it possible to investigate entrepreneurial intention with six neuroscience methods?	Entrepreneurial intention is influenced by five factors: recognition of entrepreneurial opportunities, evaluation and risk taking, entrepreneurial cognition, entrepreneurial behavior and entrepreneurial decision making..
Bai et al (2022)	Sensitive assessment of creativity and entrepreneurship education to achieve professional differentiation.	The BP (Backpropagation) neural network model is highly generalizable to students' creative enterprise abilities,
Egana-delSol et al. (2023)	Neurophysiological markers of emotion regulation predict efficacy of entrepreneurship education	Programs designed to develop social-emotional skills are effective in improving entrepreneurial outcomes as they develop students' ability to regulate their emotions.

Source: Created by the author using Nicolau et al. (2021).

Of course, the work done is not limited to these. Hatak and Zhou (2019) conceptualized entrepreneurial health as an important dimension of human capital (measured as subsequent annual income and subsequent subjective well-being) that drives entrepreneurial success. Shane et al., (2020) found that the neural interaction of the investor increases when entrepreneurs showcase their desired ventures in front of the investors, which in turn affects their interest in investing in the new venture.

Lahti et al. (2019) investigated the emotional bonds that entrepreneurs have with their start-ups and found that these are similar to the emotional bonds between parents and children. According to studies claiming that testosterone positively affects the tendency to be entrepreneurial in men and women (White et al., 2006; Greene et al., 2014; Unger et al., 2015; Bönte et al., 2016; Nicolaou et al., 2018), hormones have an effect on decision making. These

studies examined serum and prenatal testosterone levels as well as testosterone transfer in both same-sex and opposite-sex twins. As a result of the studies, it has been understood that testosterone has a significant effect on being an entrepreneur. Other research has shown an interaction between cortisol and epinephrine (Wolfe and Patel, 2017) and testosterone and the need for success (Unger et al., 2015) in entrepreneurs.

### **3. Neuroscience Methods, Tools and Approaches Used in Entrepreneurship Research**

Modern technological advances have led to the production of small, portable devices and electrodes that are used largely in marketing efforts and can potentially be very proficient at exploring the entrepreneurial mind in a real environment. In particular, there have been significant advances in understanding entrepreneurial neurophysiology. EEG (Electroencephalogram) is one of the most frequently used tools in this sense. Studer et al., (2013) investigated the relationship between resting brain activity, psychological traits (such as sensitivity to punishment and reward), and risk-taking behavior through a modern EEG (and fMRI) approach. Their results showed that the prefrontal cortex (an important brain area for high-level cognitive processes, behavioral control and decision making) certain core activity of the brain and psychological traits can predict risk-taking behavior. In the study by Vieito et al., (2015), brain activity of 20 (volunteer) investors was monitored using EEG during different financial activities (such as selling, buying and holding) to investigate whether certain market outcomes affect brain activity and responses.

Another neuroscience tool used in entrepreneurship research is MEG (Magnetoencephalogram). This method is based on the principle that the electrical activity produced by populations of neurons is accompanied by the generation of magnetic fields. Ioannides et al. (2000) in their study to investigate how the brain responds to cognitive and emotional stimuli, found that the brain responds differently to cognitive and emotional stimuli. Tallon-Baudry et al. (2011) investigated how the human brain is activated when participants are presented with money and neutral stimuli. It has been observed that money activates the reward system in the brain like other physiological incentives and can be distinguished in a much shorter time than other stimuli.

Functional Magnetic Resonance Imaging (fMRI) is the tool used in entrepreneurship research and provides much more detailed information than other neuroimaging methods. (fMRI) Functional magnetic resonance imaging (fMRI), unlike EEG and MEG devices, allows the visualization of changes in blood flow in the brain (Morin, 2011).

When the entrepreneur makes an investment decision in a risky environment or takes action to seize an opportunity, there are some differences in heart rate and

blood pressure compared to other individuals. The neuroscience tool used to detect these changes is the EKG (Electrocardiogram). As Krueger and Welpel (2014) point out, "entrepreneurial action has important emotional bases". Considering how the heart relates to our emotional perception, investigating how heart rate (or blood pressure) changes under certain stimuli or situations provides important information for entrepreneurial decision making.

Since it is suggested that emotional stimuli involuntarily activate facial expressions, the EMG (Electromyogram) approach ignores the voluntary control of emotion and detects involuntary differences. It is the most commonly used face EMG in entrepreneurship research. Balconi and Pagani (2015) explored social hierarchies and emotions using facial EMG along with EEG and other behavioral measures. Experimental results have shown that negative emotions (for example, involuntary positive activity) and poorer cognitive performance follow a decline in social status. Künecke et al. (2014) tested the relationship between involuntary movement and emotion using facial EMG. During the research, the participants' perception of face and emotion in multitasking were examined and it was concluded that facial fold activity was related to individual emotion perception activity.

Sight is man's most developed sense. While the areas related to vision make up 30 percent of the cerebral cortex, each of the other sensory areas is less than 10 percent (Colosio et al., 2017). Therefore, it is important for entrepreneurship scholars to focus on eye-related processes as the first stage of sensory perception and cognitive processing. Two methodologies are used to detect visual activity. These are: Electrooculography (EOG) and eye tracking. Hüsser and Wirth (2014) used eye tracking to investigate the effect of limited attentional resources on investors' investment decision-making behaviors. In the research, it has been determined that there is a relationship between attention to past performance and investors' purchase intentions.

Another of the neuroscience methods used in entrepreneurship research is the tools that enable the measurement of electrodermal activity. Lo and Repin (2002) included ten professional traders in their study to investigate the role of emotions in financial decision making, taking into account skin conductivity and blood parameters. The role of emotions in decision making through the skin conductivity response is supported by other articles (Bechara et al., 1999; Bechara et al., 2005). This makes it easier to identify the changes physically created by the processes related to entrepreneurial decision making and risk taking.

The turning point of entrepreneurship research is the emergence of approaches that assume that one of the most important reasons for an individual to be an entrepreneur is genetically based. As a matter of fact, Nicolaou et al. (2011) in a study on twins suggested that there is a possible link between the presence of a gene

(DRD3) that encodes a type of dopamine receptor (special protein molecules selectively activated by dopamine) and entrepreneurship. It has been found that individuals with a certain genetic makeup (ie, people with a specific genetic makeup of the DRD3 gene) are more likely to engage in entrepreneurial behavior or other thrill-seeking activities. An interesting study by Barnea et al. (2010) found that there is a significant relationship between the family environment and the behavior of young investors. Other researchers have compared entrepreneurial tendencies in adopted children (Lindquist et al., 2015). Contrary to previous evidence, the authors showed that the influence of adoptive parents (entrepreneurs) is twice as significant as the genetic contribution (biological parents). Zhang et al. (2009) included both identical and fraternal twins in their study. As a result of the research, it has been concluded that the tendency of women to be entrepreneurs is genetically based, while men are caused by the external environment.

In the human body, decision making works through two complementary systems: the nervous system, which is

based on neurotransmitters (chemicals that enable communication between nerve cells or between a nerve cell and another type of cell, such as dopamine or serotonin) and the endocrine system, which is mediated by hormones. The most common neurotransmitters are dopamine, GABA, serotonin and norepinephrine. Hormones, on the other hand, are chemicals secreted directly into the blood from glands and organs such as the thyroid, pancreas, gonads and pineal gland (Colosio et al., 2017). Simeon et al., (2007) stated that there is a relationship between cortisol and psychological resilience, while Yildırım and Derksen (2012) state that there is a relationship between testosterone and leadership and aggression. Mehta and Prasad (2015) found an interaction between testosterone and cortisol in risk-taking behaviors. Neuroscience tools and methods used in entrepreneurship research are not limited to those described in the study. However, the mentioned tools and methods are the most used in entrepreneurship research. Neuroscience tools and methods used in entrepreneurship research are shown in Figure 1.

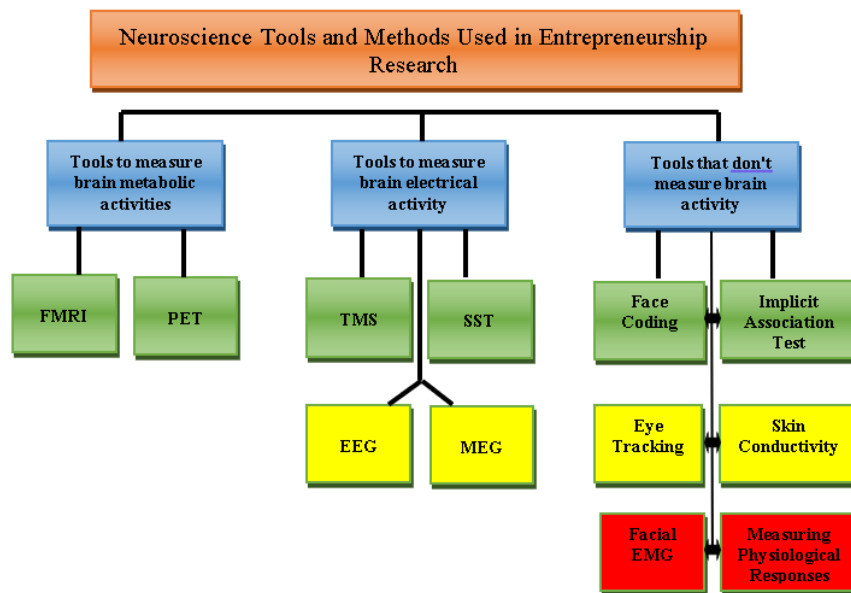


Figure 1. Neuroscience tools and methods used in entrepreneurship research (Bercea, 2013).

4. Method

Within the scope of the research, bibliometric analysis method was used to evaluate the relationship between the themes in the literature. The basic idea of bibliometrics is to measure the academic output of individuals and institutions (Ball, 2018). In the research, studies in the international literature on entrepreneurship and neuroscience were examined. Web of Science (WoS) was used in the creation of the data set to be examined within the scope of the research. Due to the fact that entrepreneurship studies take place quite a lot in the literature, a screening limitation was put in the relevant citation indexes between the years 2006-2023. Another limitation is that the studies in the literature were searched only on Web of Science (WoS), and other

international databases such as Scopus, PubMed and Elsevier ScienceDirect were excluded. In addition, choosing the language of the studies conducted in English is another limitation of the study. In this part of the study, bibliometric analyzes of the concepts of "entrepreneurship and neuroscience", "entrepreneurship and genetics", "entrepreneurship and biology" and "neuroentrepreneurship" are included.

4.1. Purpose of the Research

In the scope of the research; As a result of the bibliometric analyzes made on the concepts of entrepreneurship and neuroscience, entrepreneurship and genetics, entrepreneurship and biology and neuroentrepreneurship as a result of quantitative data and numerical measurement indicators, it is aimed to

present the studies on the concepts to the attention of researchers with a holistic perspective and to offer suggestions about what needs to be done in future studies.

**4.2. Data and Analytics**

Different bibliometric analysis tools are used in the literature. In this study, the VOSviewer program was preferred because of its strengths in terms of functionality. It is considered to be an important program that provides convenience to researchers in order to discover evolutions, relationships and new concepts in the literature. In addition, it enables in-depth analysis of data sets as it provides visualization, mapping and multidimensional analysis. It is based on the bibliometric data of different types of papers scanned in the Web of Science (WoS) database on 14.03.2023 and published between 2006 and 2023. As a result of the research, 379 publications on the words “entrepreneurship” and “neuroscience”, 346 publications on “entrepreneurship” and “genetics”, 183 publications on “entrepreneurship” and “biology”, and only 9 publications on “neuroentrepreneurship” were identified. The contents indexed in Web of Science (WoS) were examined as

criteria through the obtained data, author-citation-journal-country-institution and keyword analysis.

**5. Results**

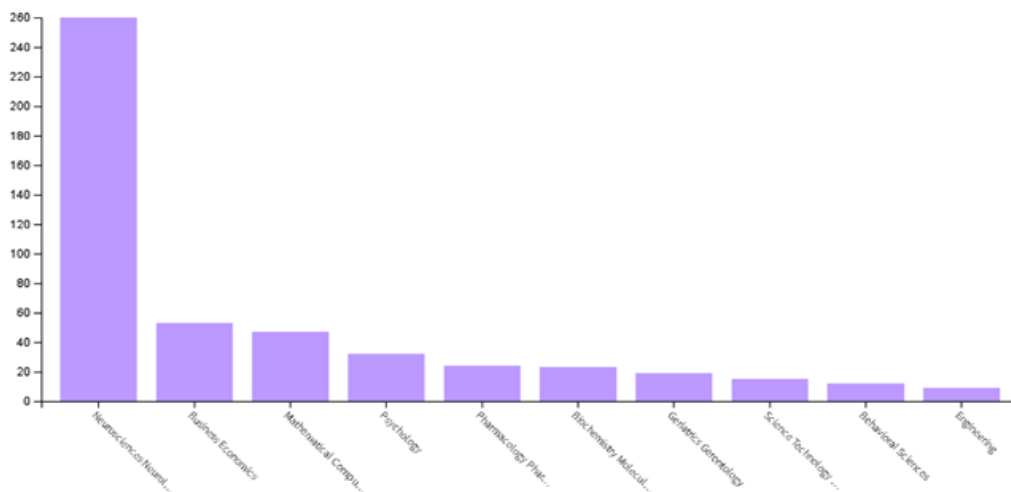
The findings obtained from the bibliometric analyzes performed under this title are presented. Bibliometric analyzes of studies published between 2006 and 2023 are included. Within the scope of the research, 917 studies were evaluated. The results of this evaluation are included in the research through graphics and tables.

**5.1. General Descriptive Statistics**

The number of the most studied areas among the 379 studies on “entrepreneurship” and “neuroscience” is shown in Table 2, and the most studied areas are shown in Figure 2. Of these, 260 are related to neuroscience neurology, 53 are related to business economics, and 47 are related to mathematical computational biology. Among the 346 publications on “entrepreneurship” and “genetics”, 146 of the most studied publications are related to genetics heredity, 44 of them are about biochemistry molecular biology and 35 of them are about business economics, and the fields of study are shown in Figure 3.

**Table 2.** Number of studies by fields

Research Areas	Record Count	% of 379
Neurosciences neurology	260	68.602
Business Economics	53	13.984
Mathematical Computational Biology	47	12.401
Psychology	32	8.443
Pharmacology pharmacy	24	6.332



**Figure 2.** Areas with the most study.

**Table 3.** Number of studies by fields

Research Areas	Record Count	% of 346
Genetics heredity	146	42.197
Biochemistry molecular biology	44	12.717
Business economics	35	10.116
Agriculture	21	6.069
Plant sciences	17	4.913

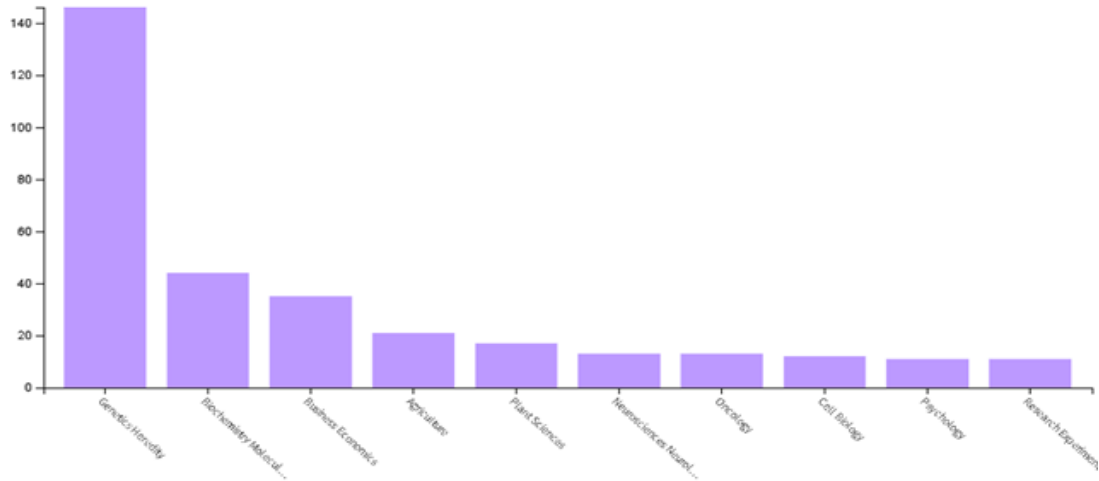


Figure 3. Areas with the most study.

183 publications related to "entrepreneurship" and "biology" were found, the most studied of which was 58 multidisciplinary sciences, 55 related to genetic inheritance and 44 of them related to business (Table 4). These areas are shown in Figure 4.

Within the scope of the study, only 9 publications related to "neuroentrepreneurship", which are directly related to entrepreneurship and neuroscience, were identified in the Web of Science (WoS) database.

**5.2. Co-authorship of Author Analysis**

According to the co-authorship analysis of the authors, a network map was created by determining at least 1 publication and at least 1 citation criteria in order to

identify the most connected and collaborating authors. It is understood from Figure 6 that the data are mapped in 3 groups, namely the red cluster with 21 authors, the green cluster with 11 authors, and the blue cluster with 7 authors. According to the analysis made among the names with the highest connection, 39 authors in the three clusters have 314 connections. Figure 7 shows that the authors who produced the most publications (12 publications Nicolau Nicos and 11 publications Shane Scott) were the most relevant authors in the analysis of at least 5 publications and at least 5 citations for each author.

Table 4. Number of studies by fields

Research Areas	Record Count	% of 183
Multidisciplinary Sciences	58	31.694
Genetics heredity	55	30.055
Business	44	24.044
Management	24	13.115
Biotechnology applied microbiology	20	10.929

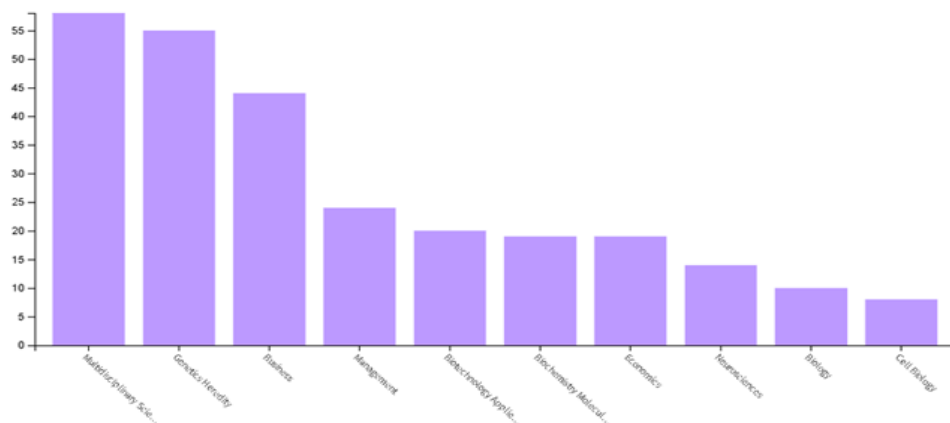
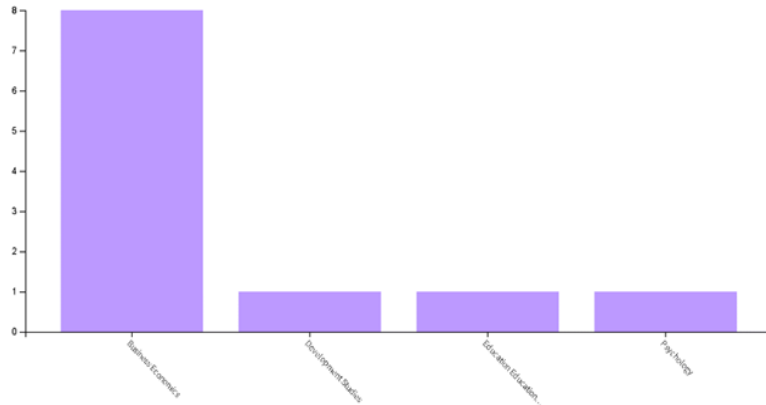


Figure 4. Areas with the most study.

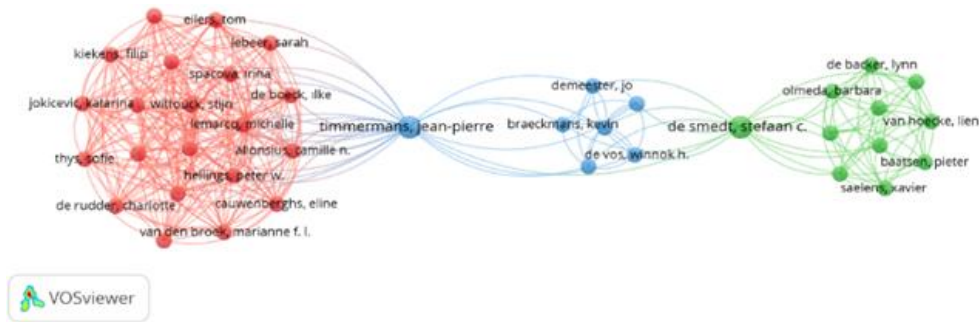


**Table 5.** Number of studies by fields

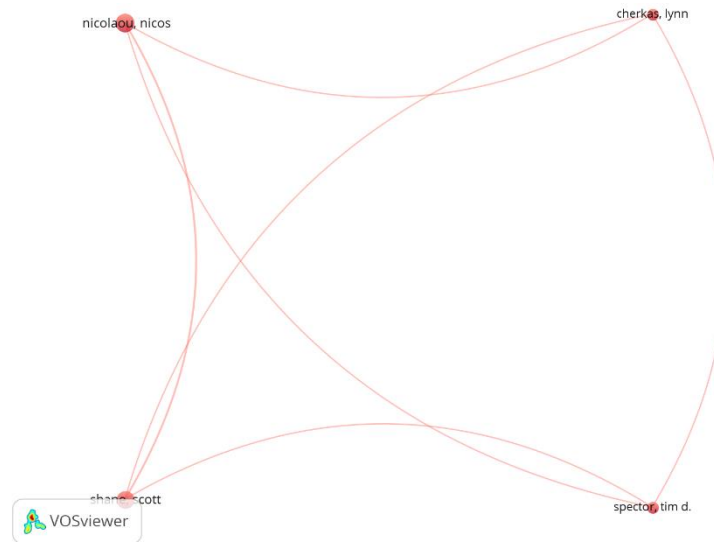
Research Areas	Record Count	% of 9
Business economics	8	88.889
Development studies	1	11.111
Education educational research	1	11.111
Psychology	1	11.111



**Figure 5.** Areas with the most study.



**Figure 6.** Co-author analysis.



**Figure 7.** Collaboration between authors and co-author ties.

**5.3. Citation of Author Analysis**

In order to determine the citation networks, a network map of at least 1 publication and at least 1 citation criteria and author citation analysis was created. In the analysis made on 688 units, which are seen to be

interconnected, a total of 7 clusters and the total connection strength were determined as 833, and these connections are shown in Figure 8. The most cited authors were Shane Scott with 723 citations and Nicolau Nicos with 703 citations.

54. Citation of Countries Analysis

In order to create a network map of the citations of the publications according to their country of origin, analysis was carried out on 38 observation units that were related to each other within the scope of the criteria of publishing at least 1 work and receiving 1 citation by a country. 6 clusters, total connection strength was determined as 713. The most cited countries were the USA (3201 citations), China (1671 citations), and England (1487 citations). In terms of number of works, the ranking is USA (57 publications), China (48 publications) and England (24 publications).

5.5. Citation of Organizations Analysis

Figure 10 shows the result of the analysis made on 310 related observation units within the scope of the criterion of publishing at least 1 publication and receiving 1 citation by an institution in order to create a network map of citations between institutions. Case Western Reserve University (12 publications), Cyprus University (10 publications), Ghent University (7 publications) are the institutions with the most publications, while the ranking is the same in terms of the number of citations (Case Western Reserve University 746 citations, Cyprus University 680 citations, Ghent University 419 citation). A total of 11 clusters and the total connection strength were determined as 1162.

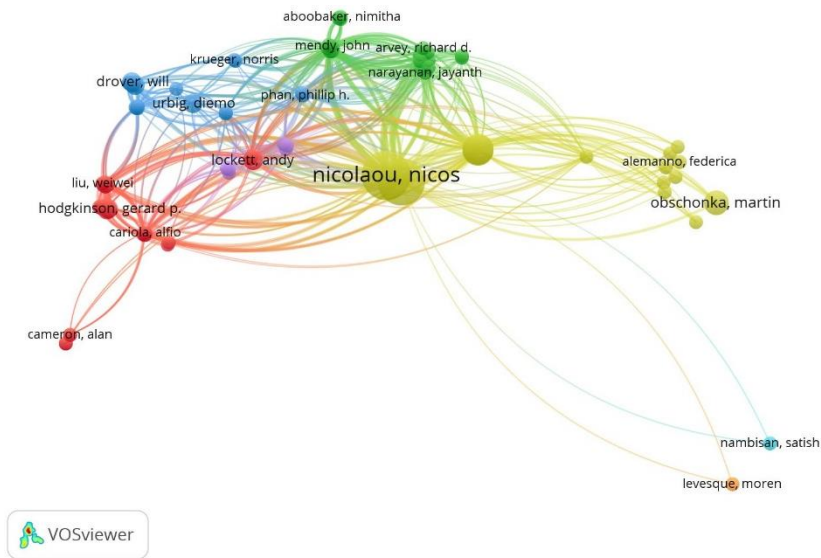


Figure 8. Citation links of authors.

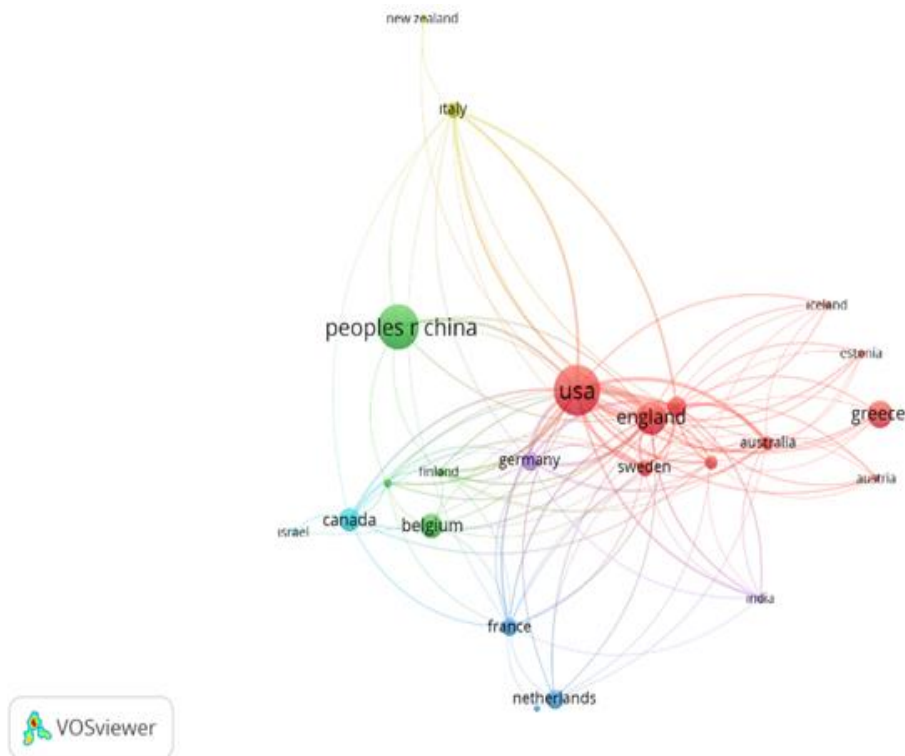


Figure 9. Country citation ties.

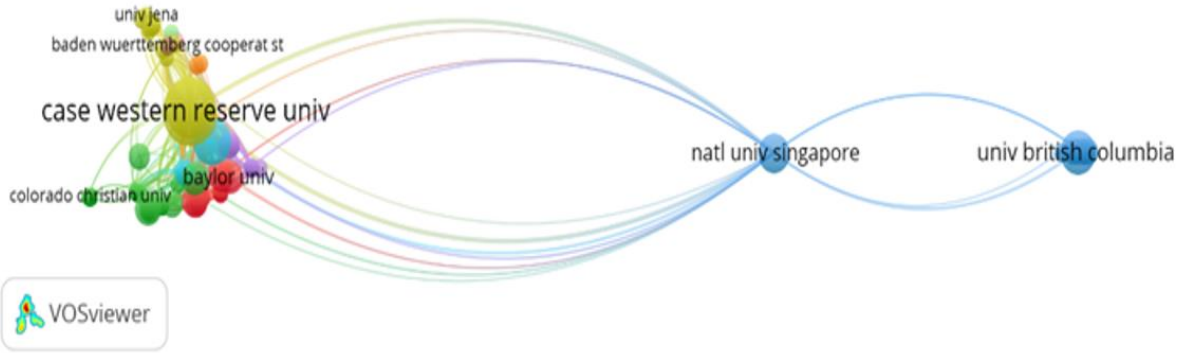


Figure 10. Citation ties of institutions.

5.6. Co-occurrence of Author Keywords Analysis

In the analysis of the most frequently used keywords in the studies carried out by the authors, it is understood from Figure 11 that there are 19 clusters according to the criterion of having at least 1 word in common, and that the most frequently used keywords are 181. Among these words, the word entrepreneurship was in the first place with 19 repetitions, neuroscience was in the second place with 10 repetitions, and the word biology was in the third place with 10 repetitions.

5.7. Co-citation Cited References Analysis

According to the analysis made according to the authors' reference to similar sources in their studies, it is understood that a reference cited is 77 studies and 3 clusters, the minimum number of citations of which is determined as at least 5. It has been determined that the total link strength is 4675, and the most commonly cited studies are Shane (2000) with 20 citations and Nicolau (2008) with 17 citations.

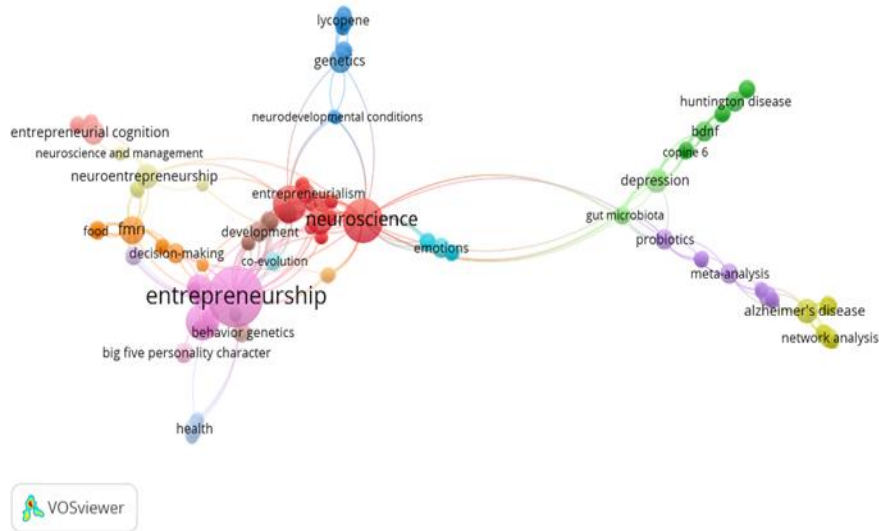


Figure 11. Most common keyword links.

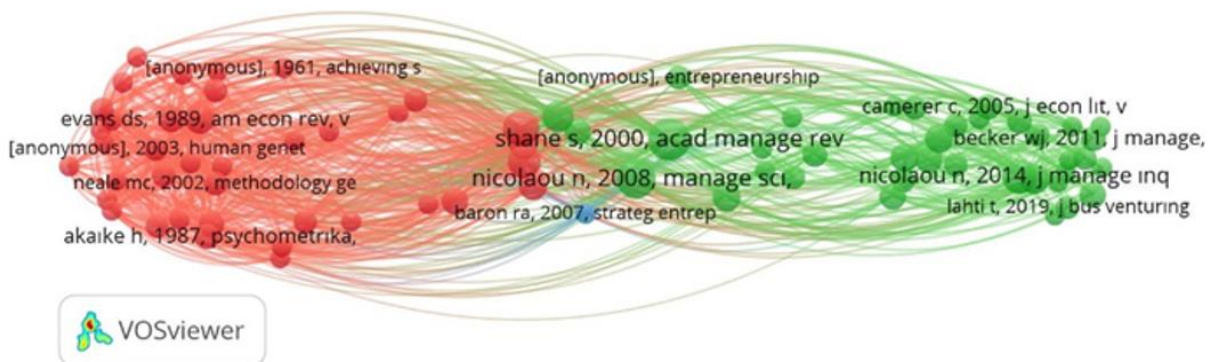


Figure 12. Co-cited authors.

## 6. Discussion and Conclusion

Entrepreneurship is one of the fields of interest today as a field of study. The importance of neuroscience methods, tools, techniques and approaches in entrepreneurship research is increasing day by day. It has become a necessity to reveal the trends needed in this field. Therefore, this study presents a comprehensive literature review on the neuroanatomy of entrepreneurship using bibliometric analysis techniques. It also provides some data and guides by visualizing the relationships between influential studies and researchers in the field. By including only the studies in WoS and choosing English in terms of language, 917 studies published between 2006 and 2023 were accessed as findings. In the research, published studies on entrepreneurship and neuroscience are analyzed bibliometrically from various aspects and provide valuable information for a better understanding and promotion of the subject.

The most researched areas within the scope of the study; business, business economics, genetic inheritance, biochemistry, molecular biology, multidisciplinary sciences and neuroscience. In the review of co-author analysis, Nicolau Nicos with 12 publications and Shane Scott with 11 publications were also found to be the authors with the highest link. In the citation analysis of the authors, the most cited authors were Shane Scott with 723 citations and Nicolau Nicos with 703 citations. Within the scope of the citation analysis of countries, the most cited countries were the USA (3201 citations), China (1671 citations) and England (1487 citations). In terms of number of works, the ranking is USA (57 publications), China (48 publications) and England (24 publications). In the evaluation of the citation analysis of institutions, Case Western Reserve University (12 publications), Cyprus University (10 publications), Ghent University (7 publications) are the institutions with the highest number of publications. In terms of the number of citations, Case Western Reserve University received 746 citations, Cyprus University 680 citations, and Ghent University 419 citations. As a result of the author's keyword analysis, the word entrepreneurship was in the first place with 19 repetitions, neuroscience was in the second place with 10 repetitions, and the word biology was in the third place with 10 repetitions. As a result of the bibliographic match analysis of the texts, the publications with the most bibliographic matches were Kruschke (2012) with 266 citations, Pouladi (2013) with 240 citations, and Boglione (2013) with 225 citations. Nicolau (2008a; 2008b; 2019) took the first three places as the work with the highest total connection strength. As a result of the co-cited references analysis, it was understood that the most commonly cited studies were Shane (2000) with 20 citations and Nicolau (2008) with 17 citations. As a result of the bibliometric analyzes, it has been understood that some fields of study that can be done with the help of neuroscience in the field of entrepreneurship are missing. In particular, studies in

which genetics, hormones, neurophysiological fields, the effect of environment-biology, behavioral genetics and these components will be handled together will guide future studies.

Parts of the ventral tegmental area, basal nuclei, prefrontal cortex, insular cortex, limbic areas (such as hippocampus and amygdala), nucleus accumbens, thalamus and hypothalamus (Songur, 2022) are the main reward system areas in the human brain. The ventral tegmental area is a dopamine-producing center that manages impulses such as reward, motivation, and cravings. When this area becomes aware of a potential reward, it starts producing a chemical called a neurotransmitter called dopamine. Oxytocin is a hormone that is released in the body at certain times. When oxytocin, known as the hormone of commitment (even when unsuccessful, does not give up being an entrepreneur) interacts with dopamine, the reward system in the brain is activated. One of the most important reward centers in the brain, the ventral tegmental area and the nucleus accumbens (Songur, 2022) are activated in the calculation of gains and losses and in making high-risk decisions. It is a deficiency that studies in the field of entrepreneurship do not examine the relationship between oxytocin, dopamine, ventral tegmental area and nucleus accumbens. Hormones and mediators such as dopamine, vasopressin (ADH) and oxytocin secreted from the hypothalamus, where the most important reward areas of the brain are located (Songur, 2022), have an important place in the stimulation of the reward system. In the studies carried out, the relationships and interactions of these areas or hormones with each other can greatly contribute to the explanation of entrepreneurial behavior. For this reason, the absence of such studies causes the desired results in entrepreneurship research to not be achieved and some questions remain unanswered. For a better understanding of entrepreneurship neurophysiologically, it is very important to examine the active centers and neural networks in the brain due to the reactions given during entrepreneurial decision making and behavior. Entrepreneurship research, which will be conducted using neuroscience tools and methods together, will contribute more to the field. The most important reason for this is that entrepreneurship is multifaceted, complex and consists of more than one element. For this reason, it is very difficult to elucidate such a complex process with the help of a single method, approach or tool.

Many studies have focused on certain characteristics of entrepreneurship or have made use of certain methods, tools and techniques. For this reason, complete and precise information about the processes related to entrepreneurial thought, behavior and decision making could not be reached. Although the development of neuroscience and its use with different disciplines allow promising results in entrepreneurship research, the desired level has not been reached yet. The fact that scientists who do research in the field of social sciences

do not have the culture and knowledge of working with different disciplines (neuroscience) has made the subject even more difficult. Entrepreneurship research, which requires a multidisciplinary approach, cannot benefit from neuroscience sufficiently. The fact that entrepreneurial behavior consists of many different components has made the subject even more difficult. In future studies, neurological, physiological, and genetic and psychoneuroendocrinological approaches should be used together. Otherwise, parts of the whole will always be missing and some questions will not be answered.

Studies advocating that biology and environmental factors should be considered together have advocated a holistic approach with the sentence "We are all biological creatures and our biology affects all aspects of our behavior, including our work" (Nofal et al., 2018). As a result of the interaction of environmental factors and genetic inheritance, individuals are more prone to become entrepreneurs (Nicolaou et al., 2008; Shane et al., 2010a; Shane and Nicolaou, 2013; Nicolaou, 2015b; Wolfe and Patel, 2017; Wolfe and Patel, 2018; Anglin et al., 2018; Shane et al. 2019). A study similar to the study by Studer et al. (2013) design will make a great contribution to the understanding of entrepreneurial behavior.

Lawrence et al. (2008) in their study investigating the phenomenon of "functional impulsivity" among entrepreneurs and managers, discovered that functional impulsivity allows people to seize opportunities in rapidly changing environments. Researchers recorded various parameters such as neurocognitive assessment (to test their decision-making skills) and demonstrated their relationship to the performance of behavioral tasks. The study, which tested whether entrepreneurs and managers differ in terms of impulsivity and risk taking, showed that entrepreneurs and managers performed equally on behavioral tasks that required "cold" cognition (rational analysis), but entrepreneurs outperformed managers in "hot" cognition. These results will help us understand why entrepreneurs are more successful at tasks that require both rational and emotional thinking.

In particular, the investigation of psychophysiological indices will contribute to a better understanding of the nature of entrepreneurial behavior. Future studies can build on this literature and compare cardiovascular parameters between male and female entrepreneurs or investors (Bellavitis et al., 2016; Bellavitis et al., 2017). The study could explore how the two groups react in different situations, such as risk taking, failure, success or uncertainty. Further research will help us understand whether different entrepreneurial attempts trigger different emotional states, leading an entrepreneur to choose a particular venture based on emotions rather than economic profit maximisation. Since the ultimate goal of the ever-evolving field of neuroentrepreneurship is to understand the psychological and biological factors that determine entrepreneurial outcomes (e.g. behavior, success), entrepreneurship and business scholars can

gain great insights by exploring psychophysiological indices. Understanding the emotions of entrepreneurs will shed light on many processes that are difficult to resolve. Lawrence et al. (2008) have shown that neuroscience can be a powerful tool to answer such research questions. In particular, the investigation of psychophysiological indices will contribute to a better understanding of the nature of entrepreneurial behavior.

The use of psychoneuroendocrinology will enable many questions to be answered in entrepreneurship research. Analysis of different hormones can offer interesting insights into entrepreneurial behavior. A different level of dopamine precursors or receptors may explain risk-seeking behavior and may be implicated as a determinant of entrepreneurial instincts. For example, Nicolaou et al. (2011) suggested a possible link between the presence of a gene (DRD3) encoding a type of dopamine receptor (special protein molecules selectively activated by dopamine) and entrepreneurship. This may be due to the higher dopamine levels these individuals need to "activate" the reward circuits in their brains. However, it should be emphasized that this study could not be replicated in larger samples (van der Loos et al., 2011). In this context, it would be beneficial to examine the responses of the brain's reward-related centers to entrepreneurial behavior. For example; In the event of a risky economic decision, the changes that occur in the "accumbens" nucleus in the brain and the measurement of the responses will provide important insights in the understanding of entrepreneurial behavior.

Using the skin conductivity method, in which electrodermal activity is measured, will be useful in detecting some changes in the body caused by entrepreneurial behavior and in obtaining information about emotional arousal, decision-making and behavior. It can also contribute to discovering unsuccessful entrepreneurial decision-making strategies. Similar studies can be conducted to explore the differences between a person who takes the entrepreneurial decision for the first time and those who have previously engaged in entrepreneurial activities. For example; New insights can be gained by comparing electrodermal activity, how partners form a successful cooperation (credibility) or how investors (e.g. venture capitalists) respond to certain investment offers, emotional responses to investment opportunities, and experience-related responses.

Understanding how events in the entrepreneurial ecosystem shape an entrepreneur's motivation or a particular decision-making process will allow significant gains. Building on the paper of Vieito et al. (2015), entrepreneurship researchers can explore important dynamics of the venture finance industry, including equity crowdfunding. The most important questions we will face in the research are: Are the investment decisions of venture capitalists affected by certain market conditions? How do venture capitalists react when the companies they invest in underperform or have

a conflict with management? What types of information affect investors' brain activity the most, and how does this affect their decision to invest (or not)?

There is little information about the correlation between biological structure and environment and individuals' preference for environments that positively affect entrepreneurship (Plomin et al., 2001; Nicolaou and Shane, 2009). Therefore, genetics can be crucial for advancing the field of entrepreneurship and offer an innovative and powerful set of tools for investigating the behavioral and cognitive patterns of entrepreneurs. Scientists can indirectly investigate the neural and physiological correlates of human behavior. A better understanding of how genetics and environment shape a person's choices (such as being an entrepreneur), behaviors, and skills (such as leadership or decision-making skills) will help to better understand entrepreneurial behavior. One of the most important elements of entrepreneurial behavior and decision making is hormones. For this reason, the relationship and effect of hormones and body chemicals on entrepreneurial thinking, intention and behavior, together with environmental or genetic factors, must be investigated. Emerging neuroscience methods, tools, techniques, and approaches allow researchers to explore the antecedents of behavior, including entrepreneurial behavior. These tools can shed light on important questions about the natural (genetic-based) or acquired (education-based) origins of entrepreneurial attitudes and the individual differences between successful and unsuccessful entrepreneurs. One of the most frequently asked questions, is there an "entrepreneurship gene"? If so, how and under what conditions does this gene affect an individual's tendency to be an entrepreneur? The answer to all these questions will only be revealed if research is carried out with a holistic approach.

**Author Contributions**

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	A.B.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

**Conflict of Interest**

The authors declared that there is no conflict of interest.

**Ethical Consideration**

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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