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RESEARCH ARTICLE

Organizational Neuroscience: A Bibliometric Analysis and Systematic Literature Review

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Abstract
The main objective of this paper is to examine the current state of the literature on organizational neuroscience. This study provides the most comprehensive overview of the development of organizational neuroscience which includes the last 13 years. It also presents how bibliometric and systematic review methodologies can be used together to explore emergent research areas. Bibliometric and systematic review methods were used to review studies carried out in the area of organizational neuroscience from 2007 to 2020. The articles were accessed through the Web of Science (WOS) database which was analyzed by using VOSviewer and SciMAT. Initially, 44 articles were determined to explain the intellectual structure of organizational neuroscience. Then, we conducted a systematic review in Scopus, WOS, and Google Scholar databases to determine which neuroscientific methodologies were prevalent in the scope of organizational neuroscience. As a result, a total of 42 studies adopting the empirical approach were identified. Evidence shows that the majority of the studies were conducted in the US and UK. The most commonly used techniques were electroencephalography (EEG) and functional magnetic resonance (fMRI). "Leadership" and "decision-making" studies were the most researched topic connected with organizational neuroscience. Although there has been a steady increase in the number of publications on organizational neuroscience in the last 20 years, empirical studies have a narrow scope in the literature.

Keywords
Organizational Neuroscience, Neurometric Measurements, Biometric Measurements, Bibliometric Analysis, Systematic Literature Review

Introduction

Although the origin of management and organization science is as old as human history, its endorsement as an academic term and a scientific field took place in the late 1800s (Locke, 1989). Since the 1800s, management and organizational science (MOS) has tried to explain the impact of human behavior on managerial and organizational processes in line with different perspectives such as strategic management, human resources, organizational theory, and organizational behavior. If we look at these perspectives, we see that they generally focus on traditional research methods such as surveys, observations, in-depth investigations, and interviews to explain human behavior in organizational contexts. Although traditional research methods provide rich information about human behavior, people generally can not

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explain the main reason for their behaviors and they have a tendency to hide their feelings and thoughts (Hubert and Kenning, 2008). Moreover, individuals who take part in the research process tend to respond with incorrect information in order to gain social acceptance (Lee and Chamberlain, 2007; Hubert and Kenning, 2008). All these problems, which are constraints of traditional research methods, are causes of inadequate or inconsistent results when explaining human behavior in an organizational context. To overcome these methodological problems, the neuroscience perspective presents new research ways to understand organizational behavior and its dynamics.

Neuroscience and its techniques are not totally new for some scientific areas such as neuromarketing, neuropsychology, and neuroeconomics (Butler and Senior, 2007). The term neuromarketing was first used in the marketing field by Smidts (2002) to explain the effect of neuroscientific tools on the relationship between the neurological response of consumers and their behavior (Lee et al., 2007). More specifically, Shahriari et al. (2020) have highlighted 311 articles between 2005 and 2017 that take part in marketing literature, focusing on the neuroscientific perspective to explain consumer behavior, decision-making process, and brand selection. Moreover, the discipline of economics also has opened its doors to neuroscience since the late 1990s (Glimcher, 2008). Neuroeconomics is used to represent the study of the economic decision-making process and reward-related behavior with neuroscientific tools (Camerer, 2007; Glimcher et al. 2009). Moreover, Srivastava et al. (2019) provided a literature review that includes the field of neuroeconomics and neurofinance and they found that there are 515 papers that include a neuroscientific perspective to explain economic behavior and decision processes. All these areas use neuroscience techniques to improve the knowledge about human behavior (Camerer, et al., 2005; Dijksterhuis, et al., 2005).

In recent years, organizational scholars have also started to pay attention to the neuroscience perspective. At this point, the inclusion of neuroscience in MOS, while pointing to a new development process compared to other science fields, has also divided the views of researchers into the positive and negative sides of organizational neuroscience. The positive side of organizational neuroscience is defined as a biologically rooted approach that gathers neuroscience and MOS together and aims to understand brain mechanisms that affect organizational behavior and managerial relationships (Becker and Cropanzano, 2010; Senior et al., 2011; Healey and Hodgkinson, 2014). On the other side, scholars indicate that there is a problem with the inclusion of neuroscience techniques into the MOS. According to this point of view, the diffusion of neuroscience techniques and viewpoints will lead to divisions in the MOS based on ethical and philosophical foundations (Gavetti et al., 2007; Lindebaum and Zundel, 2013; McLagan, 2013).

Based on all these explanations, our position is close to Healey and Hodgkinson's (2014) work which indicates that critical realism and socially situated cognition will help to improve

organizational neuroscience based on the socially embedded nature of organizational life. Yet, we also believe that if researchers do not understand the neuroscience paradigm and its methodologies, this will lead to support divisions in the field and the proliferation of ethical problems.

As organizational neuroscience is a new area, the attention of researchers is increasing day by day. To turn this attention to the improvement of organizational neuroscience, it is necessary to examine previous research on organizational neuroscience, and the intellectual framework on which they are based.

In this regard, the literature includes few reviews about organizational neuroscience. Sezgin and Uçar (2015) conducted a systematic review of studies on neuroscience in organizational behavior research between 2005-2013. Wang (2019), presented a literature review of the application of the organizational neuroscience to leadership studies. Similarly, Issac and Issac (2019) documented neuroscience applications in leadership studies and conducted a bibliometric analysis which included publication patterns of research. Recently, Prochilo et al. (2019) conducted a review of the literature from 2008 to 2015 which included only empirical studies about organizational neuroscience. Ascher et al. (2018) looked into the applications of neuroscience in strategic management through a literature review and classification of the international journal articles from 2005 to 2013. A recent systematic review, conducted by Dolaşkan and Boz (2020), examined the perspective of neuroscience in three themes which included theory and method, organizational behavior, and leadership. İmamoğlu et al. (2021), like Dolaşkan and Boz (2020) in an earlier review, argued that the importance of the neuroscience perspective provides deeper insight for organizational behavior studies. Nofal and Nicolaou (2021), provided a comprehensive literature review of the biological perspective on the entrepreneurship area.

All these reviews about organizational neuroscience have remarkably contributed to literature. However, these studies focus on particular areas such as management, leadership or organizational behavior and do not offer a comprehensive perspective. In order to fill this gap, the aim of the current study is to provide a comprehensive viewpoint of organizational neuroscience and to examine the growth of empirical research from 2007 to 2020.

Using integrated methodology, which includes bibliometric techniques (VOSviewer and SciMAT) and a systematic review overview, we examine the current status of organizational neuroscience. To the best of our knowledge, this is the first study examining the growth of the organizational neuroscience perspective through the lens of a bibliometric approach and systematic review.

In detail, the main contributions of this study include: (1) offering a comprehensive summary of knowledge on organizational neuroscience; (2) providing a systematic classification

of empirical research and techniques on organizational neuroscience; (3) presenting a useful guideline for future research on organizational neuroscience.

Methodology

Bibliometric process

This study involved three main steps, namely: database creation, bibliometirc analysis, SciMAT analysis research (Figure 1).

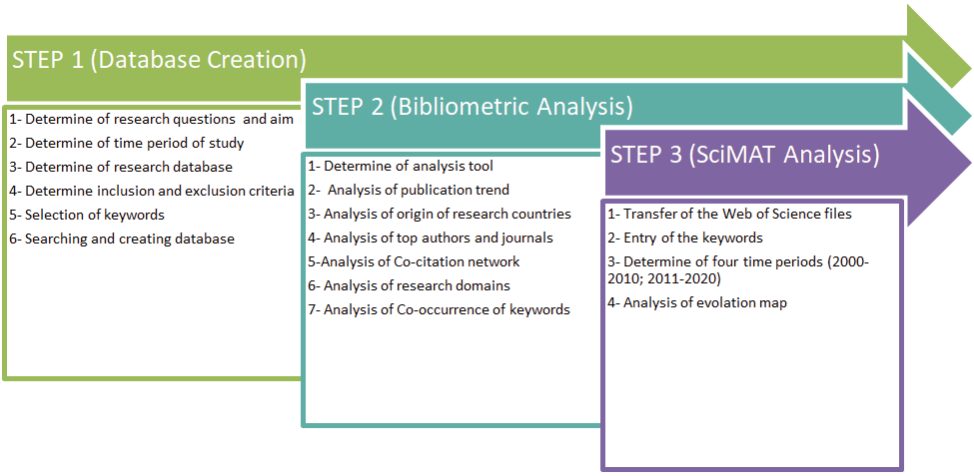

Figure 1. Main steps of research methodology (Adapted from Sharifi et al., 2020)

Figure 1 presents the main steps of the research methodology (Sharifi et al., 2021). Step 1 includes the database creation process in line with the aim of the study and research questions. As mentioned in the literature part, the main aim of this research is to examine the current state of the literature on organizational neuroscience. Moreover, this aim includes two key questions. One of them is "What are the most influential research dynamics (countries, journals, authors, growth rate) that have contributed to organizational neuroscience?" To answer this question we collected data from Web of Science. Web of Science was selected for processing of the data creation because it is a multidisciplinary search tool which provides more consistent information and citation indexing for bibliometric analysis (Van Leeuwen, 2006).

We setted on three inclusion criteria prior to the process of database creation. First, articles had to have been published between 2000 and September 2020. Second, we only included the studies that mentioned the words "organizational neuroscience" and "organizational cognitive neuroscience" in their title, keywords or abstract yielding 76 results. Third, we only included research, book chapters or review articles in English in our dataset which resulted

in 44 articles. Since no studies conducted before 2007 were found in this search, the targeted time interval was accepted as the date of the first study and the research was updated to cover the years 2007- 2020.

We used two software programs which complemented each other (VOSviewer, SciMAT) to perform the bibliometric analysis (Step 2, Step 3). There are several software programs that provide visualitation in the context of bibliometric analysis, such as CiteSpace, CitNetExplorer, HistCite, and GraphPad Prism 5. The reasons why VOSviewer software program was preferred in this study are that VOSviewer supports overlay visualizations and the analysis process works each operating system in Java context (Eck and Waltman, 2014; Bornmann and Haunschild, 2016). Based on these advantages, VOSviewer was used to visualize the review which reflected the main patterns of organizational neuroscience. Moreover, SciMAT software has been used to determine the evolution of organizational neuroscience over the past twenty-year period. The reasons for selecting SciMAT software is that it provides a longitudinal framework for discovering thematic areas (Cobo et al., 2011; Castillo-Vergara et al., 2018). The longitudinal framework helps to reveal a deeper understanding of the development and changes in the area of organizational neuroscience. To understand the evolution process and thematic subfields from 2007 to 2020, we divided this time line into two time periods which were 2007-2010 and 2011-2020 with 7 and 37 publications respectively.

Systematic review process

The second research question of our review is "What is the main focus of empirical studies on organizational neuroscience (preferred methods and main topics)?" The main aim of this question is to determine empirical growth in the scope of organizational neuroscience and provide knowledge about neuroscientific methods for future researchers. To answer this question, we conducted a systematic literature review, which was proposed by Tranfield et al. (2003) (Figure 2).

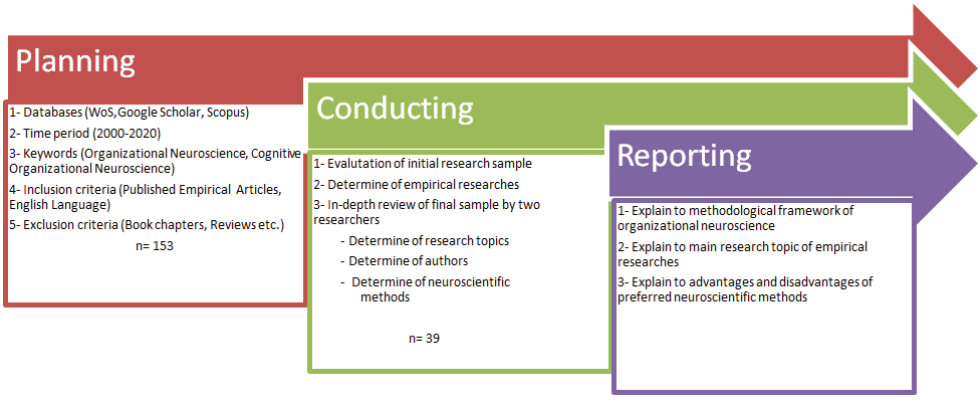

Figure 2. Main steps of systematic review process

In order to gain an understanding of the empirical development of organizational neuroscience literature, we extended our search area and conducted our review in three electronic databases (WOS, Scopus and Google Scholar). We bound our review period to the same as the bibliometric process (2007–2020). We also used the same keywords (organizational neuroscience and cognitive organizational neuroscience) in the search process. We only included studies that used organizational neuroscience techniques in their research procedure. Briefly, studies which consider the ethical aspect of organizational neuroscience, or the reviews and book chapters about organizational neuroscience research and its techniques were excluded and only empirical studies were included in the main analysis. This led us to the identification of 42 articles which were empirical studies about organizational neuroscience.

Results and Discussion

Research Interest, Publication, and Growth

A sum of 44 articles, which were found in Web of Science databases, published in the past 20 years up until the end of September 2020, covering the organizational neuroscience domain were included in our data set. Figure 3 displays the frequency of organizational neuroscience papers on a yearly basis between 2007 to 2020. Between 2013-2015 a massive increase occurs in the number of published articles. In 2015, a peak in the number of published articles occurs with 8 papers in a year. It is seen that there is a relatively decreasing trend after 2015. This decrease may be due to the increase of empirical studies in the field and the long research processes required by these kinds of research. Yet, it is thought that the sharp decline in 2020 is due both to the fact that the year has not yet ended and there are relatively long manuscript acceptance periods, especially for empirical studies.

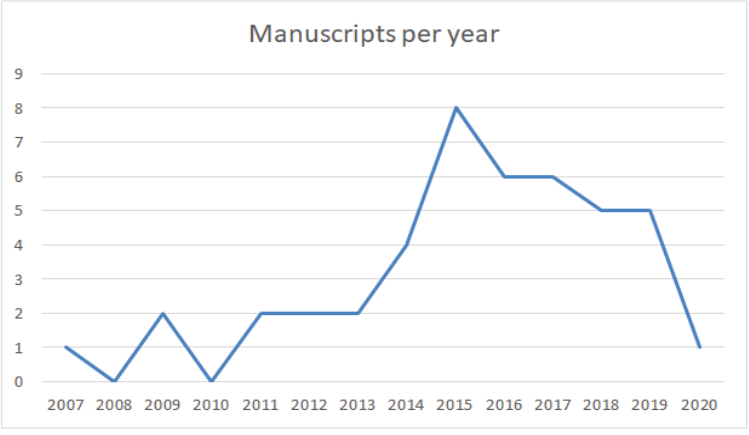

Figure 3. Year wise publication trend of organizational neuroscience

Active Journals

Another analysis was carried out regarding the journals in which the studies in the field of organizational neuroscience are published most frequently. According to the results stated in Figure 4 (bibliographic coupling of journals), the vast majority of the publications belong to the journal of Frontiers in Human Neuroscience (4). According to the citation indicator, Strategic Management journal is the most impactful journal (333 citation), followed by Journal of Long Range Planning (122 citations), Organization Science (90 citations), Journal of Business Ethics (78 citations), and journal of Psychology: Interdisciplinary and Applied (73 citations).

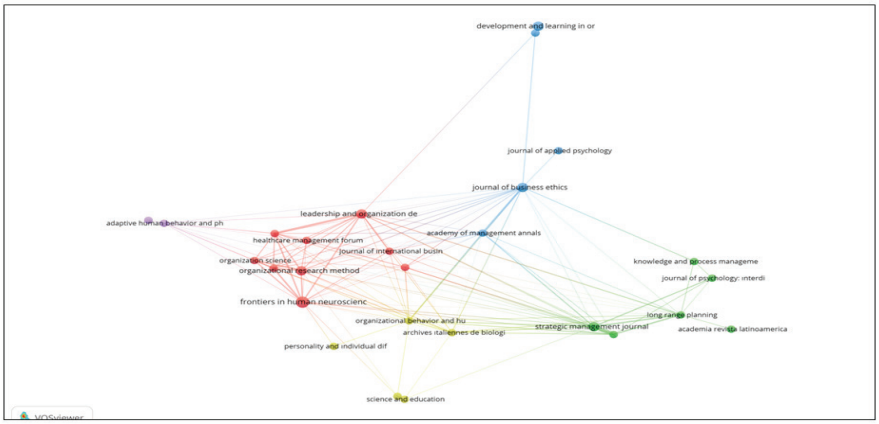

Figure 4. Bibliographic coupling of journals in the field of organizational neuroscience

Active Countries

Considering the affiliations of the 44 articles examined within the scope of organizational neuroscience, it is seen that a great many of the studies on organizational neuroscience belong to the United Kingdom (18), followed by the United States with 13 articles. The highest number of citations is also found in the United Kingdom (555), followed by the United States at 271, and Denmark with 69 citations (Figure 5).

Distinguished Authors

The famous authors in the domain of organizational neuroscience are tabulated in Figure 6. In consideration of the authors in the area, it is seen that the top three authors have published an identical number of organizational neuroscience studies. While the number of citations of the five authors were examined via Scopus and Web of Science databases, it is seen that Nick Lee and Carl Senior are in the first place with the 5 studies. The other three authors (Butler M.J.R.; Hodgkinson G.P.; and Healey M.P.) have at least two studies, and in Figure 6,

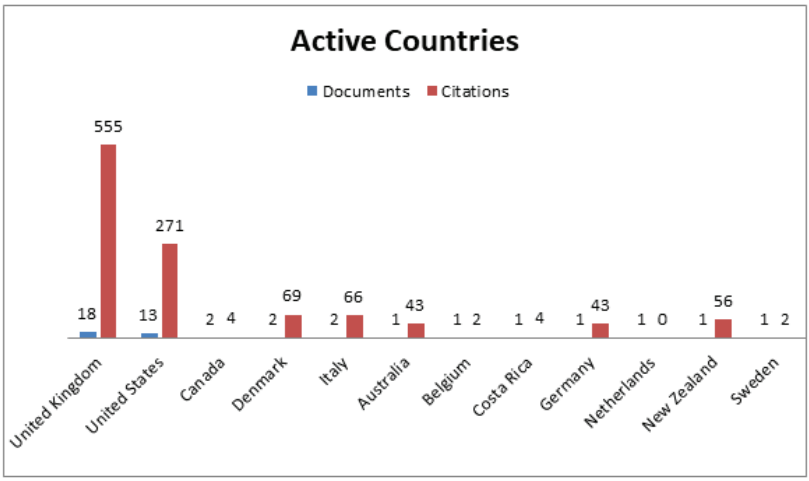

Figure 5. Active countries on scope of organizational neuroscience

it also shows that with 414 citations, Hodgkinson G.P., is the most influential author within the scope of organizational neuroscience.

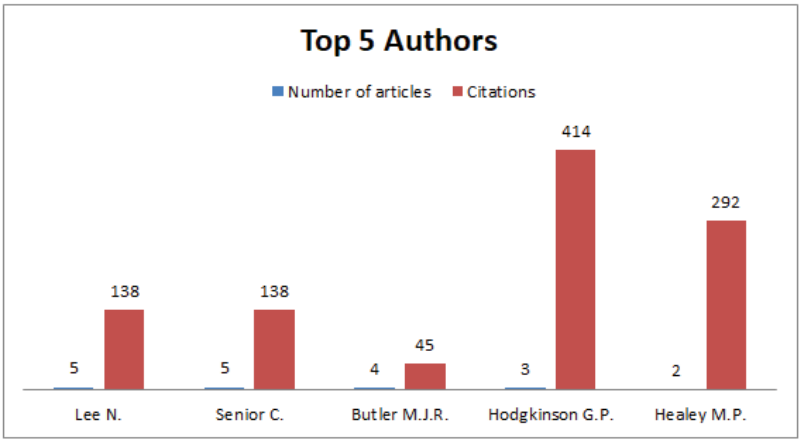

Figure 6. Top 5 authors with the largest number of publications in the organizational neuroscience field

Co-citation Network on Cited Authors

We selected the authors which had been cited a minimum of 20 times, and between the 4474 cited authors 14 of them met the threshold.

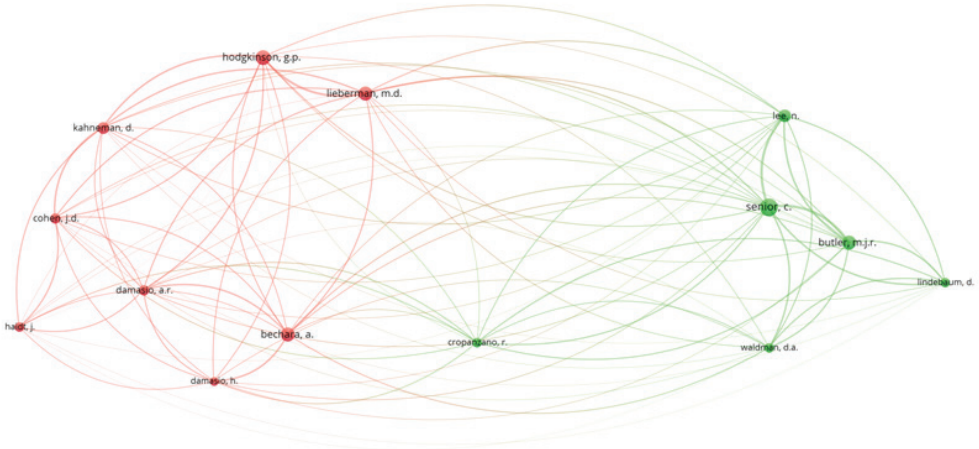

Figure 7. Co-citation map of authors

The most regularly cited authors are Senior, C. (57 citations), Hodgkinson, G. P. (43 citations), Butler, M. J. R. (41 citations), Bechara, A. (39 citations), and Lieberman, M. D. (39 citations).

Cluster 1 contains authors from cognitive neuroscience (i.e., Cohen, J.D.; Damasio, A. R.; Damasio, H.), business ethics (i.e., Haidit, J.), micro economy (i.e., Kahneman, D.), psychology (i.e., Bechara, A.; Lieberman, M. D.).

Cluster 2 encompasses authors from organizational justice and workplace emotion (i.e., Cropanzano, R.), organizational behavior (i.e., Waldman, D. A.; Senior, C.), marketing (i.e., Lee, N.), and management (i.e., Butler, J.R.; Lindebaum, D.)

Co-citation Network on Cited References

To provide a deeper understanding of the structure of the cited references in the organizational neuroscience, we performed a co-citation analysis of the cited references. Figure 8, provided below, shows the network of references' co-citation relations. We obtained 2945 cited references and employed a threshold of a minimum of 3 times. We got a set of 8 references which also represent influential research in the scope of organizational neuroscience.

Figure 8. Co-citation network on cited references

As shown in Figure 8, the references' co-citation network formed 2 clusters. Cluster 1 includes four references and it represents the research organizational neuroscience field and its theoretical roots (shown in red). The most cited reference is Becker et al. (2011) (273 times). Cluster 2 also has four references and it represents the social cognitive neuroscience perspective (shown in green).

Conceptual Structure and Evolution of Organizational Neuroscience

To provide the main themes and historical viewpoint of the evolution of the organizational neuroscience perspective, strategic diagrams were built using SciMAT software. For each period from 2007 to 2020, a conceptual structure was generated as well as the evolutionary maps of fields.

As seen in Figure 9, the first decade which represents between 2007 to 2010, few documents were found addressing organizational neuroscience. Organizations and workplace concept are motor themes which have an effective role in the introduction of the neuroscience perspective to MOS. In addition to these motor themes, organizational justice is an emerging theme which appeared in only one study. Table 1 shows indicators (documents, h-index, centrality and density) of each theme in the period 2007-2010.

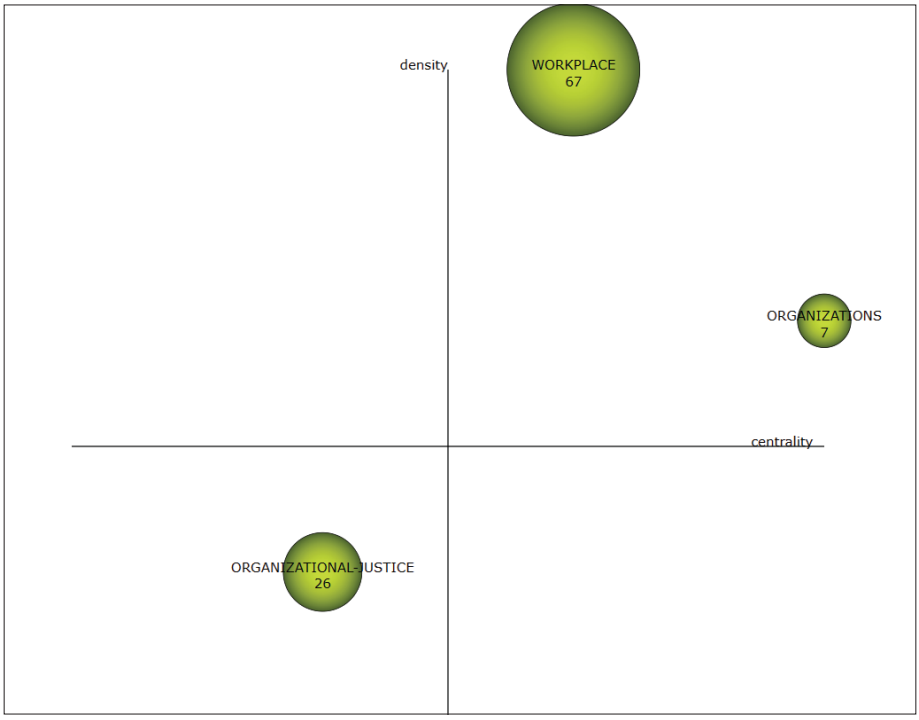

Figure 9. Strategic maps (2007- 2010)

Table 1
The Nodes of the Strategic Maps (2007-2010)

	2007-2010			
Themes	**Document**	**h-Index**	**Centrality**	**Density**
Organizations	2	2	75	466.67
Workplace	2	2	75	277.78
Organizational Justice	1	1	0	150

While interest in organizational neuroscience increased in the second period, this interest led to the prominence of new research topics in the field. More specifically, in the period 2011-2020, the organizational research field revolved around 12 main themes (Figure 10). Organizational justice is consolidated as a motor theme, which was an emerging theme in the period 2007-2010. Moreover, decision-making, behavioral strategies, and leadership are basic themes. Each of them links with the workplace concept which was a motor theme in 2007-2010 and reflects management research. Highly developed topics include organizational theory, intelligence, and organizational decision making but these topics also indicate isolated areas in the scope of organizational neuroscience. Emerging/disappearing topics (lower left quadrant) include themes such as organizational transformation and strategic consensus which have lower centrality and density. Table 2 shows indicators (documents, h-index, centrality, and density) of each theme in the period 2011-2020.

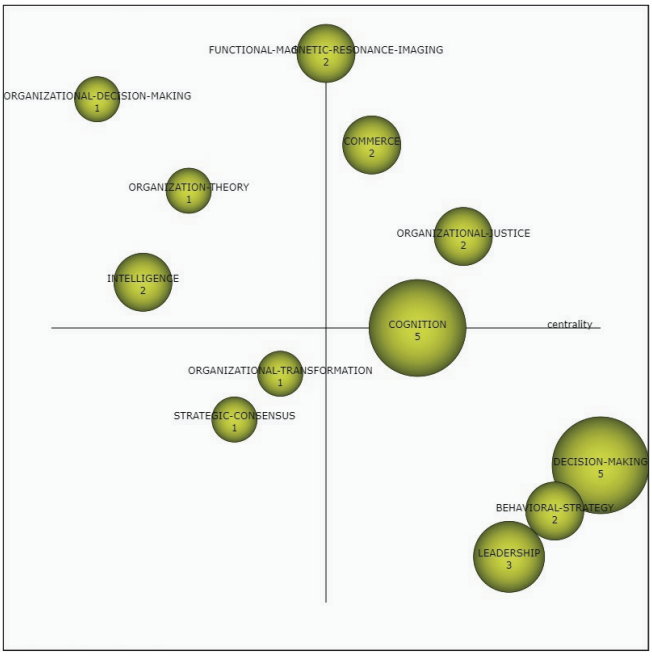

Figure 10. Strategic maps (2011- 2020)

Table 2
The Nodes of the Strategic Maps (2011-2020)

		2011-2020		
Themes	**Document**	**h-Index**	**Centrality**	**Density**
fMRI	2	2	7.5	420.83
Commerce	2	1	41.25	270.83
Decision Making	5	3	276.53	98.61
Cognition	5	3	47.78	106.25
Organizational Justice	2	2	68.33	134.38
Leadership	3	2	101.67	68.75
Organizational Decision Making	1	1	0	300
Intelligence	2	1	0	108.33
Organizational Theory	1	1	0	200
Behavioral Strategy	2	2	164.17	70
Strategic Consensus	1	1	0	100
Organizational Transformation	1	0	0	100

Analysis of Thematic Areas

Figure 11 presents the main thematic evolution of the organizational neuroscience perspective. According to this map 3 concepts, which include organizations, workplace, and organizational justice, have received more attention from organizational scholars in first period of the evolution of the field. More specially, the theme of the workplace is linked with the 12 sub-themes which include fMRI, commerce, decision-making, cognition, organizational justice, leadership, organizational decision-making, intelligence, organizational theory, behavioral strategy, strategic consensus, and organizational transformation. These sub-themes represent to management perspective in the period of 2007-2011.

The theme of organization is a more central research topic compared with the workplace theme. Eight sub-themes are related to the organizational context, such as the business change process, affective states, social behavior, organizational performance, forgiveness, empathy, and creativity. These sub-times represent the organizational behavior perspective in the period of 2007-2010.

Organizational justice is a new emerging topic in the first period. This theme includes three subthemes (fairness, theory of mind, and neuro-organizational justice) which also represent the organizational behavior perspective.

Figure 11. Thematic areas in the evolution process of organizational neuroscience

In the evolution process of the field, the first decade reflected the infancy era of organizational neuroscience. The second period (2011-2020) shows that the organizational justice theme, which in the previous period is being maintained, is still effective for the evaluation of fields. Moreover, the research topics are visibily diversified in the last period (12 themes). Especially, decision making, cognition, and leadership are dominant thematic areas that shape the research interest. Figure 12 presents related sub-themes of each dominant thematic area to provide a deeper understanding of the current tendency of the fields.

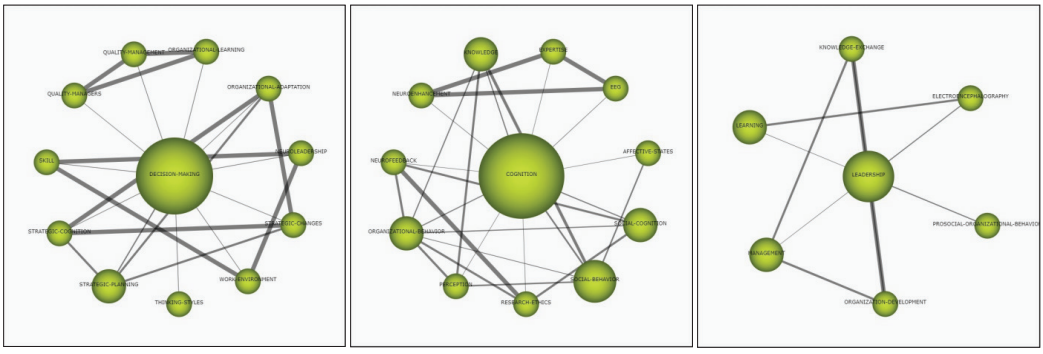

Figure 12. Sub-themes of dominant thematic areas (2011- 2020)

According to the sub-themes network (Figure 12), decision-making is mainly associated with the strategic management process (quality management, strategic change, strategic cognition, power, quality of managers) and organizational behavior (organizational learning, skill, thinking styles). The cognition theme also has a central role that is associated with prominent sub-themes, such as organizational behavior, emotions, social behavior, and knowledge. The rest of the sub-theme network consists of minor areas, such as neuro-feedback, expertise, EEG, research ethics, perception, and social cognition. According to the sub-themes network of leadership, there are seven clusters that represent different research domains that become prominent. At this point, management, learning, and prosocial organizational behaviors have a more dominant role than other sub-themes.

Systematic Review of the Empirical Research on Organizational Neuroscience

Our systematic review considers 153 articles in the field of organizational neuroscience collected from the Web of Science, Scopus, and Google Scholar databases. However, only 42 of the 153 (27.4%) researches in this list have empirical research methods. The application status of different neuroscience techniques in 42 articles and prominent research topics on organizational neuroscience and the advantages/limitations of each technique are summarized in Tables 3 and 4.

It can be observed that in the 20-year period, EEG is the most popular neurometric measurement method used in organizational neuroscience (Wang et al., 2020; Waldman et al., 2019; Edison et al., 2018; Villalba-Diez et al., 2019; Yang and Li, 2018; Bonnstetter et al., 2018; Bonnstetter et al., 2015; Hannah et al.,2013; Balthazard et al., 2012; Waldman et al., 2011). According to Wang et al. (2020) the EEG technique and measurement process help to examine team dynamics such as team member attention, team interaction and the problem-solving process. In addition to that, EEG based measurement has also been used in an MOS study to identify neutral signals of leadership behavior and decision-making processes (Balthazard et al., 2012; Jack et al., 2019). The main reasons for the increase in the use of EEG in organizational neuroscience context can be explained by EEG's overcoming the limits provided by fMRI and its relatively low research costs for organizational context.

Another instrument that became prominent for organizational neuroscience is fMRI (Kokubun et al., 2020; Lelieveld et al., 2020; Shane et al., 2020; Rybnicek et al., 2019; Lemmers-Jansen et al., 2018; Huffcutt et al., 2018; Molenberghs et al., 2017). Especially, fMRI is the first neurometric technique used by Decety et al. (2004) in the scope of organizational neuroscience. Previous research has also pointed out the significant measurement effects of fMRI on Machiavellianism (Bagozzi et al., 2013), organizational justice (Dulebohn et al., 2009), social influence (Mason, et al., 2009), leadership (Boyatzis et al., 2012) and decision-making (Laureiro-Martínez et al., 2015) in organizational life.

Table 3
Presentation of the Scientific Production Profile of the 42 Empirical Articles on Organizational Neuroscience

Electroencephalography (EEG)	**Functional Magnetic Resonance (fMRI)**	**Heart Rate (HR)**	**Eye Tracking**	**Galvanic Skin Response (GSR)**	**Voice Pitch**	**Facial Coding (FACs)**
Waldman et al. (2011) Balthazard et al. (2012) Hannah et al. (2013) Bonnstetter et al. (2015) Eskenazi et al. (2016) Wang Lei et al. (2016) Venturella et al. (2017)* Waldman et al. (2017) Yang & Li (2018) Bonnstetter et al. (2018) Duan (2018) Liu & Xu (2018) Zhang (2018) Edison et al. (2018) Crivelli et al. (2019) Villalba-Diez et al. (2019) Wang et al. (2020)	Decety et al. (2004) Peterson (2005) Dulebohn et al., (2009) Mason et al. (2009) Boyatzis et al., (2012) Bagozzi et al., (2013) Laureiro-Martínez et al. (2015) Molenberghs et al. (2017) Haesevoets et al., (2018) Lemmers-Jansen et al. (2018) Huffcutt et al. (2018) Rybnicek et al. (2019) Kokubun et al. (2020) Shane et al. (2020) Lelieveld et al. (2020)	Akinola and Mendes (2014) Venturella et al. (2017)* Balconi et al. (2019)* De Longis et al. (2020)	Gerpott et al. (2018) Maran et al. (2019) Sun et al. (2020)	Venturella et al. (2017)* Balconi et al. (2019)*	Klofstad & Anderson (2018) De Waele et al. (2019)	Trichas and Schyns, (2012) Trichas et al. (2017)

* Research which used biometric and neurometric techniques together.

The advantages, which cause fMRI to be preferred most widely in organizational neuroscience, can be listed as spatial and temporal resolution of the brain, and the measurement of activity in different brain regions simultaneously (Robertson et al., 2017). Although fMRI is the preferred method, it has some limitations, such as high cost, expensive preparation processes, and restriction of participants in a narrow area in the measurement process.

Although a growing body of literature generally includes neurometric measurement, the use of biometric measurements in organizational neuroscience has become widespread in the last six years. Organizational neuroscience comprises a number of biometric techniques that can directly measure those aspects now considered crucial in the process of organizational

contexts, such as work-group dynamics, decision-making process, leadership behavior, and psychophysiological responses of employees in terms of information storage. At this point, the main biometric techniques used in organizational neuroscience can be listed as follows: eye tracking (Sun et al., 2020; Maran et al., 2019; Gerpott et al., 2018), heart rate analysis (De Longis et al., 2020), galvanic skin response (Venturella et al., 2017; Balconi et al., 2019), voice pitch (Klofstad and Anderson, 2018), and speech rate analysis (De Waele et al., 2019).

One of the frequently used biometric measures is eye tracking. A recent eye-tracking study conducted by Gerpott et al. (2018) involved 18 leaders and non-leaders who were asked to rate their perception of leadership signals in 42 muted video clips of the team meetings, and their eye-gazing patterns to visual attention toward emergent leaders were analyzed. Another study by Maran et al. (2019) showed that leaders' eye-directed gaze that linked with audience members is part of their charisma. These studies showed that applied eye-tracking techniques help to justify the organizational context, especially in the leadership topic.

Heart rate analysis, as with eye tracking, is a biometric technique that tracks the electrical signal created by the heart. The measurement of heart rate has been applied in different research studies in organizational neuroscience in order to assess different processes in employees' and managers' reactions. For instance, De Longis et al. (2020) showed that the use of heart rate variability can be associated with negative emotions and exhaustion at work. In another study, heart rate was used to determine the psychophysiological responses of leaders and employees in the performance evaluation process (Balconi et al., 2019).

In the field of organizational neuroscience, there are some studies showing how Galvanic Skin Response (GSR) can be helpful in understanding the manager's and employee's emotional responses. Usually, GSR is used with other techniques in a complementary manner. For instance, Venturella et al. (2017) tested different communication styles of leaders using heart rate analysis, GSR, and EEG. The results showed positive correlations between heart rate signals, EEG, and GSR. Similarly, Balconi et al. (2019) also used GSR measurement integrated with heart rate analysis to explain the psychophysiological responses of leaders and employees. Another biometric measurement method in organizational neuroscience researches is voice analysis. Voice analysis can be applied both with voice pitch and speech rate in different researches. For instance, Klofstad and Anderson, R. C. (2018) used voice pitch analysis to explain the relationship between voice pitch and leadership ability. In another study, voice pitch and speech rate analysis were used together to explain the vocal cue effect on the organizational crisis process and crisis strategies (De Waele et al., 2019). All these studies suggest that the application of the techniques of neurometric and biometric measurements in the field of organizational neuroscience has its important advantages to explore the complex nature of human behaviors. In other words, the extant research on the application of neuroscience in MOS suggests that it holds some salience, and in the organizational sphere is worthy of exploration.

Table 4
Advantages and Limitations of Biometric and Neurometric Techniques in Organizational Neuroscience

	Prominent topics	**Advantages**	**Limitations**
EEG	Soft skills (Bonnstetter et al., 2015; Bonnstetter et al.,2018) Business unit controllers (Eskenazi et al., 2016) Leardership (Waldman et al., 2011; Balthazard et al., 2012; Hannah et al., 2013; Venturella et al., 2017; Waldman et al.,2017; Edison et al., 2018) Entrepreneurship (Yang, and Li, 2017) Economic management (Duan, 2018) Entrepreneurial cooperative behavior (Liu, and Xu, 2018) Enterprise management (Zhang, 2018) Stress management (Crivelli et al., 2019) Problem-solving behaviors (Villalba-Diez et al., 2019) Team process (Wang et al., 2020)	Mobility of EEG enables research outside the context of laboratories such as factories, firms etc. EEG provides deeper knowledge of relationship between brain mechanisms and emotional responses Use of EEG and its methodology is easier than fMRI.	The process of recording brain signals can differ from person to person (Kenning et al. 2007). Data collection from participants who have long hair is difficult and this situation effects the quality of EEG data. Experimental settings and data artifacts can influence results (Wang et al. 2008). It is necessary to allocate an average of 30 minutes for each participant during the experiment. This situation may create time pressure for the researcher under organizational conditions. The price of a 32-channel EEG is more than $ 35,000. This situation may pose a budget problem for a comprehensive research process.
fMRI	Investor behavior (Peterson (2005) Organizational justice (Dulebohn et al., 2009) Social influence (Mason et al., 2009) Machiavellianism (Bagozzi et al., 2013) Decision-making (Laureiro-Martínez et al., 2015) Leadership (Boyatzis et al., 2012; Molenberghs et al., 2017) Cooperation (Decety et al., 2004; Lemmers-Jansen et al., 2018) Human resources (Huffcutt et al., 2018) Work motivation (Rybnicek et al., 2019) Work engagement (Kokubun et al., 2020) Entrepreneurship (Shane et al., 2020)	fMRI provides deeper knowledge of the relationship between brain mechanisms and emotional responses fMRI can detect changes which include chemical composition, metabolic activity and fluid in the brain (Wang et al. 2008; Perrachione et al. 2008).	Experimental processes which involve fMRI methodology have strict ethical procedures (Wang et al. 2008) The obligation of the participants to remain still during the experiment makes the data collection processes difficult (Zurawicki 2010). fMRI is an expensive method and the realization of the experimental process requires a laboratory environment. The data analysis process is complex and difficult (Kenning et al. 2007).

	Prominent topics	Advantages	Limitations
Eye-Tracking	Leadership and team interaction (Gerpott et al., 2018) Charismatic leadership (Maran et al., 2019) Work-group dynamics (Sun et al., 2020)	Visual attention provides more information for managers on the decision-making process. Diversity of eye tracker tools enables research to be conducted outside the context of the laboratory, such as factories, firms etc. Price of eye tracker systems is cheaper than most other neuroscientific tools (EEG, fMRI etc.) Eye tracker system has an uncomplicated methodology and implementation process.	Eye tracking systems can be used for free from a location with wired and wireless options. However, determining the attention level and attention orientation of a single person in the field of management organization where interpersonal interaction is a priority may not be sufficient for every research design. Also, an experimental design is often not replicated. Additionally, it is often impossible to repeat a study designed in a real-world environment by providing exactly the same conditions (Meißner and Oll, 2019).
GSR	Leardership (Balconi et al., 2019; Venturella et al., 2017)	GSR has an uncomplicated methodology and implementation process. Also, it is relatively cheaper than the other neuroscientific instruments.	To understand whether the level of emotional arousal measured is related to a positive or negative feeling, it should be used integrated with different instruments (Ayata et al., 2017).
Facial Coding	Leardership (Trichas et al., 2017; Trichas and Schyns, 2012)	Facial coding is an emotion recognition method conducted via software. In addition to its ease of use, it provides advantages to the researcher such as the absence of physical contact with the participant, the option to re-analyze by recording and practical analysis algorithms.	FACs coding methods are often questioned for reliability and validity (Skiendziel et al., 2019).
Voice Pitch	Organizational crisis communication (De Waele et al., 2019) Crisis response strategy (Klofstad, and Anderson, 2018)	Voice pitch analysis offers significant advantages in terms of not having to study face to face with the participants. Also, it is possible to use secondary data.	Sample-specific changes like phonetic, cultural and characteristic differences require a rich sound database to detect the targeted changes in terms of expected validity.
HR	Stress-performance (Akinola and Mendes, 2014) Leadership (Balconi et al., 2019; Venturella et al., 2017) Emotion in organizational behaviors (De Longis et al., 2020).	HR electrodes can be integrated into daily clothing and so heart rate variability can be captured in daily routines. HR software packages can be easily integrated with other physiological measurement instruments.	In order to provide specific information about the process experienced by the individual, HR must be used in integration with other neuroscientific methods. Electrodes that contacted the body may foreclose simulating real-life research (Shu et al., 2020).

Conclusion

In this study, we used various bibliometric tools and a systematic review to explain the evolutionary process of organizational neuroscience in the last twenty years. In the first step

of our bibliometric analysis, the results of publication trends on the topic of organizational neuroscience were presented in WOS from 2007 to 2020. In fact, in the first design of the research, the year 2000 was chosen as the starting year, as the first intersection of neuroscience and business disciplines. However, the first period of the research started in 2007, since there was no study in the field of organizational neuroscience until 2007. As a result, a total of 44 articles in the organizational neuroscience field were collected, followed by a thorough bibliometric analysis. Our findings in this step presented the number of publications over time (2015 is the most productive year), productive researchers (Lee, N.; Senior, C.), most cited researchers (Hodkingson, G.P.; Healey, M.P.) as well as the countries (the United Kingdom and United States) and journals with most impact (Strategic Management Journal, Journal of Long Range Planning) related to organizational neuroscience.

The second step of our bibliometric analysis is related to the evolution of the subject of organizational neuroscience which includes the change of conceptual themes and thematic areas in the last twenty years. During the period 2007-2010, there are few research themes to reflect the development process of organizational neuroscience. In this point, the main motor themes include terms of organization and workplace. These themes are related to the application area of neuroscience techniques in MOS. They also provide insight into organizational context and workplace behavior that can be explained from a neuroscience perspective. Organizational justice is an emerging theme in the same period. It has low density and centrality but our analysis showed that this theme returned to motor themes in the next period (2011-2020).

From 2011 to 2020, there were 12 research themes related to organizational neuroscience. This increase in research themes is an indication that organizational neuroscience has attracted more researchers in the last 10 years. Especially, six themes (motor and basic themes), which contributed to the development of organizational neuroscience, include organizational justice, commerce, cognition, decision-making, behavioral strategies and leadership studies. In addition to these themes, organizational transformation and strategic consensus are emerging themes which will provide new research streams for future research.

The final step of our reseach included a systematic review to understand the emprical development of organizational neuroscience. We collected our datas from WOS, Scopus and Google Scholars databases. A total of 42 empirical studies which used neuroscientific tools were evaluated on the basis of their metodologies and research topics. Several points are worth noting for future research.

Organizational neuroscience instruments have the potential to overcome the disadvantages of traditional research tools. Traditional methods are limited when reflecting participant emotions and the main reasons for their behavior. In other words, people have a tendency to hide their real emotions and thoughts because of social presuress. On this point, neuroscience tecniques provide more sensetive data processing againt the information retention tendency and remove the social pressure effect from the data collection process (Varnum, 2016).

According to our systematic review, leadership (Balconi et al., 2019; Maran et al., 2019; Gerpott et al., 2018; Molenberghs et al., 2017; Trichas et al., 2017) is the area in which these tecniques are most widely used. These researches show that neuroscience tecniques provide deeper knowledge about the cognitive process of leadership. This finding is also supported by our bibliometric results. In the period of 2011-2020, leadership is a dominant research theme. This theme also has sub-themes which include learning, knowledge, management, prosocial organizational behavior, organizational development and neuroleadership. We hope that the sub-themes of leadership will inspire future research to provide neurometric and viometric cues of leadership behavior and relations.

Our results suggests that organizational neuroscience provides a sound approach for future research topics such as the decision-making process and organizational justice. These topics also show parallelism with research themes in the period of 2011-2020. In addition to that, 42 empirical studies, which were determined in the literature review, show that EEG and fMRI are the most preferred instruments to research these themes. We hope that future research will use different neurometric and biometric tecniques such as GSR, EMG, hearth rate analysis, facial coding and voice pitch to provide more information about these themes.

Another result of our systematic review is related to the neuroscience devices that are not preferred by researchers. In the search process, we couldn't find any functional near-infrared spectroscopy (fNIRS) studies in the scope of organizational neuroscience. fNIRS, is an optical brain monitoring technique that uses near-infrared spectroscopy for functional brain imaging. Near-infrared light allows direct or indirect measurement of brain activity by measuring changes in blood flow in the frontal lobe of the brain. However, there has been an increase in the use of fNIRS methodology in different research fields such as marketing (Krampe et al., 2018; Liu et al., 2018), economy (Cheng et al., 2015; Wanniarachchi, 2020) and psychology (Lukanov et al., 2016; Al-Shargie et al., 2017; Porto et al., 2020). All these studies have indicated that fNIRS is an effective neurometric technique to explain workload, decision-making, and emotional and cognitive processes. Moreover, Pinti et al. (2020) pointed out that fNIRS has better spatial and temporal resolution compared with EEG. In support of this notion, we expect that future research will focus on the fNIRS methodology to explain leadership cognition, decision-making processes, and team relations.

In the empirical studies examined during the systematic review phase, it is noted that in general only one organizational neuroscience method is used at a time. There are quite a limited number of studies that use different integrated measurement techniques (Balconi et al., 2019; Venturella et al. 2017). In future research, integrated use of neurometric and biometric tools should be developed to establish a comprehensive perspective for organizational neuroscience.

Taken together, the major contributions of these bibliometric and systematic reviews are the results of examining the organizational neuroscience literature. These results offer the

researchers and scholars a guide to further explore the organizational neuroscience area and the methods. This study also states an important gap in empirical studies about organizational neuroscience which needs to be filled in the future. To the best of our knowledge, this is the first research that investigates the evolution of organizational neuroscience via bibliometric analysis and a systematic review process.

Several limitations must be considered when interpreting the findings of this study. Firstly, our bibliometric processed only the Web of Science database. Especially, SciMAT and Vosviewer tools retrieve only one data extension such as ISIWos, Pubmed, and Scopus in the analysis process. This situation prevents the analysis of different databases together. Nevertheless, future research could be focused on different databases such as Scopus, and Google Scholar, and they could be analyzed in an integrated manner to provide wider knowledge. Second, the literature review and bibliometric process are generated with the keywords "organizational neuroscience" and "organizational cognitive neuroscience" in their title, keywords, and abstract. However, this restriction is not adequate to capture the full information from the data. Apart from keywords, full texts should be included for a more comprehensive exploration. Finally, our data sources consist only of published articles, books, and chapters. Future researches should include multi-sources, such as doctoral theses and conference proceedings which would be more convincing.

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