Neuroscience approach for management and entrepreneurship: a bibliometric analysis

Valentina Cucino
Institute of Management and Department EMbeDS,
Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna, Pisa, Italy
Mariacarmela Passarelli
Department of Law and Business Science, University of Calabria, Rende, Italy
Alberto Di Minin
Institute of Management and Department EMbeDS,
Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna, Pisa, Italy, and
Alfio Cariola
Department of Business and Law, University of Calabria, Rende, Italy

Abstract

Purpose – This study focuses on the role of individuals in the innovation management process, by concentrating on leaders and associated behaviors. Specifically, Entrepreneurial Leadership (EL) represent one of the most important fields of innovation management that has become increasingly multifaceted and interdisciplinary with its evolution. Thus, the purpose of this study is to examine a newly emerging research trend with a new lens that is “neuroscience”.

Design/methodology/approach – This paper finds an evidence-based roadmap by reviewing the literature with a quantitative Bibliometric Analysis (BA) employing Co-Citation (Co-C) and bibliographic coupling analysis (BcA) to find linkages between the leadership and entrepreneurship literature and the neuroscience literature.

Findings – This study identifies five promising groups of research areas such as the organizational approach, the biological approach, the cognitive approach, the emotional approach and it identify five future research topics such as dynamic skills in innovation exploitation process, the human aspect of leadership, the building process of leadership, the biological perspective of leadership and the application of neuroscience in the ecosystem. Moreover, we find an evidence-based roadmap for stimulating focused EL within the broad topic of innovation management research, to move the field forward.

Originality/value – Although the past few years have observed the necessity of review studies on the subsets of biological factors, no reviews have sought to bring those different subsets together into a broader biological perspective. This study provides important indications on the interdisciplinary developments between the neuroscience aspects and EL, as a new emerging paradigm within the broad field of innovation management.

Keywords Bibliometric analysis, Biology, Entrepreneurs, Leadership, Neuroscience, Innovation management

Paper type Research paper

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1. Introduction

Innovation management is driven by the realization that innovation is a key factor in the competitiveness and survival of an organization (Akbari et al., 2020b; Ort and van der Duin, 2008). Indeed, it is an organizational activity relates to changes, where managers establish new processes and new activities, while leaders define new directions and motivate people (Hamel, 2006; Kotter, 2008). In this study, we focus on the role of individuals in innovation management processes, by concentrating on leaders and associated behaviors (Sjödin et al., 2019; Zuraik and Kelly, 2019). Due to their prominent role within organizations, in fact, leaders affect organizational conditions under which innovation management may be generated and implemented (Crossan and Apaydin, 2010; Alblooshi et al., 2020). Innovation management and entrepreneurship are a combination of the two is vital to organizational success and sustainability in today’s dynamic and changing environment. Innovation and entrepreneurship are not confined to the initial stages of a new venture, rather, they are dynamic and holistic processes in entrepreneurial and innovative organizations (Zhao, 2005).

In this perspective, various studies have considered leadership as one of the organizational attributes underlying change and innovation (Alblooshi et al., 2020; Kremer et al., 2019; Zuraik and Kelly, 2019). Leaders may impact innovation management by reducing uncertainty and complexity associated with its pursuit (Birkinshaw et al., 2008; Zuraik and Kelly, 2019) by improve employees’ innovation work behavior in the context of knowledge-based firms (Bagheri et al., 2020) by communicating a shared vision, supporting change, and innovation climate (Afsar and Umrani, 2020). Leaders are key individuals within organizations that are instrumental in identifying new trends in the environment and needs within the organization for which innovation management may be desirable (Bagheri et al., 2020). They would also be particularly important in supporting initiatives related to changing practices, processes, or structures (Alblooshi et al., 2020). Thus, the role of leadership has been found to be relevant in different fields, especially in entrepreneurship.

Within the wide literature of innovation management, several authors have focused on the concept of Entrepreneurial Leadership (EL). EL is “leadership role performed in entrepreneurial ventures, rather than in the more general sense of an entrepreneurial style of leadership” (Leitch et al., 2013, p. 348). EL is an emerging paradigm that has received increased attention from both scholars and professionals due to its importance in improving innovation, competitiveness, success and growth of public or private organizations (Akbari et al., 2020a; Bagheri and Akbari, 2018; Bagheri et al., 2020; Iqbal et al., 2020; Leitch et al., 2013). Fontana and Musa (2017) analyze how EL fosters all elements in the intellectual property (i.e. idea generation, idea development or idea diffusion). Bagheri et al. (2020) argue that CEOs’ EL improves their employees’ innovation work behavior through enhancing their individual and team creativity self-efficacy. More concretely, an organization with EL would have a more effective innovation process (Bagheri and Akbari, 2018; Bagheri et al., 2020).

In turbulent and uncertain environments, entrepreneurial leaders recognize new opportunities and drive firms innovation and growth (Akbari et al., 2020a). However, in addition to the ability to transform these opportunities into innovative ideas, entrepreneurial leaders manage innovation the process of recognizing opportunities in their business, thus overcoming the challenges of the context (Bagheri, 2017; Bagheri and Akbari, 2018; Bagheri et al., 2020). Indeed, EL is a unique leadership style that focuses on making heterogeneous talents work in an organization more creatively and innovatively in collective processes to respond to an uncertain business environment (innovation management process) and to create coherent strategies and novel outcomes (innovation management performance) (Fontana and Musa, 2017).

The cross-disciplinary research and practice in innovation management are imperative to productively and efficiently contribute to the overall firm’s activities (Ort and van der Duin, 2008). It is recognized in the innovation management literature that entrepreneurial leaders
have distinctive attributes and qualities that derive from individual characteristics (Bagheri and Harrison, 2020). Thus, as suggested by some studies, research on EL could be enriched by an interdisciplinary approach (Harrison et al., 2018; Stead and Hamilton, 2018). More concretely, in this context, neuroscience studies could advance research on EL because it manages to explore the neurophysiological substrates of mental processes and corresponding behaviours (Massaro et al., 2020). In particular, neuroscience studies could link unobserved mental constructs (e.g. loss aversion with physiological events) (Powell, 2011) through new methodologies (Waldman et al., 2017; Lerner et al., 2020).

The literature on neuroscience applied to entrepreneurship is extensive and several studies on the subject can be found in many journals and business subfields (Nofal et al., 2018; Shane, 2009; Shane et al., 2010; Nicolaou and Shane, 2014) including EL. However, most studies based on different methodologies have a variety of views. In fact, these studies cannot generate an overall analysis of the topic and they do not allow to identify in a structured way the different future research trends in the field of managerial innovation. However, most studies based on different methodologies have a variety of points of view. For example, some studies only conducted brain research. In particular, Massaro et al. (2020) using functional neuroimaging to study entrepreneurial behaviors leaving out the biological approach while Powel (2011) analyze the potential contributions of brain research to strategic management but not in the specific field of entrepreneurship. Similarly, although Waldman et al. (2017) discussed leadership in neuroscience through qEEG assessment an extensive review on the topic is still missing.

Furthermore, other studies have used genetic predispositions. For example, Nicolaou and Shane (2014) investigate how genetic factors may influence the tendency of people to engage in entrepreneurial activity. Johnson (2009) and Nicolaou and Shane (2009) examined genetic predispositions to activity entrepreneurship through quantitative genetic studies on twins only. However, these studies are exploratory and consider a single aspect of the neuroscience domain.

Finally, Nofal et al. (2018) carry out a critical review of the intersection of biology and management, but it is not exhaustive regarding entrepreneurship field.

Moreover, as mentioned by Shane (2009, p. 67): “Much of this research has been published in journals that management scholars do not routinely follow and the different studies themselves have been isolated from each other” so it is it became problematic to interpret the results of the studies. Consequently, the literature needs a deep theoretical analysis to explores EL from the point of view of neuroscience, investigating its development in the entrepreneurship literature (Moore et al., 2019).

Therefore, to fill this gap in the literature, this study uses bibliometric methods and visual maps to show an extensive structured review of the literature on EL and neuroscience. More concretely, the aim of this study is to examine the main works investigating EL and neuroscience literature in order to identify the new emerging research trend by proposing an evidence-based roadmap for stimulating research on EL in innovation management research.

Based on these arguments, this study addresses two research questions:

**RQ1.** What main research areas are covered by the literature focusing on neuroscience and EL, within the management field?

**RQ2.** What are/should be the theoretical foci for the current/future literature on EL, within the management field?

To achieve our goals, we conduct a quantitative Bibliometric Analysis (BA) employing co-citation (CoC) and bibliographic coupling analysis (BcA) to find linkages between the leadership and entrepreneurship literature and the neuroscience literature. BA is a tool that complements systematic reviews of the literature. BA, through objective analysis techniques,
strengthens the systematic analysis. This type of analysis enables an in-depth assessment of the advanced literature and has been used in entrepreneurship (Lampe et al., 2019) and leadership fields (Alblooshi et al., 2020; Iqbal et al., 2020). However, according to our knowledge a literature lack of a BA combining the literature on entrepreneurship and neuroscience. Standing form this gap our review analyzed the two different literatures with the leas of neuroscience. More concretely, through the CoC we identify five research areas that we strengthen through the BcA analysis. More concretely, by applying BcA analysis we deepen the analysis of our first clusters related to CoC analysis and thus we identify five future research clusters.

Thus, our analysis highlighted a considerable number of research on the neuroscientific aspects of leadership in entrepreneurship, identifying (1) five clusters representative of current research areas of interest, mainly related to the studies of the nervous system in EL research, such as organizational approach, the biological approach, the cognitive approach, the emotional approach; and (2) five promising groups of research topics such as the dynamic skills in innovation exploitation process, the human aspect of leadership, the building process of leadership, the biological perspective of leadership and the application of neuroscience in the ecosystem.

The remainder of this paper is organized as follows. Section 2 describes the theoretical background of the study, illustrating the relevance of neuroscience in entrepreneurship studies. Section 3 provides details on the study’s research strategy and design. Section 4 reports the study’s findings. Section 5 provides our concluding remarks, envisioning an agenda for further research.

2. Neuroscience in entrepreneurial leadership

Research in the innovation management field has adopted in the last ten years (2010–2020) an individual-based perspective by applying the organizational neuroscientific approach to entrepreneurial decisions. Indeed, although a first line of this research began examining genetic predispositions to entrepreneurial activity through quantitative genetic studies of twins in 2009 (Johnson, 2009; Nicolaou and Shane, 2009), the first associations that analyze how biological parameters can influence the identification of the opportunity or starting a business are made in 2010. Thus, since 2010, the integration of these research fields has generated new strands of research in various management sub-fields (e.g. Nicolaou et al., 2011; Waldman et al., 2011b; Wenerfelt et al., 2012).

More concretely, neuroscience contributes to innovation management research and in particular in entrepreneurial field in several ways (de Holan, 2014; Nicolaou and Shane, 2014). First, neuroscience may help us understand how rational and emotional aspects of entrepreneurs’ decision-making are related to the functioning of entrepreneurs’ brain (Nicolaou and Shane, 2014). By investigating neural mechanisms based on decisions (Mitchell et al., 2014), neuroscience addresses the individual level of entrepreneurship. In particular, it analyzes how entrepreneurs think, and identify and manage opportunities (Mitchell et al., 2007). Second, neuroscience helps us clarify how emotional elements such as “passion” or “volition” influence entrepreneurs’ decision-making (Hikkerova et al., 2016), entrepreneurs’ behavior (Foo, 2011), identification of new entrepreneurial opportunities (Baron and Enssley, 2006; Patel and Fiet, 2011), and how the entrepreneurial cognitive process is carried out (Hayton and Cholakova, 2012; Moore et al., 2019). Third, neuroscience through neurofeedback interventions (Waldman et al., 2011a) can advance the study of leadership for a better understanding of the different leadership styles (Waldman et al., 2020) and the cognitive mechanisms that underlie a leadership style (Bagheri et al., 2020; Iqbal et al., 2020), also helping the understanding of ethical dynamics (Lindebaum, 2013). Fourth, neuroscience addresses various aspects of the biological perspective (Bönte et al., 2016), helping scholars
understand how genetic components impact both the identification of business opportunities (Nicolaou et al., 2009) and the tendency to set-up a business (Bönte et al., 2016; Nicolaou et al., 2008). Moreover, a physiologic approach, which examines the role of hormones, helps management researchers explore how individual differences in testosterone levels are correlated with, for example, innovation management and entrepreneurship (Bönte et al., 2016).

Therefore, further research is required in the innovation management literature to investigate possible future developments in neuroscience research combining entrepreneurship and leadership (Figure 1).

The contributions of neuroscience in management have questioned the various scholars on the different hypotheses of use of neuroscience (Massaro et al., 2020) and in particular whether the use of neuroscience in entrepreneurship research must be considered a field in its own right (Krueger, 2007), if instead the use of neuroscience must be considered a field within the biology of the business framework (Nofal et al., 2018), or whether it is to be incorporated into organizational neuroscience (Waldman et al., 2017). Thus, this study aims to reduce the fragmentation in innovation management and entrepreneurship research by highlighting the relevant evidence in research on entrepreneurship and future lines of research.

3. Bibliometric analysis
3.1 Methodology
Our paper adopts a BA to answer the proposed research questions. Several scholars in the field of innovation management (Akbari et al., 2020b; Suominen et al., 2019), entrepreneurship (Ferreira, 2018; Lampe et al., 2019), and neurosciences (Gómez et al., 1990) have recognized the importance of BA. More concretely, BA is a tool that complements systematic reviews of the literature. BA, through objective analysis techniques, strengthens the systematic analysis.

BA allows us to identify influential authors and reveal their interrelationships (Ferreira, 2018). This approach is based on the statistical analysis of scientific documents and relative citations. This type of analysis allows us to identify the level of expansions in a specific research field and future research trajectories. More concretely, there are two different methods of analysis of citations are used to identify publications in a specific research field.
The first method is CoC analysis, which is employed when two documents are cited independently in one or more documents (Small, 1973).

The second method is BcA, which is used when two documents refer to a third common documents in their bibliographic graphs, indicating the probability that these documents linked topic. The “coupling strength” of two given documents is greater according to the number of citations to other documents they share (Ferreira, 2018; Kessler, 1963; Martyn, 1964).

BcA and CoC analysis are complementary. More concretely, the simultaneous use of BcA and CoC allows a more accurate analysis of the literature. Indeed, in a database where links are restricted, BcA analysis clustering the latest documents and only a limited number of very old papers, while CoC clustering clusters the eldest documents, without clustering newer documents that have not yet been cited.

3.2 Data collection
We have created an ad hoc protocol to perform BA (Ferriera, 2018). The selection of articles occurred in three steps. First, we selected the query. The proposed search strategy was based on a structured query, implemented using an extensive citation database. The query was designed to meet the purpose of this paper. Second, the database was selected. The citation database required for the purposes of our research was mindfully selected to reduce the risk of neglecting any pertinent scientific contribution. We used Elsevier’s Scopus because (1) it is one of the largest citation databases in the world; (2) it indexes around 70 million documents since 1788 and (3) covers various subject areas, ranging from biological sciences to management and social sciences (Cavallone and Palumbo, 2020). Moreover, the Scopus database includes data on academic publications, including affiliations and citations. The authors referred to Scopus because it includes the greatest number of indexed publications. The query was adapted to the certain attributes of the search engines included in each scientific database. Specifically, the query (TITLE-ABS-KEY ("neuroscience" AND "entrepreneur*") OR TITLE-ABS-KEY ("neuroscience" AND "leadership") OR TITLE-ABS-KEY ("neuroscience" AND "management")) was searched in the Scopus database. This search strategy identified 3,394 articles (2020, October).

Third, we set the exclusion criteria. We imposed no limitation in the research strategy relating to the year of publication or classification of document. This criterion was adopted by the authors to be exhaustive in the search for scientific contributions. The only two limitations allowed were the choice of language and categories. The English language was chosen because it is the official language for research that meets the international standards. This search strategy identified 3,262 articles. The categories “social science”, “management” and “business” were used because they best describe the field of investigation. The final sample comprised 396 scientific articles. Thus, following Ferreira (2018) and we present a BA based an analysis of 396 documents.

More concretely, our analysis aims to identify (1) the main articles relating to neuroscience in entrepreneurship; (2) the most influential players in the sector; (3) the respective networks of authors; and (4) possible future research developments in the field.

3.3 Data analysis
The first step of BA is identifying the tools. Two tools were used in this study. The first was the VOSviewer software (www.vosviewer.com). VOSviewer allows the construction and visualization of bibliometric networks, with magazines, researchers, based on common citations, BcA, or paternity relationships (Van Eck et al., 2010). VOSviewer builds a map based on a three-phase recurrence matrix: (1) a “similarity matrix”, to apply mapping method (Waltman et al., 2010) using the strength of the association; (2) a mapping method, to build a
map that reflects the extent of similarity between objects (Van Eck et al., 2010); and (3) translation, rotation, and reflection, to correct the optimization problem described in the literature (O’Connell, 1999).

The second tool was Bibliometrix, an R package for running extensive science mapping analysis which allows authors to perform analyses and graphs for sources, author, and document level and for conceptual, intellectual and social knowledge structures (Aria and Cuccurullo, 2017).

4. Findings

4.1 Descriptive analysis

In the following section we report the descriptive statistics of the database obtained from Bibliometrix. The database includes 424 documents for a total of 848 authors (2.4 authors per document). The database comprises articles (256), books (30), book chapters (46), conference papers (297), and conference reviews (4). To avoid excluding potentially essential documents (even if unpublished), short surveys (1), notes (8), and reviews (41) were also included. The reference period covers 2010 to 2020 (Table 1).

Since the 2000s, topics such as education, mental health services, and methodological issues have received increasing attention. However, since 2010, the most widely covered topics have converged toward cognitive, managerial, and decision-making issues. Thus, the integration of these research fields has generated new strands of research in various management sub-fields (e.g. Nicolaou et al., 2011; Waldman et al., 2011b; Wernerfelt et al., 2012). Moreover, in those

| Description                        | Results |
|------------------------------------|---------|
| Documents                          | 424     |
| Sources (journals, books, etc.)    | 291     |
| Keywords plus (ID)                 | 1,327   |
| Author’s keywords (DE)             | 1,132   |
| Period                             | 2010–2020|
| Average citations per documents    | 13.2    |
| Authors                            | 923     |
| Author appearances                 | 1,073   |
| Authors of single-authored documents | 143   |
| Authors of multi-authored documents | 780   |
| Single-authored documents          | 166     |
| Documents per author               | 0.459   |
| Authors per document               | 2.18    |
| Co-authors per documents           | 2.53    |
| Collaboration index                | 3.02    |

| Document types | Results |
|---------------|---------|
| ARTICLE       | 256     |
| BOOK          | 30      |
| BOOK CHAPTER  | 46      |
| CONFERENCE PAPER | 29   |
| CONFERENCE REVIEW | 4   |
| DATA PAPER    | 1       |
| EDITORIAL     | 4       |
| ERRATUM       | 2       |
| LETTER        | 2       |
| NOTE          | 8       |
| REVIEW        | 41      |
| SHORT SURVEY  | 1       |

Table 1. Documents description

Neuroscience approach for management
years, a study of Cropanzano and Becker (2013) was published that analyzed organizational neuroscience by analyzing three aspects (1) the contemporary technical state of modern neuroscientific tools (2) the ethical implications of future investigations, including the possibility that neuroscience can enrich and improve life of people and (3) a more open ethical aspect that considers not only the pros but also the cons of neuroscientific analyzes.

4.2 Co-citation analysis

From the 396 sampled articles, we obtained 25,215 cited references. In line with Eom (2009), we used a minimum threshold of four citations of a cited reference, obtaining 87 articles, five clusters, and 852 links. The CoC analysis reveals five clusters that represent the research topics of interest (see Figure 2).

4.2.1 Red cluster – “organizational approach”. Studies related to this cluster explore behaviors within organizations through the lens of neuroscience. More concretely, the application and implications of brain science are being studied to analyze behavior (Becker and Cropanzano, 2010; Becker and Menges, 2013; Raichle and Snyder, 2007) and strategies (Powell, 2011) in organizational settings. Organizational neuroscience holds great promise for the advancement of organizational research and practice (Lee et al., 2012; Powell, 2011; Senior et al., 2011) because it investigates the neural mechanisms involved in perception, attention, categorization, memory, attitudes, language, emotional regulation, executive function, decision making (Cacioppo et al., 2008) Although it has developed rapidly, it is the subject of methodological challenges that must be considered when conducting research in neuroscience applied to organizational behavior, such as the need to address the methodological and technological challenges of research (Ashkanasy et al., 2014). However, several studies nowadays have focused on applying neuroscience to organizational theories. This phenomenon has generated a substantial increase in the number of applications of neuroscience to organizational contexts (Becker, 2011; Senior et al., 2011), in particular on leadership. In particular, several studies have addressed the role of leaders in firms through the lens of neuroscience (Lee et al., 2012). Some studies have analyzed the visionary behaviors of leaders through the quantitative electroencephalogram (Waldman et al., 2011a). The use of the electroencephalogram has become widespread due to its temporal accuracy.
Other studies have extensively analyzed the implementation of neuroscience as a tool for human resource leadership, particularly with regards to the behavior of human resources in innovation management (Becker et al., 2010, 2011). Other studies analyzed the genetic influences of leaders and found that we found that genetic influences are stronger for those twins who had relatively poorer social environments (Zhang et al., 2009).

4.2.2 Green cluster – “new emerging paradigm on leadership research: the biological approach.” Studies within this cluster analyze insights from social neuroscience to explore new paradigms in leadership research. Indeed, insights from social neuroscience may offer a more embodied and socially situated view of cognition in leadership (Healey and Hodgkinson, 2014; Senior et al., 2011). The human ability to make decisions and implement long-term goal-oriented behaviors depends on the planning system (Becker et al., 2011), which can select the action that should produce the expected results (Becker and Cropanzano, 2010). Conversely, habit-based decision making resides in older brain structures and involves much slower learning. Indeed, habit systems push managers to continue past entrepreneurial behaviors and give up new innovative actions (Becker and Cropanzano, 2010) because this system automatically matches situations to actions based on previous experience. However, some neuroscience studies show how to overcome these entrepreneurial difficulties. For example, Becker and Cropanzano (2010) suggest reversing the “status quo” to start a conscious planning system. Indeed, the achievement of challenging objectives can undermine the status quo by modifying the decision-making process and the habits of the entrepreneurial system (Becker and Cropanzano, 2010).

The second area of research focuses on the relationship between intuition and decisions that guide behavior. Authors within this group seek to link different discourses, ideas, methods and discoveries that contain analyzes of cognitive neuroscience and organization theory (Bulter and Senior, 2007; Senior et al., 2011). Indeed, within these studies, new approaches emerge ranging from ethical studies to biology studies to explain the implications that neuroscience has in leadership (Lee et al., 2012; Farah et al., 2005). In particular, some studies have analyzed the role of neuroscience in influencing inspirational leadership (Waldman et al., 2011a), premature leadership (Lindebaum and Zubdel, 2013) and the differences between transformational and non-transformational leaders (Balthazard et al., 2012).

Although within this cluster the potential of neuroscientific methodologies is highlighted (Aston-Jones and Cohen, 2005) some authors advise caution in the use of neuroscience as an application to evaluate the behavioral and decision-making processes of entrepreneurs due to moral problems related to “application of neuroscience in leadership studies” (Ashkanasy et al., 2013, 2014).

4.2.3 Purple cluster – “cognitive approach”. In the purple cluster, neuroscience is studied as a tool for analyzing the decision-making process of entrepreneurial leaders. In particular the studies in this cluster the decision-making process is understood as the decisions that affect the organizational results, the strategic choices and the performance levels of innovation managers and leaders (Hambrick and Mason, 1984). More concretely, all choices aimed at identifying new opportunities and organizing themselves effectively and efficiently to welcome them fall within the notion of decision-making process (Teece, 1997). In this cluster, three areas of interest to both economists and psychologists are examined through innovation management research: (1) decision making under risk conditions (Loewenstein et al., 2008) and uncertainty (2) intertemporal and social choice (Lieberman, 2000, 2007) and (3) decision making (Loewenstein et al., 2008; Kahneman and Klein, 2009). In particular, some studies highlight the potential of the study of neuroscientific research with respect to psychological applications (Hodgkinson and Healey, 2011) by emphasizing the application of neuroscience as an evolutionary tool for the psychological analysis of individuals (Hodgkinson et al., 2009).
4.2.4 Yellow cluster – “emotional approach”. Although we have identified a specific cluster in the study of emotions in entrepreneurial processes, the central focus of the yellow cluster is the study of cognitions in the entrepreneurial decision-making processes of leaders.

Decisions in a complicated situation require explicit reasoning and guided decision making (Bechara et al., 1997). However, explicit reasoning is preceded by an unconscious phase that uses neural systems other than those that support declarative knowledge. In other words, reasoning is knowledge-driven (Dane and Pratt, 2007).

Cognitions play an important role in influencing the behavior and characteristics of leaders and are believed to influence organizational learning, tacit learning, information seeking, entrepreneurial decision making, creativity, and innovation management. Understanding how cognitions work can help leaders make more appropriate decisions in management (Hodgkinson and Sparrow, 2002; Zajonc, 1980; Ericsson and Charness, 1994).

In the field of cognition, some studies have focused on the role of bias and how it can help decision-making by ensuring beneficial behavior (Bechara et al., 1997), others have focused on intuitions as a guide to judgment (Bowers et al., 1990). Other studies have focused on the role of emotional intelligence, highlighting its potential for behavioral choices (Landy, 2005) but also underlining its inadequacy for leadership studies (Locke, 2005).

Finally, other studies have discussed how cognitions drive insights (Bowers et al., 1990). In this case, we define intuition as “the ability to understand or know something immediately, without conscious reasoning” (Oxford English Dictionary). In this area, some authors investigate how insights drive decision making (Dane and Pratt, 2007), while others discuss how insights lead to informed judgment in the context of discovery (Volz and Cramon, 2006).

4.2.5 Blue cluster – “brain approach”. The main focus of the purple cluster is the EL in neuroeconomic experimental study. Several studies have proposed a neural model for economic decisions (Bechara and Damasio, 2005). Neuroeconomics uses knowledge of brain mechanisms to inform economic analysis and fuses economics with biology (Ochsner and Lieberman, 2001).

Neuroscientists use various tools to provide behavioral explanations, including brain imaging, animal behavior, and recording of individual neuronal activity (Posner and Petersen, 1990; Rizzolatti and Craighero, 2004). Many authors use functional neuroimaging techniques (eg, BrainMap) to better understand the functioning of the brain in the cognitive process (Poldrack, 2006), predict decision-making processes (Knutson et al., 2007), study how emotions affect the decision-making and behavior (Foo, 2011). Other authors emphasize the role of biological applications in influencing entrepreneurial innovative actions in conditions of uncertainty (Shane and Venkataraman, 2000). Within this cluster, some studies have discussed how neuroscience can take part in economic research. Indeed, Camerer et al. (2005) discuss how simple rational choice models are useful for understanding the Bayesian integration of sensorimotor information, while Cohen (2005) discusses applications to game theory. Finally, other studies have suggested neuromarketing as an application for managerial practice (Hubert and Kenning, 2008).

4.3 Bibliographic coupling analysis
CoC data were used to identify scientific publications and research trends (Ferreira et al., 2018) interrelated with neuroscience, entrepreneurship and management. However, to provide future research directions, we strengthen our first CoC results through the BcA analysis. Studies show that BcA techniques can be used to identify “hot” research topics (Glänzel and Czerwon, 1996). Therefore, the second step of the analysis was to perform BcA.

In line with Di Stefano et al. (2010), we applied a minimum number of citations of 20 documents. From 424 documents in our database, the software extracted 66 documents. In the network, 16 documents were not connected to each other. The largest set of connected
items consisted of 49 documents. The total strength of the bibliographic links coupled with other documents was evaluated. Documents with the maximum total link strength were selected.

In particular, **Figure 3** provides a detailed description of research trends. More concretely, we have clustered the 396 identified articles into five broader research fields based on their theoretical approach and research aims. In **Figure 3**, the results show five larger research areas (Glänzel and Czerwon, 1996).

4.3.1 **Purple cluster** – “dynamic skills in innovation exploitation process”. The purple cluster includes studies that cover the strategy creation and exploitation process within the innovation management perspective. Some studies provide an understanding of how managers’ minds manage the exploration-exploitation dilemma (Laureiro-Martínez et al., 2010).

The ability to detect, capture and transform knowledge requires that managers have cognitive and emotional skills (Hodgkinson and Healey, 2011). Understanding dynamic skills in terms of entrepreneurial cognition and motivational antecedents and how individual action and interactions affect performance is at the heart of this cluster (Foss and Pedersen, 2016). In the strategic management literature, for example, the cluster highlight that the executive judgment and strategic decision making have foundations in psychology (Hodgkinson et al., 2009). The use of neurostrategies to explain behavioral dynamics in the formation of the strategy and dynamic skills of leaders plays a fundamental role in the innovation management literature (Foss and Pedersen, 2016). Powell (2011) analyzes the intersection between strategy and neuroscience highlighting its potential, while Hodgkinson and Healey (2014) analyze the implications of neuroscience arguing that dynamically capable leaders succeed in stimulating radical innovation. However, most current studies are based on a cold logic that downplays the significance of cognitive processes for strategic adaptation (Hodgkinson and Healey, 2011).

Due to the increased use of neurophysiology techniques in psychology and economics and the continued use of functional magnetic resonance, several researchers have begun to discuss the implications of neuroscience for entrepreneurial and innovation management studies (Healey and Hodgkinson, 2014).

Through these techniques and a multidisciplinary approach, various studies belonging to this cluster propose a different way of combining research in neuroscience, psychology and...
management to advance knowledge of the micro-foundations of managerial decision-making (Laureiro-Martínez et al., 2010).

4.3.2 Green cluster – “neuroscience in human aspect of leadership”. The red cluster highlights the human approach of leadership by focusing on the study of emotions. Studies within this cluster emphasize the role of affect and cognition as an integral part of entrepreneurial rationality (Hayton and Cholaková, 2012; Kenning et al., 2007) in innovation management (Pech and Cameron, 2006) and analyze the neuroscience perspective to support analysis (Becker and Cropanzano, 2010; Lee et al., 2012). Through traditional methodological tools, it is not possible to understand how the mind of the leader transforms knowledge or experience into decisions, or how such knowledge may or may not lead to actions, happy or not (de Holan, 2014). One solution could be to use the tools of neuroscience and in particular the brain to examine how leaders use their knowledge and experience to make decisions (de Holan, 2014; Beugré, 2009). Through a multidisciplinary approach, some studies show that a greater understanding of tacit knowledge can be achieved by integrating neuroscience, evolutionary biology and psychology (Waldman et al., 2011a, b). For example, by integrating affective neuroscience and biology, some authors offer a more holistic approach to leadership development, showing how leaders should emphasize coaching as a fundamental part of their role and behavioral habits (Boyatzis et al., 2006, 2012). Other studies use neuroscience to investigate the cognitive processes underlying the recognition of entrepreneurial opportunities (Pech and Cameron, 2006). Finally, some studies focus on the emotional intelligence of entrepreneurs to identify links between the emotional intelligence of leaders and the results of followers (Antonakis et al., 2009).

4.3.3 Yellow cluster – “building process of leadership”. The leadership training process is studied within the yellow cluster. More concretely, within this cluster, neuroscientific theories are analyzed to understand the formation of the decision-making process of leaders both from a managerial and organizational point of view (Hodgkinson et al., 2009). In particular, to understand the formation of decision making, the neuroscientific and evolutionary basis of the behavior of leaders (Lo, 2004) and the behavior of leaders from a biological point of view are analyzed through advances in cognitive neuroscience (Lee, 2012). Further studies instead focus on tacit knowledge. In particular, Bennet and Bennet (2008) explores the concept of tacit knowledge by providing a new model of information and knowledge consistent with neuroscience. Other studies analyze what pushes leaders to make a moral choice and to put it into practice (Moore and Gino, 2015). Moore and Gino (2015) in particular highlight how intuition, affection, physiology and identities support and inform a more deliberative reasoning process in the construction and implementation of moral behavior and we then describe how these processes affect the choices of leaders in carrying out their actions. Finally, a group of studies analyzes the effects of neuroscience through studies on the brain (Spring, 2012).

4.3.4 Red cluster – “biological perspective of leadership”. Neuroscience can significantly aid the advancement of organizational research and practice. However, its rapid development has also generated technological and methodological challenges. Therefore, the red cluster seeks to sensitize researchers to the moderate use of neuroscience techniques to study the leadership dynamics and behavioral habits of leaders within organizations (Lindebaum and Jordan, 2014). Therefore, (Ashkanasy et al., 2014), propose a roadmap to enable researchers to advance multidisciplinary research on organizational behavior through a neuroscientific approach based on the moderate use of neuroscience techniques. In this cluster, we consider the ethical implications of future investigations of innovation management (Lindebaum and Zundel, 2013) through a constructive approach, considering the possibility that neuroscience can enrich and improve the lives of leaders (Cropanzano and Becker, 2013).

Studies within this cluster emphasize the applications of neuroscience to the study of premature leadership (Lindebaum et al., 2013), the differences between resonant and
dissonant leaders (Boyatzis et al., 2012) and encourage interaction with neuroscience for a Greater understanding of international affairs (Tenzer et al., 2017).

Within this cluster emerges a new approach to the study of neuroscience for innovation management studies. The new approach is a biological approach, an approach that analyzes biological dynamics through the study of the hormones of leaders (Nicolau et al., 2018; Butler et al., 2016; Nofal et al., 2018). In particular, research in this regard has begun to investigate the influence of testosterone, which is known to be associated with aggression and proactivity (Nicolau et al., 2018) highlighting how testosterone is associated with the likelihood of undertaking an entrepreneurial activity (Nicolau et al., 2018). Other studies have looked at testosterone prenatals in same-sex and opposite-sex twins. Other research has instead analyzed the interaction of cortisol and epinephrine in business leaders (Wolfe and Patel, 2017). Finally, other studies have examined how the creativity of business leaders increases with physiological recovery during nocturnal sleep (Weinberger et al., 2018).

4.3.5 Blue cluster – “application of neuroscience in the ecosystem”. The future trend emerging from the blue cluster is related to the application of neuroscience to the social sciences. The study of brain sciences is influencing the current understanding of human behavior by bringing out a neurobiological “colonization” of social and human sciences (Rose and Rached, 2013). New neuroscience-based thinking styles create different applications in the social and political context (Rose and Rached, 2013). Neuroeconomic neuropsychiatry, neurotheology and neuroaesthetics are just some of the possible applications of neuroscience.

On the social side, some studies focus on personality disorders (Pickersgill, 2011), highlighting the potential of neuroscience to translate and improve also clinical practice. Other studies analyze the role of empowerment, self-realization and discipline as dynamics that influence leadership behaviors (Thornton, 2011). Finally, some researches address neuromarketing (Kumar et al., 2013), highlighting how neuroscience is increasingly considered a possible basis for new business and management practices (Schneider and Woolgar, 2012), especially in the innovation management field.

Within these studies, the development of new types of digitally mediated “biopedagogies” of body optimization, “psychopedagogies” of emotional maximization and “neuropedagogies” of brain enhancement emerge (Williamson, 2016).

From a political point of view, some studies use the neuroscience lens to understand neurobiological language within specific political contexts (Broer and Pickersgill, 2015), highlighting how neurobiological concepts can be used to construct and support a particular imaginary of citizenship and the role of the state.

5. Discussion and conclusions
Bibliometric analyzes allowed us to answer our research questions (RQ1: What main research areas are covered by the literature focusing on neuroscience and EL, within the management field? RQ2: What are/should be the theoretical foci for the current/future literature on EL, within the management field?). More concretely, several studies have considered leadership as one of the organizational attributes underlying change and innovation management (Elenkov et al., 2005; Peters and Waterman, 1984). Indeed, an organization with EL have a more effective innovation process (Bagheri and Akbari, 2018; Bagheri et al., 2020). EL is a quite promising paradigm that has been applied to beat the dynamic evolving of innovation ecosystem (Leitch and Volery, 2017; Bagheri and Akbari, 2018). EL has got consideration of both scholars as a crucial factor in innovation management strategies (Fontana and Musa, 2017; Bagheri, 2017; Bagheri and Akbari, 2018; Akbari et al., 2020a; Bagheri et al., 2020; Iqbal et al., 2020).

Leadership studies has become increasingly multifaceted and interdisciplinary with its evolution (Perruci and McManus, 2012; Yammarino, 2000). Among the various sciences that can enrich the understanding of the role of leadership, one that is still little researched is that...
of neuroscience. In particular, the basis for a new school of thought that incorporates neuroscience in the field of EL needs to be investigated (Nofal et al., 2018; Shane, 2009; Nicolaou and Shane, 2014; Shane et al., 2010).

This study used BA to investigate how neuroscience contributes to the field of EL, and more generally to the field of innovation management, by addressing the subfield of entrepreneurship and the process that encourages engagement in entrepreneurial actions. In particular, the proposed approach is in line with Moore et al. (2019), investigating how neuroscience contributes to the field of EL and more generally to the field of innovation management. Research and interdisciplinary practice in innovation management are indispensable to help productively and efficiently the overall functioning of a company (Ort and van der Duin, 2008). Thus, this study proposes a new approach that combines physiology and psychology to understand the fundamental and emergent properties of the brain. These highlights are consistent with the view proposed by Kandel et al. (2012) that the biological basis of learning, memory, behavior, perception, and consciousness represents the "ultimate challenge" for the biological sciences. During the 20th century, neuroscience began to be recognized as a distinct academic discipline, with relationships with biology and psychology. The modern neuroscience approach (Kandel and Squire, 2001) includes the emergence of the cellular and molecular neuroscience of signaling, a mechanistic view of brain development, the impact of neurology and psychiatry, a new alignment of neuroscience and psychological science, the neuroscience of cognition, and the bridging of cognitive neuroscience with molecular biology in the study of memory storage. In line with this modern approach, the analysis of BcA identifies new trends related to the application of biology to management and entrepreneurial issues. Future research will aim to conduct an explanatory study.

To the best of our knowledge, this is the first work to attempt to systematize the literature on neuroscience and EL, within the field of innovation management, by using BA. Specifically, by using CoC analysis, this study identifies the past trends in the literature in specific fields of neuroscience and entrepreneurship (Figure 2). By applying the BcA technique, the main research streams are consolidated, and new trends of investigation in the research field are identified (Figure 3).

To improve the current understanding of EL with the neuroscience lens, we synthesized the different ways through which previous research has conceptualized entrepreneurial organizations and analyzed how these are reflected in the literature through a BA.

5.1 Implications for researchers
This study contributes to EL and innovation management literature in different ways. First, by employing a BA, it contributes systematic insights into the evolution of neuroscience in EL and management field. This is the first study to propose a literature review that combines neuroscience and management literature using specific BA techniques recognized in several management disciplines (Akbari et al., 2020b; Suominen et al., 2019). Mapping the literature allows key research areas in the field to be identified, as well as the authors working in the field. This information is of great interest to both new and existing researchers, as it guides them in directing their work. The study consolidates the main research streams, providing a comprehensive overview of the field. It then attempts to identify the multifaceted and interconnected nature of the research area, outlining new emerging trends, thus encouraging further research advancements.

Second, it highlights several trends consolidated in the literature by using CoC analysis. Some consolidated trends emerge from the analysis of CoC and the temporal analysis. Five clusters are identified representing the current topics of interest, mainly related to studies of the nervous system in EL research, such as neurology, cognition processes, and brain mechanism processes.
Third, this study provides novel insights into the perspectives of the neuroscience field applied to entrepreneurship as a key driver for innovation management. More concretely, in this study we answer our RQ1 (i.e. What main research areas are covered by the literature focusing on neuroscience and EL, within the management field?) by identifying five main research areas covered by the literature focusing on neuroscience and EL in the management field. In particular, through the CoC we identify five research areas that we strengthen through the BcA analysis. Thus, we first identify five promising groups of research areas such as the biological approach, the brain approach, the social approach, the cognitive approach and the emotional approach. Moreover, as suggested by some authors (Bönte et al., 2016; Lerner et al., 2020), we have also applied neuroscience to EL and we discover future research trends. More concretely, by applying BcA analysis we deepen the analysis of our first clusters related to CoC analysis and thus we identify five future research clusters. In Table 2, we identify five hot research topics (Glänzel and Czerwon, 1996).

Thus, from the BcA, a multidisciplinary trend emerges, related to the application of the individual approach of neuroscience within the innovation management literature. Specifically, it comes out a specific cluster devoted to the application of neuroscience to the EL across the exploration-exploitation process of innovation (i.e. Dynamic skills in innovation exploitation process). The EL concept, in fact, could be considered a crucial aspect in all the organizations that deal with innovation management strategies as the study of

| Research topic                                      | Short description                                                                 | Representative articles                                                                 |
|-----------------------------------------------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Dynamic skills in innovation exploitation process   | These studies focus on the use of neurostrategy to explain the managerial         | Foss and Pedersen (2016), Powell (2011), Hodgkinson and Healey (2011),                  |
|                                                     | behavioural dynamics in the innovation                                           | Hodgkinson et al. (2009), Healey and Hodgkinson (2014), Laureiro-Martinez et al. (2010),  |
|                                                     | exploitation process                                                              | Hodgkinson and Healey (2011)                                                          |
| Neuroscience in human aspect of leadership          | These studies focus on the role of emotions and cognition as an integral part of  | Hayton and Cholakova (2012), Kenning et al. (2007), Becker and Cropanzano (2010),     |
|                                                     | entrepreneurial leadership                                                        | Bennet and Bennet (2008), Waldman et al. (2011a), Waldman et al. (2011a, b), Boyatzis et al. (2012),|
|                                                     |                                                                                  | Antonakis et al. (2009)                                                               |
| Building process of leadership                      | These studies focus on the use of neuroscience tools to study how entrepreneurs   | Hodgkinson et al. (2009), Lo (2004), Lee (2012), Bennet and Bennet (2008), Moree       |
|                                                     | use their knowledge and experience to make decisions                             | and Gino (2015), Spring (2012)                                                       |
| Biological perspective of leadership                | These studies focus on the use of biological perspective of entrepreneurship by   | Lindebaum and Jordan (2014), Boyatzis et al. (2006), Ashkanasy et al. (2014),           |
|                                                     | examining the role of hormones                                                    | Lindebaum and Zundel (2013), Cropanzano and Becker (2013), Lindebaum et al. (2013),    |
|                                                     |                                                                                  | Boyatzis et al. (2012), Tenzer et al. (2017), Nicolau et al. (2014), Butler et al. (2016), |
|                                                     |                                                                                  | Nofal et al. (2018)                                                                  |
| Application of neuroscience in the ecosystem        | These studies focus on brain sciences influencing understanding in the            | Rose and Rached (2013), Rose and Rached (2013), Pickersgill (2011), Kumar et al. (2013), |
|                                                     | entrepreneurial ecosystem in terms of social and political context                | Schneider and Woolgar (2012), Thornton et al. (2011), Williamson (2016), Broer and     |
|                                                     |                                                                                  | Pickersgill (2015)                                                                   |

Table 2. Future research trends
neuroscience can also support the study of the emotions and cognitions of leaders (i.e. *Neuroscience in human aspect of leadership*).

Moreover, the application of neuroscience can involve leaders operating in firms and in technology transfer offices. New insight can be offered, to define new exploitation strategies for knowledge, technologies and research result, and to enhance innovation performance. Furthermore, the application of neuroscience can support the leader in understanding the social context and, more generally, the ecosystem of the company or organization (i.e. *Application of neuroscience in the ecosystem*).

Thus, this study provides also important indications on the interdisciplinary developments between the biological aspects and EL as a new emerging paradigm of innovation management strategies (i.e. *Biological perspective of leadership*). In particular, the application of neuroscientific cognitive techniques to leadership research is one of the future trend topics that emerge most prominently in the BcA. Several studies have addressed the behavior of leaders from a biological point of view through the progress of cognitive neuroscience (*Bönte et al.*, 2016; *Lee*, 2012).

Finally, from a broad innovation management perspective, this study systematizes the research in the field, allowing current and potential entrepreneurs to access this knowledge and translate it into practice more easily (i.e. *Building process of leadership*). Future developments in research on innovation management may be achieved, with a focus on the role of EL across the innovation process phases (idea generation, selection, development and diffusion).

### 5.2 Managerial implications

The neuroscience perspective has also practical implications. First, it improves our understanding of how psychological traits influence entrepreneurs’ minds handle the exploration–exploitation dilemma that is a crucial issue in the innovation management field (*Greve*, 2007).

Second, it also enhances our understanding of the antecedents of cognition and motivational factors by showing that these are often influenced by neuroscience factors (*Foss and Nicolai*, 2016). The neuroscience perspective has some important implications also on the links between the emotional intelligence of leaders and the results of followers, through the innovation process (*Antonakis et al.*, 2009).

Other implications consider the biological perspective to examine the role of hormones in entrepreneurial decisions. Indeed, through the measurement of cortisol and functional magnetic resonance imaging, some authors analyze how the interactions of explicit and implicit processes is linked to modeling emotions, attitudes, and behaviors. This line of research would also have the potential to answer various enquiries in the opportunity recognition among academic entrepreneurs and innovation managers, to exploit new technologies and generate innovation from their research results.

Finally, neuroscience has several implications also on social and political science. Indeed, new styles of thinking based on neuroscience create different behaviors in the social context (*Rose and Rached*, 2013). From a political point of view, neuroscience can help to understand how neurobiological concepts can be used to build and support a particular imaginary of citizenship in pushing inventions across the innovation process (*Broer and Pickersgill*, 2015).

### 5.3 Future research directions

The research in this area is still puzzling. Neuroscience combines physiology, anatomy, molecular biology, developmental biology, cytology, mathematical modeling, and psychology to understand the fundamental and emergent properties of neurons and neural circuits. The understanding of the biological basis of learning, memory, behavior, perception, and consciousness, coherently with *Kandel et al.* (2012) affects all aspects of our behavior,
including our work. By ignoring our neuroscience aspects, management researchers are missing an important part of the explanation for managerial and entrepreneurial behaviors.

Scholars will need to address these issues in their study designs to encourage empirical researches able to improve the understanding of the neuroscience influences on entrepreneurial forward. This review has systematically provided a summary of what has been achieved in this area of research and has offered several directions to take the field forward. This area of research proposes several challenges: the challenges of conducting interdisciplinary research, the challenges to propose experimental researchers in the field of management and entrepreneurship, the challenge to propose specific researchers in the field of entrepreneurship, by using the different lenses of neuroscience (e.g. physiology, anatomy, molecular biology).

On this perspective, driven by the goal of responding to our RQ2 (i.e. What are/should be the theoretical foci for the current/future literature on EL, within the management field?), our review suggests several areas for future research.

First, more explanatory factors and more outcome variables should be examined empirically. The review shows that research in this area is characterized mainly by theoretical studies with limited empirical evidence. It is time to extend this area of research by proposing more empirical investigations, especially in the field of innovation management.

Second, in entrepreneurship, employing a biological viewpoint, is needed also to examine topics such as motivation (Krueger, 2007; Sarasvathy, 2004), entrepreneurial intention (Hayton and Cholakova, 2012; Lerner et al., 2020; More et al., 2019), entrepreneurs’ thinking styles, skills, and goal commitment (Bönte et al., 2016), innovation management and exploitation of technologies (Greve, 2007).

Third, it is doubtful that much entrepreneurial behavior is explained exclusively by human neuroscience. Most entrepreneurial actions are generated also by the interaction of human neuroscience variables and other exogenous factors (e.g. ecosystem); thus, further research should empirically explore how exogenous and neuroscience variables interact, to influence entrepreneurial behaviors.

Lastly, along with the individual level of analysis, additional research should also consider neuroscience techniques into the study of entrepreneurial teams and innovation development teams. Researchers are encouraged to use neuroscience techniques, such as qEEG, to examine the relations among entrepreneurs, such as their interpersonal conflicts and negative/positive affect (Waldman et al., 2017).

Nevertheless, limitations are taken into our study. The study covered a broad scope of literature with a neuroscience approach based on a specific search query. However, including additional keywords in a search query may help build a more comprehensive dataset, thus providing additional empirical insights. Nevertheless, a small literature now shows that brain function is associated with entrepreneurial behavior, as demonstrated by neuroscience studies in leadership, decision making, entrepreneurship.

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About the authors
Valentina Cucino is a Postdoctoral Scholar at Scuola Superiore Sant’Anna, Pisa, Italy. She got a PhD in Management Innovation, Sustainability and Healthcare at Scuola Superiore Sant’Anna in Pisa. Her main research streams are technology transfer, entrepreneurship and purpose-driven innovation. Valentina Cucino is the corresponding author and can be contacted at: valentina.cucino@santannapisa.it

Mariacarmela Passarelli is an adjunct professor of Management and Technology Transfer at the University of Calabria. She got a PhD in Economics and Management at Sant’Anna School of Advanced Studies (Pisa, Italy) and she was visiting scholar at HAAS Business School (Berkeley). She worked also as an expert for exploitation research activities with international players (AREA Science Park, Ernst and Young and PricewaterhouseCoopers). She is also an expert on European Founds. Her main research streams are technology transfer, innovation in the SMEs and entrepreneurship. She published several articles and papers on international journals and magazines.

Alberto Di Minin is Full Professor of Management at the Institute of Management of the Scuola Superiore Sant’Anna in Pisa. Alberto is also Research Fellow with the Berkeley Roundtable on the International Economy (BRIE), University of California–Berkeley and Social Innovation Fellow with the Meridian International Center of Washington, DC. Alberto deals with Open Innovation, appropriation of innovation and science and technology policy. I also work on technology transfer, intellectual property and R&D management.

Alfio Cariola graduated with honors in Engineering and Ph.D. in Management, is full professor of Economics and Business Management at the University of Calabria. Since 2018 he has been Director of the Department of Business and Legal Sciences and member of the Academic Senate. He is author or coauthor of various books and international and national publications on Business Planning, Financial Valuation of companies and investments (also in Project Financing and for the Public Private Partnership), Corporate Finance, Performance Measurement and Management and Operations Management. He is also speaker in national and international conferences, teacher in Master’s and consultant.