Entrepreneurship & Regional Development
An International Journal

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tepn20

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To cite this article: Gagan Deep Sharma, Justin Paul, Mrinalini Srivastava, Anshita Yadav, John Mendy, Tapan Sarker & Sanchita Bansal (2021): Neuroentrepreneurship: an integrative review and research agenda, Entrepreneurship & Regional Development, DOI: 10.1080/08985626.2021.1966106

To link to this article: https://doi.org/10.1080/08985626.2021.1966106

ENTREPRENEURSHIP & REGIONAL DEVELOPMENT
https://doi.org/10.1080/08985626.2021.1966106

Routledge
Taylor & Francis Group

ARTICLE

Neuroentrepreneurship: an integrative review and research agenda

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ABSTRACT

There is emergent literature that converges from neuroscience and entrepreneurship research, but the definitions and interlinkages are still inconsistent. We conduct a systematic literature review of 167 papers on the interface between neuroscience and entrepreneurship to address this. We observe the literature trends examining the interlinkages between neuroscience and entrepreneurial intention through six antecedents, namely - molecular neuroscience, systems neuroscience, behavioral neuroscience, cognitive neuroscience, social neuroscience, and computational neuroscience. Our findings suggest that entrepreneurial intention impacts entrepreneurial activity through five factors, including (1) opportunity recognition, (2) evaluation and risk-taking, (3) entrepreneurial cognition, (4) entrepreneurial behavior, and (5) entrepreneurial decision-making. From our discussions, the links among the neural factors affecting entrepreneurship are identified, and a research agenda highlighting a pathway for future studies is proposed.

ARTICLE HISTORY

Received 25 May 2021
Accepted 2 August 2021

KEYWORDS

Decision-making; Entrepreneurial intention; Entrepreneurship; Neuroscience; Opportunity recognition

1. Introduction

Neuroentrepreneurship has been a prominent subject in recent years due to the significance of brain functioning in entrepreneurial decision-making (Korpysa 2020; Nicolaou et al. 2019; de Holan 2014; Krueger and Day 2010; Nicolaou and Shane 2014; Tracey and Schluppeck 2014). Shane and Venkataraman 2020, 218) noted that 'the field of entrepreneurship involves studying sources of opportunities; the processes of discovery, evaluation, and exploitation of opportunities; and the set of individuals who discover, evaluate, and exploit them'. In recent years, the term entrepreneurship has expanded to include the cognitive science approach of decision-making by considering the entrepreneurial mindset and heuristic theories (Boudreaux, Nikolaev, and Klein 2019), as well as the identification of cognitive mechanisms that can empower entrepreneurs to make decisions faster and more effectively (Marshall, Dibrell, and Eddleston 2019). This leads to the concept of neuroentrepreneurship that is suggestive of the underlying premise for the study of entrepreneurship with brain functioning. The integrative view on neuroentrepreneurship scales up to the cognitive effort involved in entrepreneurial knowledge, intention, and mindset (de Holan 2014). The entrepreneurial mindset concept may indeed be revisited with a neuroscientific outlook that is concerned with

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Supplemental data for this article can be accessed here.

discovering the structure and functions of the nervous system. The body of knowledge in the field of neuroentrepreneurship vows to address some looming questions, namely (a) are there different cortical activations in the brain leading to successful entrepreneurial decisions? (Nicos Nicolaou and Shane 2014; Nofal et al. 2018; Pérez-Centeno 2017; Foo 2011; Welpe et al. 2012; Krueger and Welpe 2014); (b) do the brain regions involved in the decision-making process simultaneously process the risk and reward opportunities for entrepreneurial success? (Pérez-Centeno 2017; Peterson 2007; Sapienza, Zingales, and Maestripieri 2009; Srivastava, Sharma, and Srivastava 2019); and (c) how does entrepreneurial orientation lead to opportunity recognition, evaluation and exploitation for better decision-making? (Ferreira, Marques, Bento, Ferreira, & Jalali, 20f15; Foo 2011; Krueger 2003; Tracey and Schluppeck 2014; Zahra, Korri, and Yu 2005). The increased emphasis on understanding the decision-making process through the prism of entrepreneurs' behaviour and competence suggests the need for further study by answering the above questions.

Existing literature in the field of neuroentrepreneurship suggests that the realization of entrepreneurial decision-making in opportunity creation and recognition can be unravelled through neuroscience (Massaro 2020; Kraus, Fabian, and Thomas 2016). A few neuroentrepreneurship studies are using neuroimaging techniques such as electroencephalogram (EEG), functional magnetic resonance imaging (fMRI), computed tomography (CT) scan and positron emission tomography (PET) to probe into the brain regions responsible for nurturing the mind's process. However, not enough research attention has been given to assess the entrepreneurship dimensions (for instance, opportunity recognition, entrepreneurial orientation and so on) through the explicit use of neuroscientific tools and techniques. For an entrepreneur, the environment is ever-changing, uncertain, and unpredictable. Often entrepreneurial decisions are founded on impulses called free acts (Michl et al. 2009). It is crucial to study the involvement of emotions in these decisions as there are different systems for risk-seeking and risk-avoiding behaviour. Undue suppression and activation in either of these may lead to decision-making errors (Peterson 2007). The rewarding system set into action when it perceives a potential reward and extends from the Ventral Tegmental Area (VTA) to the nucleus accumbens (NAcc) of the limbic system (where dopamine is also present) and up to the medial prefrontal cortex (MPFC). On the other side, the brain's less-defined loss avoidance system runs through the amygdala and anterior insula of the limbic system.

The theoretical framework arising from neural precursors and developing into the entrepreneurial intention, finally directing towards the entrepreneurial activity, is exhibited in Figure 1.

The precursors of entrepreneurial intention (neural processes, role of neurotransmitters, behavioural and socio-cognitive factors) show the robust nature of biological sciences in examining outcomes. Neuroscience can provide answers to many unattended questions of the origin and evolution of entrepreneurship. Firstly, the neural precursors suggest the need for more significant examination through experimental (neuroimaging techniques, nuclear magnetic spectroscopy, etc.) and empirical methodology. Secondly, the hormones' mediating effect on genetic inclination and biochemical factors (neurotransmitters) function in an integrative manner as one embarks on entrepreneurial cognition. Therefore, it is pertinent to view the restricted literature on testosterone, dopamine, and cortisol from a management perspective. Thirdly, since the environmental factors interact with neural factors (such as gene-environment interaction) to approve entrepreneurial activity, it is crucial to explore the socio-cognitive and behavioural factors such as attitude, subjective norm, and perceived intention that mediate or indirectly impact entrepreneurial intention (Ajzen 1991; Brunel, Laviolette, and Radu-Lefebvre 2017; Laviolette, Lefebvre, and Brunel 2012).

While past studies have highlighted behaviour-driven entrepreneurial intention (Paul and Shrivatava 2016; Paul, Hermel, and Srivatava 2017), a comprehensive review of the literature in neuroentrepreneurship must be conducted to conceptualize the field (Lortie and Castogiovanni 2015). In terms of traditional discourse, entrepreneurship should be considered in the form of human activities carried out in search of previously undiscovered business opportunities and the human capacity to bear risk. The ability to act, particularly in the face of risks and uncertainties, and adjust to a changing environment and internal motivation, is critical for an entrepreneur to perform

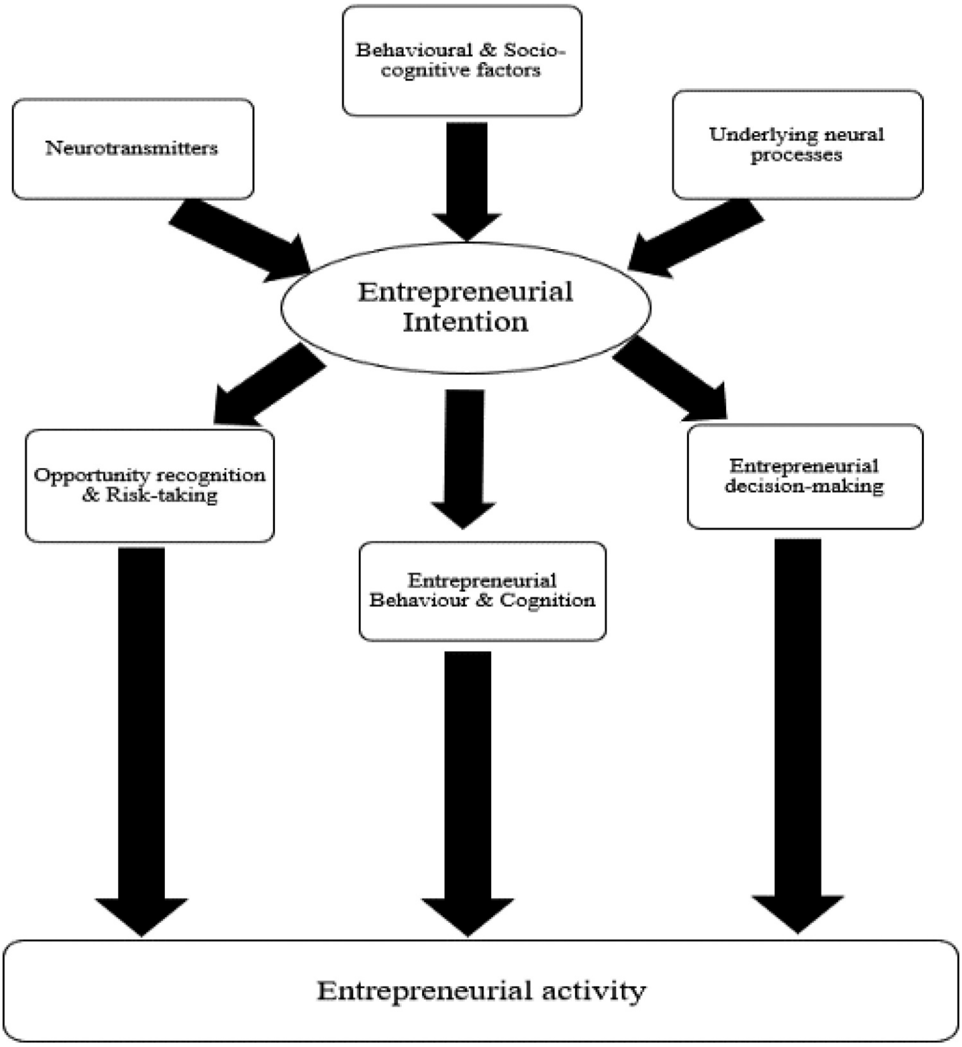

Figure 1. Theoretical framework.

consistently and effectively in the marketplace. The ability to track one's business environment, analyse the present situation, forecast potential market patterns, and put ideas into practice, both by the entrepreneur and their employees, is a sign of entrepreneurship (Korpysa 2020). As a result, a variety of cognitive neuroscience approaches are being used to understand the nature of entrepreneurial practices. In the existing literature, Korpysa (2020) has recapitulated the scientific breakthroughs in determining the effect of neuronal impulses on the entrepreneurial phase. de Holan (2014) claims that integrating neuroscience methods and technology into entrepreneurship research will be beneficial, while Tracey and Schluppeck (2014) have argued the role of neuroimaging techniques in establishing the field of neuroentrepreneurship and this biological determinism could disturb the social sciences. Krueger and Welpe (2014) have discussed an overview of how neuroscientific methodologies can be applied to current research problems in entrepreneurship. However, the argument about using neuroimaging techniques to understand the entrepreneurial mindset is an underdeveloped area.

By undertaking this theoretical review, the authors of this paper shall direct the researchers to overcome such limitations about the proper use of neuroimaging techniques to appreciate the brain areas responsible for the risk-reward systems of an entrepreneurial brain. Further, the perception among social scientists about the understanding of entrepreneurial behaviour from a neuroanatomical perspective is also a limitation as the role of neurotransmitters in decision-making is established in neurosciences. Hence, the need to incorporate neurochemistry methods to explain neurotransmitters' role and genetic biomarkers in entrepreneurial mindset is also discussed in this review and shall pave the way from the past limitations of the literature (Xiaoyu et al. 2019; Drover et al. 2017).

Therefore, to further refine the neuroentrepreneurship literature, this paper provides a potential trajectory for the origins of the entrepreneurial decision-making process in the brain. We undertake the reductionist approach to simplify the research problem's complexity in neuroentrepreneurship and articulate the research agenda in this upcoming field (Bear, Connors & Paradiso 2005; Nordqvist 2012). Pérez-Centeno (2017) categorizes eight branches from neuroscience relevant to entrepreneurship (cognitive, behavioural, systems, affective, cultural, social neurosciences, computational neurosciences, and neuroinformatics). We exclude neuroinformatics and cultural neuroscience and include the rest of the six branches in our study since neuroinformatics integrates data across all areas of neuroscience to help understand the brain and treat diseases; and cultural neuroscience looks at how the brain, minds and genes shape beliefs, practices and cultural values over different periods. This review shows the neural underpinnings that direct researchers to understand the brain's entrepreneurial mindset and cognitive load origin.

The breakthrough brought in the age of the social sciences, which developed a neurological-psychological orientation and has revealed the potential to explore the individual traits of an entrepreneur about questions as who an entrepreneur is and why they act in specific ways. Fuster (2011) concentrates on Hayek's viewpoint that creating individual knowledge is generated through associations between neuronal assemblies encoding simultaneous sensory system to build cognitive networks and, thus, can help understand individual entrepreneurial behaviour. Furthermore, the focus of entrepreneurship study is how entrepreneurs think and make decisions; emphasizes the importance of neurosciences in this regard, claiming that we have only scratched the surface of what neuroscientist can do for entrepreneurship, and we know only a little abot the neural undpinnings of entrepreneurship. In this regard, Nicos Nicolaou and Shane (2014) suggest to embrace the theories and methodologies of neuroscience and use this brain-based approach for understanding the origin of entrepreneurial behaviour. The development of a well-designed experiment is required to successfully apply the neuroscientific method to the examination of entrepreneurial cognition. This review suggests analysis of cognitive-affective-hormonal processes, which can be depicted at the neurological level for a brain-driven approach to entrepreneurial intention. The understanding of hormonal and genetic differences (serotonin (5HTTLPR) and dopamine (DRD4) polymorphism gene) influence the circuitry, anatomy, and function of the brain (Krueger and Welpe 2014; Nicos Nicolaou and Shane 2014). Additionally, research exploring entrepreneurial decision-making from the conception of business and across all events that trigger the entrepreneurial decisions shall provide new evidence on the interplay of neurological processes involved in the entrepreneurial decision-making process.

This integrated review pertains to understanding the evolution of cognitive mechanisms of decision-making involved across the different stages of the entrepreneurial process and the role of motivation in conceptualizing the entrepreneurial operations with the role of areas of the brain involved. Since entrepreneurship is a dynamic process, it necessitates neuroscientific methodologies to be taken into account for exploring entrepreneurial action.

We contribute to the emerging body of knowledge in entrepreneurship and neuroscience by presenting a comprehensive synthesis of missing aspects of neural compositions that could be beneficial to entrepreneurial decision-making. How entrepreneurial recognition pertains to only a particular set of individuals by engaging them in entrepreneurial activities can be explored through gene-environment studies. We mainly address whether or not entrepreneurs' neural composition is responsible for

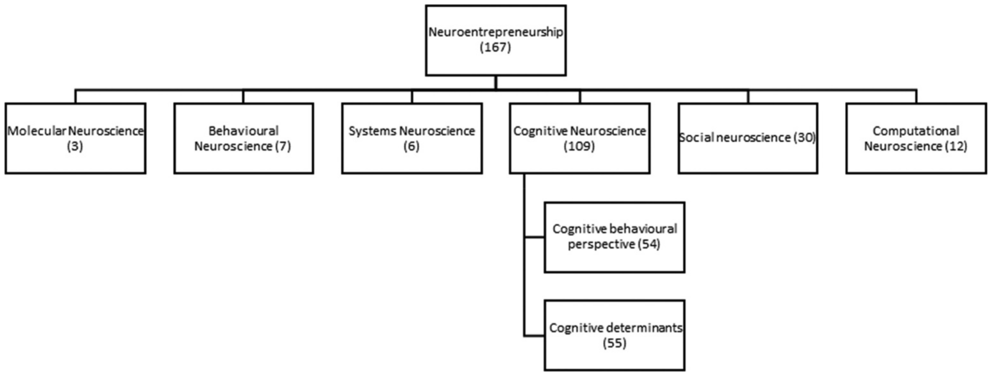

Figure 2. Organizing framework.

creativity, risk-taking, and decision-making driving them towards entrepreneurship (Alvarez and Urbano 2012; Baron 2007; Chen, Chang, and Lo 2015; Krueger and Day 2010; Ward 2004). This paper's overall contribution involves setting up future research agendas while providing an interesting framework for analysis marked by ambiguity, novelty, and heightened emotion during entrepreneurial activity.

The paper is structured as follows. The second section discusses the methodology and review strategy for the paper; the third section presents a summary of the findings of prior studies; the fourth section highlights the mechanisms through which relevant neural aspects impact the composition of a new entrepreneurial set of capabilities; the fifth section discusses the theoretical underpinnings of the reviewed papers; the sixth section presents the future research agenda, and the last section concludes the research.

2. Methodology

Neuroentrepreneurship is induced by neuronal circuits prone to cognitive prejudices that cause entrepreneurial biases. The interaction between neuroscience and entrepreneurship illustrates how the entrepreneurial personality's innate characteristics are manifested (Nicolaou and Shane 2014; Nicolaou, Spector, Hunkin, Cherkas, & Shane 2009; Nofal et al. 2018). Using organizing framework (see Figure 2), we explain entrepreneurship's neural perspective mechanisms.

2.1 Search and selection criteria

Figure 3 shows the search and selection process for this review. First, we identify the keywords related to the main and sub-themes discussed in our organizing framework (shown in Figure 2) and convert those into a Boolean query. For instance, 'entrepreneur*, enterprise' directly relates to all the research work falling in the gamut of entrepreneurship. From the neuroscience perspective, neuro*, brain, biolog*, cog*, physio*, genet* comprise the keywords used. The primary motivation for using these keywords stems from past studies from a neurobiological perspective (Butler et al. 2016; Nofal et al. 2018; Pérez-Centeno 2017). Second, the research papers matching the query are extracted from the Web of Science (WoS) database as it provides comprehensive citation search and access to multi-disciplinary research (Li et al. 2010; Paul and Criado 2020; Paul et al. 2021; Paul and Rosado-Serrano 2019). Third, all the extracted papers are passed through the inclusion-exclusion criteria (see Figure 3).

The selected 167 papers reviewed in this study are available as an online appendix, categorized into main themes and sub-themes (as per our Organizing framework in Figure 2).

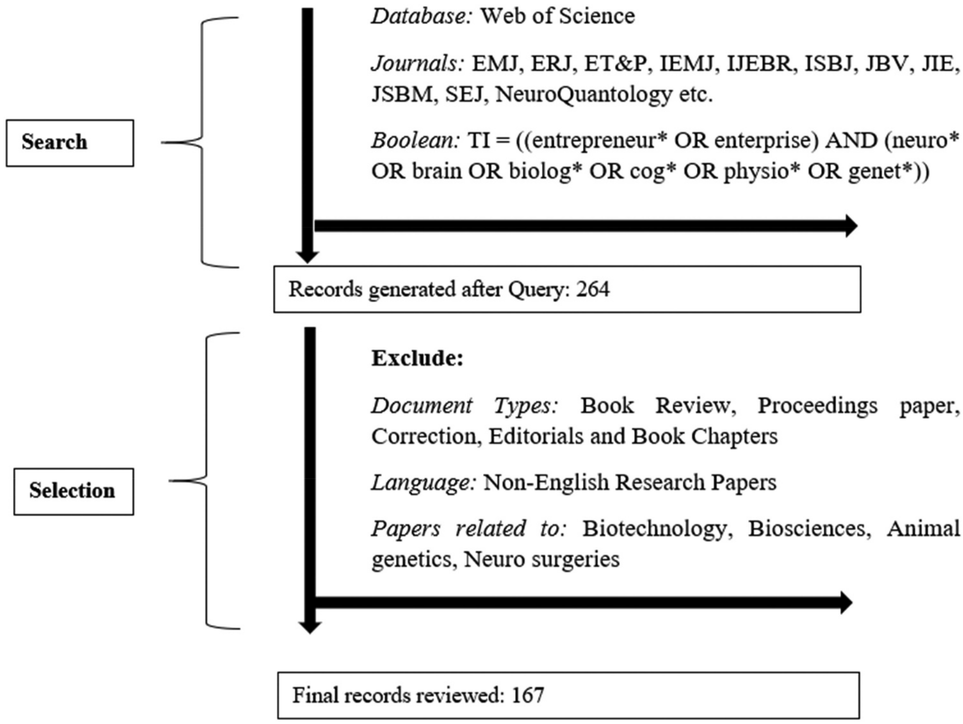

Figure 3. Search and selection process.

2.2 Reporting the review

Our methodology is conducted as per the protocols suggested and inspired by prior studies (Tranfield, Denyer, and Smart 2003; Paul and Mas 2020; Srivastava, Sharma, and Srivastava 2019; Liñán, Paul, and Fayolle 2020; Paul and Criado 2020; Paul and Feliciano-Cestero 2021; Srivastava et al. 2020). Following the methodology seen in most downloaded review articles (Paul and Benito 2018; Mishra, Singh, and Koles 2021; Hao et al. 2021; Ruggeri, Orsi, and Corsi 2019; Paul and Rosado-Serrano 2019; Goyal and Kumar 2020), We review the selected articles through thematic analysis and the theoretical underpinnings (widely used methods and theories) and develop future research agenda following SPAR-4-SLR method (Paul et al. 2021). The theories, which are the vital components for gaining theoretical insights to understand how studies have measured and analysed the models, are synthesized in Table 3. Table 4 provides an overview of the widely used data collection methods in prior research.

3. Neurosciences and entrepreneurial decision-making

Over the years, viewing entrepreneurship from a neuroscience lens has gained momentum (de Holan 2014; Nicolaou and Shane 2014; Nofal et al. 2018; Tracey and Schluppeck 2014). For instance, de Holan (2014) proposes neuroscience can help understand entrepreneurship while simultaneously listing limitations when neuroimaging techniques are used (fMRI and EEG). Nicolaou and Shane (2014) and Nofal et al. (2018) on the other hand see an interdisciplinary approach as more suitable for contemporary organizations.

The research trajectory of entrepreneurship shall follow the path of evolution of *Homo sapiens* recognized as the most cognitively advanced organisms. In the rest of this section, we discuss the key outcomes from the literature on entrepreneurship using neuroscience as a sub-field.

Extant literature studying the intersection of entrepreneurship with Neuroscience[1] identifies the idea of a brain-driven approach for entrepreneurship (de Holan 2014; Pérez-Centeno 2017; Thornton 2011; Tracey and Schluppeck 2014). Emerging research aims at recognizing the activations in the brain's regions through an evoked entrepreneur and entrepreneurs' behavioural response to different stimuli. We use a reductionist approach to identify the neural underpinnings of entrepreneurship which prompts a level of analysis focusing on molecular neuroscience, cellular neuroscience, systems neuroscience, behavioural neuroscience and cognitive neuroscience. We found three studies dealing with molecular neuroscience, six studies explaining systems neuroscience, seven papers discussing behavioural neuroscience for entrepreneurship, 109 papers explaining the cognitive aspect of neuroentrepreneurship and 30 papers on social neuroscience. Computational neuroscience holds 12 papers. It is important to mention that studies on interdisciplinary aspects such as neuromarketing, neuroeconomics, neurofinance and neuroentrepreneurship are clustered through neurosciences. Many studies are taken from neuroeconomics to help refine decision-making in entrepreneurial studies. Neuroeconomics has been able to identify the region of the brain through fMRI and EEG to conclude economic choices under uncertain risky or rewarding conditions (Naqvi, Shiv, and Bechara 2006; Gabay et al. 2014; Grabenhorst and Rolls 2011; Minati et al. 2012; Paulus et al. 2001; Peterson 2007; Pirtošek, Georgiev, and Gregoric-Kramberger 2009). The outcome of our analysis from other interdisciplinary studies suggests that there is a need to study entrepreneurship more holistically (i.e. from basic molecular to cognitive levels). To this end, authors have borrowed insights from neuroeconomics and neuromarketing to understand decision-making and from other credible sources that help us understand brain functioning and entrepreneurial cognition in terms of the 'how' part of entrepreneurial decision-making (de Holan 2014; Grégoire, Corbett, and Mcmullen 2011; Nicolaou & Shane 2013). As exhibited in Table 1, the existing literature is filled with shortcomings of neuroentrepreneurship, and a deeper analysis facilitates a better understanding. Starting with molecular neuroscience, we shift towards cognitive and computational neuroscience to articulate a more profound and precise understanding of the role of neuroscience in entrepreneurship.

3.1 Molecular neuroscience

Molecular neuroscience studies various molecules associated with the brain and nervous system. Molecules in the brain function as messengers (neurotransmitters), allowing neurons to form neural networks for information transmission and neurons' guarding (Bear, Connors & Paradiso 2005). Molecular neuroscience helps understand the genesis of cognitive neuroscience. The discussion of molecular neuroscience provides a deeper understanding of decision-making's behavioural and cognitive aspects. The molecular milieu of the neurons is indirectly modulated by genes, which regulate the synthesis of proteins and the encoding of different proteins for the neurotransmitter system (Ramsøy and Skov 2010). Nicolaou and Shane (2010) explain the effect of zygosity on entrepreneurial intention and occupational choice. Johnson (2009) considers the impact of genetics on entrepreneurship as unclear and suggests combining phenotype[2] with other biological and psychological characteristics. The explanation of differences among the individual traits can be accounted for because genes are passed from one generation to the next, explaining why some individuals are more creative than others (Yadav and Bansal 2021). Hence, entrepreneurial intention among individuals is correlated with genetic variation (Nicos Nicolaou et al. 2011). Certain genetic markers are selected on a priori hypothesis of their biological function and significance in genetic variation leading to candidate-gene studies (Beauchamp et al. 2011; Nofal et al. 2018). Serotonin (5HTTLPR) and dopamine (DRD4) polymorphism genes are associated with risk-taking activities (Kuhnen, Chiao, and Harpending 2009). The role of biomarkers in genetic variation may respond to specific behavioural characteristics in entrepreneurial decision-making.

Table 1. Findings of the extant literature relating neurosciences with entrepreneurship.

Neuroscience	Studies	Dependent Variable	Independent Variable	Findings
Molecular Neuroscience	Zhong (2018)	Entrepreneurial brain	Neuroplasticity	Neuroplasticity hitherto proves to be useful in memory formation, and decision-making which is essential for an entrepreneurial brain
	Kuhnen, Chiao, and Harpending (2009)	Entrepreneurial decision making,	Single nucleotide polymorphism (rs1486011) of DRD3	The role of biomarkers in genetic variation may respond to specific behavioural characteristics in entrepreneurial decision making, i.e. these are significant determinants of risk-taking
	Nicolaou et al. (2011)	Tendency to be an entrepreneur	Single nucleotide polymorphism (rs1486011) of DRD3	The positive association between single nucleotide polymorphism (rs1486011) of DRD3 and tendency to be an entrepreneur
	Zhong (2018)	Decision-making	Thickness of cortex and volume of grey matter in the brain	Employees in an enterprise with all-involvement innovation ability have a higher thickness of cortex and volume of grey matter in the lateral occipital lobe of the right hemisphere
Systems Neuroscience	Zheng (2018)	Innovation behaviour	Big Five Personality Traits	The EEG-based neurofeedback training system can improve the innovation behaviour of enterprise personnel and is positively associated with extraversion, openness to experience, agreeableness, conscientiousness and negatively associated with neuroticism
	Li (2018)	Innovation and entrepreneurship education	BP neural network	Improvements through the use of BP neural network in college graduates for innovation and entrepreneurship education
Behavioural Neuroscience	Thornton (2011)	Enterprises	Material and spiritual motivation	Enterprises should focus on measures that can activate, direct and sustain goal-driven behaviour and bring a positive impact on current intrinsic motivation
	Wiklund, Patzelt, and Dimov (2016)	Entrepreneurial action	ADHD (Attention-deficit hyperactive disorder)	An influential part of disorders like ADHD (Attention-Deficit Hyperactive Disorder) in entrepreneurial action
	Verheul et al. (2015)	Entrepreneurial intentions, self-employment	Higher level of ADHD behaviour	A higher level of ADHD behaviour is positively associated with entrepreneurial intentions
Cognitive Neuroscience	Grégoire, Corbett, and Mcmullen (2011)	Entrepreneurial cognition	Cognitive resources and mental representations	Working of entrepreneurship cognition can be viewed as an interaction between cognitive resources and mental representations

(*Continued*)

Table 1. (Continued).

Neuroscience	Studies	Dependent Variable	Independent Variable	Findings
Cognitive Behavioural Perspective	Baron (2007)	Generation of new ideas and opportunity recognition	Affect	Role of 'affect' in generating new ideas, recognizing opportunities and acquiring essential resources for venture creation
	Grégoire et al. (2015)	Entrepreneurship	Situated cognition, fear, the influence of affective dynamics on entrepreneurship intuition, opportunity evaluation and entrepreneurial team cognition	Dimensions such as situated cognition, fear, the influence of affective dynamics on entrepreneurship intuition, opportunity evaluation and entrepreneurial team cognition strongly influence entrepreneurship
	Fuller et al. (2018)	entrepreneurial self-efficacy and entrepreneurial intention	anticipatory entrepreneurial cognition, self-efficacy beliefs	Entrepreneurial self-efficacy and entrepreneurial intention is mediated by anticipatory entrepreneurial cognition, which is further affected by self-efficacy beliefs
	Muñoz (2018)	Sustainable decision-making in entrepreneurship	Cognitive factors	Cognitive factors (purpose-driven, determined; value-based, vacillating; value-based, unintended; single motive, single solution; and purpose-driven, hesitant) responsible for sustainable decision-making in entrepreneurship
	Tipu (2015)	Entrepreneurial ethics	Cognitive	Linkages among entrepreneurial actions and cognitive dissonance with entrepreneurial cognitions, moral awareness and moral judgement.
Cognitive Determinants	Ward (2004)	Attention	Creativity	Paradoxical role of knowledge to 'attention' and it can either enhance or inhibit creativity
Social Neuroscience	De Carolis and Saparito (2006)	Entrepreneurial behaviour	Environment (i.e. social networks) and cognitive biases	Entrepreneurial behaviour results from an interaction between the environment (i.e. social networks) and certain cognitive biases of entrepreneurs
	Baron (2000)	Entrepreneurial success	Cognitive factors (counterfactual thinking, overconfidence and susceptibility to cognitive biases) and social psychology factors (social competence, social perception, pursuance and social adaptability)	Interlinkage between cognitive factors and social psychological factors is vital for entrepreneurial success
	Tran and Von Korflesch (2016)	Social entrepreneurship intention	Personality traits	Social entrepreneurship intention is linked to personality traits, social entrepreneurial outcome expectation and self-efficacy with social cognitive career theory (SCCT)

3.2 Systems neuroscience

Systems neuroscience explains the brain's complex neuronal circuit and how it works. It describes the analysis of the sensory inputs, perception formation of the inputs, decision-making and execution (Bear, Connors & Paradiso 2005). Decision-making is an influential agenda derived from the underlying brain processes and systems neuroscience for entrepreneurship (Krueger 2003; Krueger and Day 2010; Shane & Nicolaou 2013; Zhong 2018). Researchers advocate using neuroimaging techniques such as fMRI and EEG to provide insights into how the brain works in entrepreneurial activity. However, a few researchers opt not to advocate these methods (de Holan 2014; Tracey and Schluppeck 2014), whilst others propose neural drivers of entrepreneurial activity (Shane & Nicolaou 2013). Zheng (2018) develops an EEG-based neurofeedback training system to improve the innovation behaviour of entrepreneurs and finds it to be positively associated with extraversion, openness to experience, agreeableness and conscientiousness and negatively associated with neuroticism. Li (2018) analyzes college graduates' innovation and entrepreneurship education and suggested improvements through the BP neural network. Zhong (2018) comparatively analyses the decision-making behaviour of employees in innovation, and results show differences in their brain structure and thickness of cortex and grey matter of the right hemisphere. This finding has a strong implication on the nerve mechanism of the brain subject to the property of plasticity, which has arisen due to long-term training and observation action (Erkut et al. 2018). The plastic changes in the brain arise because of new connections among neurons at the molecular level. Plasticity hitherto proves to be useful in memory formation, information integration and decision-making (Erkut et al. 2018; Zhong 2018), which is essential for an entrepreneurial brain. Neuroimaging techniques can help investigate an entrepreneurial brain to understand the involvement of different brain regions, grey and white matter's involvement and structural connectivity in decision-making.

3.3 Behavioural neuroscience

Behavioural neuroscience studies biological behaviour and neural networks of integrated behaviours (Bear, Connors & Paradiso 2005). Zhang (2018) suggests that enterprises should focus on activating, direct, and sustaining goal-driven behaviour for positive impact. Entrepreneurship studies explain the influential part of disorders like Attention-Deficit Hyperactive Disorder (ADHD) to positive and negative entrepreneurial behaviours (Wiklund, Patzelt, and Dimov 2016). Verheul et al. (2015) suggest that a higher level of ADHD behaviour is positively associated with entrepreneurial intentions. Also, a particular aspect of hyperactivity is associated with self-employment (Verheul et al. 2016). Henceforth, critical examination of ADHD accounts for understanding entrepreneurial intention.

3.4 Cognitive neuroscience

Cognitive neuroscience studies the neural mechanisms responsible for higher levels of mental activity (Bear, Connors & Paradiso 2005) and provides key insights in understanding the entrepreneurial action (Baron and Ward 2004; Grégoire, Corbett, and Mcmullen 2011; Randolph-Seng et al. 2015). For example, the episodic experiences and affective valuations result from activity in a neural substrate (cortical areas and subcortical nuclei) occurring due to entrepreneurial experiences. This aspect explains two sub-themes under cognitive neuroscience as presented in the organizing framework, namely – 'Cognitive Behavioral Perspective' and 'Cognitive Determinants'.

The cognitive behavioural approach is mainly used to manage hurdles by changing thinking to change behaviour. From this perspective, Baron (2007) identifies the role of 'affect' in generating new ideas, recognizing opportunities and acquiring essential resources for venture creation. Lortie and Castogiovanni (2015) identify the Theory of Planned Behaviour in understanding entrepreneurship by providing an analogy to the cognitively planned behaviour for opportunity recognition and venture creation. Entrepreneurial behaviour can be explained by using cognitive and discursive approaches and grounding them in intra-individual cognitions and inter-individual discourses. In contrast, the phenomenological approach explains the individuals' lived experiences (Berglund 2015). The cognitive dimension of corporate governance influences managers' behaviour, financial (in)discipline and cognition (Wirtz 2011). The cognitive and behavioural influences impact the entrepreneurial process through value creation and the development and deployment of capabilities (Pryor et al. 2016). The same set of environmental conditions of uncertainty and complexity have different effects on corporate and independent entrepreneurs (Garrett and Holland 2015). Fuller et al. (2018) find that entrepreneurial self-efficacy and entrepreneurial intention is mediated by anticipatory entrepreneurial cognition and self-efficacy beliefs. Tipu (2015) establishes linkages among entrepreneurial actions and cognitive dissonance with entrepreneurial cognitions, moral awareness and moral judgement.

The cognitive perspective of entrepreneurship seeks to bridge the gap between entrepreneurship and human cognition. The existing literature on human cognition supports the risk of potential bias and error, implying the irrationality behind cognitive processes. Entrepreneurs become susceptible to several cognitive biases when faced with information overload, uncertainty, novelty, emotion and time pressure (Baron 1998). Cognition neuroscience can prove to be a powerful tool for understanding entrepreneurs' 'why' questions. These questions may append to the why part of choosing to be an entrepreneur. Baron (2004) addresses these questions through prospect theory to help reduce risk and signal detection and regulatory focus theory to show entrepreneurial alertness, respectively.

Researchers can use resources from the cognitive toolbox by identifying and describing reaction time, priming, measures of working memory, and measures of creative cognition for expansion of research in the entrepreneurial cognitive domain (Baron and Ward 2004). Ferreira et al. (2015) employ the multiple criteria decision analysis (MCDA) to measure individual entrepreneurial orientation (EO) and classify profiles that enhance informed decisions on business partnerships and fund allocation. Grillo, Ferreira, Marques and Ferreira (2018) also use the MCDA technique for cognitive mapping to assess the most innovative SMEs. Karayev et al. (2018) demonstrate the cognitive tools for dynamic analysis of enterprise business strategies, i.e. a cognitive strategy and map analysis. Enterprise Cognitive Computing Applications (ECC) can help improve business processes by fortifying an organization's operational excellence, customer delight and employee experience (Tarafdar, Beath, and Ross 2017).

The integrative approach to study entrepreneurship from a neural perspective can help advance the scholarship in entrepreneurship by applying neuroscientific techniques to analyse entrepreneurial intentions and activity (Nofal et al. 2018).

3.5 Social neuroscience

Entrepreneurial behaviour is also a result of the interaction between the environment (i.e. social networks) and certain cognitive biases of the entrepreneurs (De Carolis and Saparito 2006). The interlinkage between cognitive (counterfactual thinking, over-confidence and susceptibility to cognitive biases) and social psychology factors (social competence, social perception, pursuance and social adaptability) is vital for entrepreneurial success (Baron 2000). Tran and Von Korflesch (2016) propose a conceptual model of social entrepreneurship intention, which links personality traits, social entrepreneurial outcome expectation and self-efficacy with social cognitive career theory (SCCT). Research has also shown a positive relationship between narrow personality traits such as aesthetic interest, dimensions of cognitive adaptability, meekness and further reveals a negative relationship of self-reproach (sub facet of neuroticism) with cognitive adaptability fit (Botha and Morallane 2019). Liguori, Bendickson, and McDowell (2018) find the application of social cognitive career theory to person and environmental/ background inputs and its impact on self-efficacy and entrepreneurial outcome expectations. Randolph-Seng et al. (2015) present a framework chronicling the dynamism of entrepreneurial cognition. A bibliometric analysis of entrepreneurial cognition with the socially situated approach reveals that entrepreneurial action is endogenous and should be expanded using a cognitive domain (Sassetti et al. 2018).

3.6 Computational neuroscience

Nordqvist (2012) defines computational neuroscience as the '*use of computers to simulate and model brain functions, and applying techniques from mathematics, physics, and other computational fields to study brain function*'. Computational neuroscience is replicated virtually to provide current solutions to an enterprise's problem. We describe the use of computational algorithms under two mainstream forms, namely genetic algorithm and genetic programming. Genetic algorithms and genetic programming can provide optimization solutions for enterprises (Whitley 2001; Zhang et al. 2013; Jin et al. 2017) and focuses on genetic operations by imitating evolutionary processes. It optimizes problem-solving methods (Ding, Benyoucef, and Xie 2006; Pan 2009; Xue, Dong, and Liu 2012; Wang et al. 2015; Jin et al. 2017) and has helped in partner selection problem resolution (Fuqing, Yi, and Dongmei 2006; Wang, Xu, and Zhan 2009) using fuzzy factors-based rules or R-GA. An optimization model for the collaboration of cost-effective partner selection in virtual enterprises is developed and has a real-life capacity (Wang, Xu, and Zhan 2009). A genetic algorithm has been used for optimizing the genetic parameters involved in production, termination and superior solution (Wang et al. 2015).

Genetic programming[3] (GP) encodes computer programmes as genes and provides solutions using genetic algorithms. Genetic programming follows the Darwinian principle of survival of the fittest with crossover recombination and mutation (Bian, Li, and Cong 1998).

Table 2 summarizes the results of the studies exploring the nexus between entrepreneurship and computational neuroscience.

It remains a well-known fact that an entrepreneur develops an enterprise by engaging in the process of entrepreneurship (Savoiu 2010). Therefore, entrepreneurial performance must be viewed as a result of entrepreneurship, and the prediction of its performance needs to be realized with appropriation in partner selection through the use of the genetic algorithm and genetic programming.

4. Mechanism

Having identified the main characteristics of neuroscience that impact entrepreneurship in the previous sections, we now present the organizing framework for entrepreneurial decision-making to set theoretical boundaries for future research agendas. The underlying mechanism is based on neural pillars to help understand entrepreneurial behaviour. Figure 4 highlights the effects of various strands of neuroscience on entrepreneurial decision-making.

The interacting elements of different neuroscience strands lead to a combined state of neural, behavioural and cognitive mechanisms, which, in turn, either directly or indirectly shape entrepreneurship. Figure 4 is further explained through sections 4.1 and 4.2, where different strands from neuroscience gradually lead to entrepreneurial decision-making.

4.1 Direct effects

Entrepreneurial cognitions are the '*knowledge structures that people use to make assessments, judgments, or decisions involving opportunity evaluation, venture creation, and growth*' (Mitchell et al. 2002, 97). Opportunity recognition is at the nucleus of entrepreneurial cognition and its perception at the individual level. When this happens, the individual discerns pattern recognition from past experiences as the hippocampus and amygdala regions of the brain arouse memory. Notwithstanding, personal factors and environmental stimulus also help instigate entrepreneurial behaviour in an

Table 2. Findings of the extant literature on computational neuroscience.

Area	Studies	Example/ case undertaken	Findings
Genetic Algorithm	Ip et al. (2003)	An electronic plant, which bid for a project for the construction of a stadium	The mathematical model (rule-based genetic algorithm: R-GA) formulated has better synthetic performance in both the computation speed and optimality for Virtual enterprises
	Ding, Benyoucef, and Xie (2006)	Two case studies of automotive and textile industries	The tool 'Optimization methodologies for Networked Enterprises' (ONE) is helpful for decision-makers as it allows the assessment of existing configurations and their optimization, whereas the risk for making wrong decisions (following huge costs) is considerably decreased by applying simulation
	Zhang et al. (2013)	Case of iPhone4 is used to demonstrate PSP in virtual enterprise	Pareto-Partner Selection Genetic Algorithm (PSGA) showed higher performance than the basic simulated annealing and particle swarm optimization and resulted in low cost, low pollution, and high-efficiency decision making for Partner Selection Problem (PSP)
	Z.-J. Wang, Xu, and Zhan (2009)	A hypothetical example of a virtual enterprise	Deeply examined various collaboration patterns between distributed partners with the corresponding evaluation metrics for collaboration time & cost and classified goals of partner selection as independent goals, association goals and constraint goals
	Fuqing, Yi, and Dongmei (2006)	A machine centre that bid for a project for a petroleum drilling machine	The multi-objective optimization model R-GA solution to risk-based PSP has better synthetic performance in terms of both computation speed and optimality
	Xue, Dong, and Liu (2012)	An enterprise equipment management system having 5 sub-processes	The optimized Enterprise Information System (EIS) structure based on time property is proposed on immune genetic algorithm (IGA) which is based on binary tree, niche algorithm and self-adaptive operators, helping enterprises obtain information system structure with better time property
	Pan (2009)	Taiwanese and Mainland Chinese companies based on financial ratios (to determine corporate management capability by employing Grey relational analysis)	The hybrid model provides better classification forecasting capability than the other models, while the ANFIS model adjusted by genetic algorithm could effectively enhance the classification forecasting capability
	Jin et al. (2017)	Examples of two global extreme value problem	Called compound arithmetic cross-over operator (GA CAC10-GA), uses a newly defined CAC, outperforms arithmetic crossover (AC10-GA) operator and has better convergence stability
	Wang et al. (2015)	Weaving production enterprise	Genetic algorithm (GA) with optimized parameters get solutions superior to manual scheduling with a quicker convergence, reducing the schedulers' labour
	Cheng, Ye, and Yang (2009)	A plastic injector enterprise that bid for a project for manufacturing a component of a plastic injector	The reverse optimization model relating to performance parameters of the manufacturing tasks (PPMT) combines the concepts of bidirectional optimization process, vector norm theory, weighting Euclidean distances and the case verifies the feasibility of the proposed approach

(*Continued*)

Table 2. (Continued).

Area	Studies	Example/ case undertaken	Findings
Genetic Programming	Pan (2012)	Employing Grey relational analysis to investigate the business operational performance of 600 enterprises in China	Adopted 3 models- genetic programming, Back-Propagation Neural Network and Logistic Regression to construct an Enterprise Operational Performance model and an Enterprise Finance Characteristic model, out of which Genetic programming yields the best classification and forecast performance, compared to the other three techniques
	Divsalar Gandomi, & Mahmood (2011)	136 bankrupt and non-bankrupt Iranian corporations based on financial ratios	The proposed genetic programming with orthogonal least squares (GP/OLS) model provides superior performance compared to the genetic programming with simulated annealing GP/SA model in bankruptcy prediction and give reliable estimates of the bankruptcy classification

Table 3. Theories used in the studies reviewed.

Theoretical foundation	Theory	Relevant Studies
Sociology Related Theories	Socio-Cognitive Career Theory(5)	(Dehghanpour Farashah 2015; Lanero, Vázquez, and Aza 2016; Liguori, Bendickson, and McDowell 2018; Tran and Von Korflesch 2016; Lent et al. 2014)
	Social Cognitive Theory (6)	(Ahmad, Xavier, and Bakar 2014; Bacq et al. 2017; Hmieleski and Baron 2009; Hornsby and Goldsby 2009; Lin 2006; Oo et al. 2018)
	Social Capital Theory (6)	(Corbett et al. 2018; Dheer and Lenartowicz 2018; García-Villaverde et al. 2018; Liñán, Urbano, and Guerrero 2011; Oo et al. 2018; Tipu 2015)
	Social Learning Theory (5)	(Bajwa, Shahzad, and Aslam 2017; Dehghanpour Farashah 2015; Fernández, Liñán, and Santos 2009; M. Schenkel, Matthews, and Ford 2009; Tran and Von Korflesch 2016)
	Experiential Learning Theory (4)	(Bonesso et al. 2018; Costa et al. 2018; Gemmell, Boland, and Kolb 2012; Groves, Vance, and Choi 2011)
Psychology Related Theories	Decision theory (4)	(De Carolis and Saparito 2006; Estelami and Nejad 2017; Knörr, Alvarez, and Urbano 2013; Dali and Harbi 2016)
	Personality Traits Theory (8)	(Bacq et al. 2017; Bajwa, Shahzad, and Aslam 2017; De Carolis and Saparito 2006; Dehghanpour Farashah 2015; Ferreira et al. 2015; Fuller et al. 2018; Sadler-Smith 2004; Shane and Nicolaou 2013)
	Theory of Planned Behaviour (TPB) and Theory of Reasoned Action (TRA) (16)	(Bacq et al. 2017; Baron, Zhao, and Miao 2015; Boukamcha 2015; Dehghanpour Farashah 2015; Ferreira et al. 2015; Gutierrez, Saiz-álvarez, & Gil Ángel 2017; Kickul, Gundry, & Whitcanack 2009; Lanero, Vázquez, and Aza 2016; Liguori, Bendickson, and McDowell 2018; W. B. Lin 2006; Liñán, Urbano, and Guerrero 2011; Siu and Lo 2013; Sommer and Haug 2011; Tran and Von Korflesch 2016; Virick, Basu, and Rogers 2015; Winkler 2013)
	Metacognitive Theory (2)	(Botha and Bignotti 2017; Haynie and Shepherd 2009)
	Effectuation Theory (3)	(Karayev et al. 2018; De Villiers Scheepers, Boshoff, and Oostenbrink 2018; M. T. Schenkel, Matthews, and Ford 2009)
	Expert Information Processing Theory (7)	(Dheer and Lenartowicz 2018; Randolph-Seng et al. 2015; García 2014; Seawright et al. 2013; Siu and Lo 2013; Smith, Mitchell, and Mitchell 2009; L. Yang 2015)
Management Related Theories	Resource-Based Theory (5)	(Del Giudice et al. 2017; Jonsson 2015; Liao 2016; Sommer and Haug 2011; L. Yang 2015)
	Dynamic Capabilities View (3)	(García-Villaverde et al. 2018; Liao 2016; Miocevic and Crnjak-Karanovic 2011)
	Competitive-Advantage Theory (3)	(Cătălina Iederan et al. 2011; Liao 2016; L. Yang 2015)
	Motivation Theory (5)	(Boukamcha 2015; Dew et al. 2015; Loasby 2007; Mitchell, Mitchell, and Smith 2008; Zhang 2018)

Parentheses in the column 'Theory' indicate the number of studies.

Table 4. Methodologies used in reviewed research papers.

Research Design	No. of papers	Study References
Experimental	32	(Bönte, Procher, and Urbig 2016; Johnson 2009; Li 2018; Morikawa et al. 2012; Nicolaou and Shane 2009; Nicolaou et al. 2009; Shane and Nicolaou 2013; J. A. Wang et al. 2015; Zhang 2018; Zhang et al. 2009; Zheng 2018; Zhong 2018; Cheng, Ye, and Yang 2009; Ding, Benyoucef, and Xie 2006; Divsalar et al. 2011; Fuqing, Yi, and Dongmei 2006; Ip et al. 2003; Jin et al. 2017; Pan 2009, Pan 2012; J.-A. Wang et al. 2015; Wang, Xu, and Zhan 2009; Xue, Dong, and Liu 2012; Zhang et al. 2013; Frederiks et al. 2019; Mensmann and Frese 2019; Wieland et al. 2019)
Quantitative using Questionnaire	81	(Adomako et al. 2016; Ahmad, Xavier, and Bakar 2014; Almobaireek, Alshumaimeri, and Manolova 2016; Alonso-Galicia et al. 2015; Alvarez and Urbano 2012; Arend et al. 2016; Bacq et al. 2017; Bajwa, Shahzad, and Aslam 2017; Baron, Zhao, and Miao 2015; Bonesso et al. 2018; Bönte, Procher, and Urbig 2016; Botha and Bignotti 2017; Boukamcha 2015; Brinckmann and Kim 2015; Chen, Chang, and Chang 2017, Chen, Chang, and Lo 2015; Claxton, McIntyre, and Wheatley 1995; Dali and Harbi 2016; Dehghanpour Farashah 2015; Dheer and Lenartowicz 2018; Fernández-Pérez, García-Morales, and Pullés 2016; Fernández, Liñán, and Santos 2009; Fini and Toschi 2016; García-Villaverde et al. 2018; Del Giudice et al. 2017; Groves, Vance, and Choi 2011; Gudmundsson and Lechner 2013; Hafer and Jones 2015; Haller and Welch 2014; K. Hmieleski and Baron 2009; Johnson 2009; Kickul et al. 2009; Knörr, Alvarez, and Urbano 2013; Lanero, Vázquez, and Aza 2016; Liao 2016; W. B. Lin 2006; Liñán, Urbano, and Guerrero 2011; Miocevic and Crnjak-Karanovic 2011; Mirjana, Ana, and Marjana 2018; Mitchell, Mitchell, and Smith 2008; Muniady et al. 2015; Nicolaou et al. 2009; Obschonka, Hahn, and Bajwa 2018; Oo et al. 2018; Palich and Ray Bagby 1995; Ren et al. 2016; Sadler-Smith 2004; Andrés and Salahodjaev 2016; Sánchez et al. 2011; De Villiers Scheepers, Boshoff, and Oostenbrink 2018; M. Schenkel, Matthews, and Ford 2009; Seawright et al. 2013; Shane and Nicolaou 2013; Siu and Lo 2013; Smith, Mitchell, and Mitchell 2009; Sommer and Haug 2011; Virick, Basu, and Rogers 2015; L. Wang and Guo 2015; Westhead, Ucbasaran, and Wright 2005; Xu 2016; L. Yang 2015; Z. Zhang et al. 2009; Ziemiański 2018; Bergner 2020; Botha and Morallane 2019; P. Chen et al. 2020; Dheer and Lenartowicz 2019; Hurst 2019; Marshall et al. 2019; Nikolić et al. 2020; Pei et al. 2020; Pérez-López, González-López, and Rodríguez-Ariza 2019; Santos et al. 2019; G. Wang et al. 2020; Wasowska 2019; Yang, Sun, and Zhao 2019; H. Zhang, Bij, and Song 2020)
Qualitative using case analysis	12	(Cătălina Iederan et al. 2011; Corbett, Neck, and Detienne 2007; Dölarslan, Koçak, and Özer 2017; Dutta and Thornhill 2014; Gemmell, Boland, and Kolb 2012; Hartog, Van Praag, and Van Der Sluis 2010; Jonsson 2015; Mensmann and Frese 2019; Onyemah and Pesquera 2015; Oyson and Whittaker 2015; Tryba and Fletcher 2020)
Mixed	3	(Gil Angel, Saiz Alvarez, and Gamez Gutierrez 2017; Estelami and Nejad 2017; Morikawa et al. 2012)
Conceptual	33	(Baron 2000, Baron 2007; Berglund and David Higgins, Professor Kiran Treh 2015; De Carolis and Saparito 2006; Dew et al. 2015; Fredin 2016; Fuller et al. 2018; Garrett and Holland 2015; Grégoire et al. 2015; Han and Zheng 2018; Haynie and Shepherd 2009; Hornsby and Goldsby 2009; Karayev et al. 2018; Liguori, Bendickson, and McDowell 2018; Mahnke, Venzin, and Zahra 2007; Muñoz 2018; Pryor et al. 2016; Randolph-Seng et al. 2015; Sánchez, Carballo, & Gutiérrez 2011; Sassetti et al. 2018; Tappi 2005; Tarafdar, Beath, and Ross 2017; Tipu 2015; Tran and Von Korflesch 2016; Usui et al. 2004; Ward 2004; Wirtz 2011; Kuechle 2019)
Review	6	(Y. Te, Swain, and Gierasch 2002; Waldman, Ward, and Becker 2017; Pérez-Centeno 2017; Dew et al. 2015; Sassetti et al. 2018; Butler et al. 2016)

individual. Social Cognition Career Theory (SCCT) provides a robust approach to understanding entrepreneurial activity from an individual's perspective. Thus, entrepreneurship can be viewed as the deployment of behavioural, cognitive and motivational processes. The three pillars of SCCT are self-efficacy, outcomes expectation and goal-oriented activity. Self-efficacy acts as an antecedent for an entrepreneurs' motivation, cognition and action. Gemmell, Boland and Kolb (2012) find a direct effect of socio-cognitive dynamics (inner group composition, trusted partner relationship, domain diversity) on the entrepreneurial ideation process. Jonsson (2015) identifies entrepreneurs' network evolution, especially at the start-up phase, connected with social capital dimensions (relational, structural and cognitive). Chen, Chang, and Chang (2017) confer the role of team cohesion on new venture performance and entrepreneurial satisfaction. Entrepreneurial intentions also coalesce with

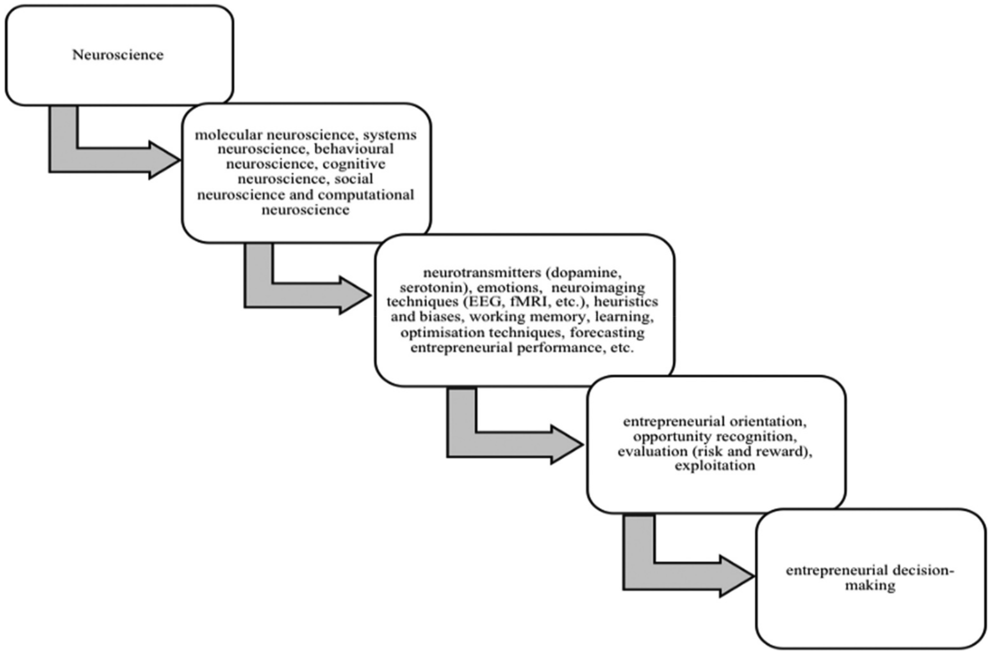

Figure 4. Neuroscience and entrepreneurial decision-making.

the risk-taking opportunity and being triggered into acting (Bacq et al. 2017). Obschonka, Hahn, and Bajwa (2018) observe that entrepreneurial intention and career adaptability are associated with entrepreneurial alertness, self-efficacy and resilience.

4.2 Mediating or indirect effects through behavioural and social-cognitive variables

Numerous studies have reported the mediating or indirect effect of neurobiological, behavioural and cognitive factors on entrepreneurial intention. Bönte, Procher, and Urbig (2016) explain the mediating effect of domain-specific risk-taking preferences on the positive association of pre-natal testosterone exposure and entrepreneurial intent. Entrepreneurial intention is related to entrepreneurial self-efficacy, which in turn is affected by risk-taking propensity, mediated or indirectly impacted by perceived entrepreneurial munificence (Bacq et al. 2017). The intermediary role of absorptive capacity (acquisition, assimilation, exploitation and transformation) on entrepreneurial orientation (innovativeness, risk-taking, proactiveness) is catenated to cognitive, social capital (shared culture, shared norms). Adomako et al. (2016) find the moderating effect of entrepreneurs' cognitive planning and creative style on entrepreneurs' persistence and optimism.

5. Theoretical underpinnings

Figure 5 exhibits the cyclic process of entrepreneurial decision-making and the brain areas involved therein.

Given the link between entrepreneurship and the individual level of cognition, it becomes pertinent to study entrepreneurs' behaviour emanating from the brain. Out of all neuroimaging techniques *viz*. electroencephalography (EEG), magnetoencephalography (MEG), single positron emission computed tomography (SPECT), positron emission tomography (PET) scan, the focus of extant literature remains on using fMRI technique due to its robust nature in recording the functional activity of the brain. Being non-invasive, it helps identify localized brain activity by using the principle

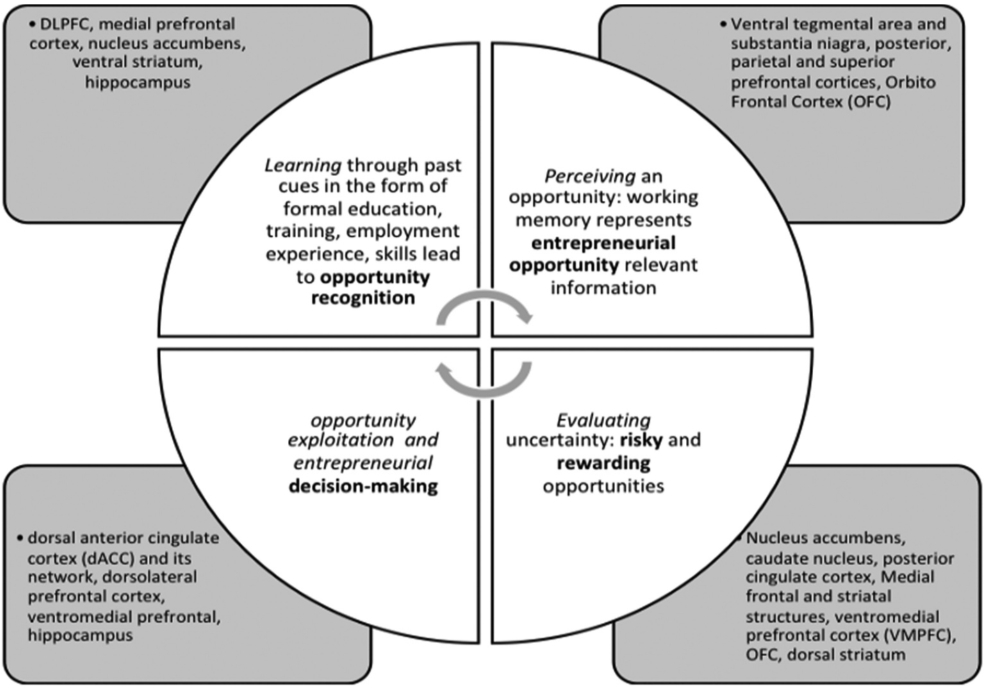

Figure 5. Brain areas involved in the entrepreneurial decision-making process.

of blood oxygen level-dependent (BOLD) signal. In recent times, fMRI has become an important probing tool for understanding the neural underpinnings during a broad spectrum of mental processes by executing psychological and cognitive tasks. The time gap of 8–12 seconds in developing experimental task designs can help in the interaction of cognitive variables that help understand decision-making strategies used by an individual during a task. Literature has witnessed activations in the temporo-frontal lobe for entrepreneurs while performing Stroop decision task. The entrepreneurial decision-making process is a cyclical learned process that depends upon past experiences, training, previous employment, education and skills for opportunity recognition which continuously shapes brain perception (Erkut et al. 2018). A priori region of interest in the brain for learning includes DLPFC, medial prefrontal cortex, nucleus accumbens, ventral striatum, and the hippocampus. Brain areas involved in entrepreneurial opportunity recognition include the ventral tegmental area and substantia niagra, posterior, parietal and superior prefrontal cortices, Orbito Frontal Cortex (OFC). Opportunity recognition then turns to opportunity evaluation in ascertaining risks (areas of risk nucleus accumbens, caudate nucleus) and rewards (medial frontal and striatal structures, orbitofrontal cortex and ventromedial prefrontal cortex (VMPFC), dorsal striatum, nucleus accumbens). Finally, entrepreneurial decision-making happens after opportunity exploitation for a goal-directed action in the dorsal anterior cingulate cortex (dACC) and its network, ventromedial prefrontal cortex, and dorsolateral prefrontal cortex (de Holan 2014; Pérez-Centeno 2017).

We did not find any integrated framework combining all the strands of neuroscience to understand entrepreneurial behaviour through our extensive review. We included neuroscience branches as they are reciprocally involved in entrepreneurial decision-making. We support that neuroscience models are the cognitive building blocks for entrepreneurial decision-making. The role of molecular neuroscience is linked with the occupational choice of an individual, opportunity recognition and career choice. Wolfe and Patel (2017) also explain the relationship between neurotransmitters epinephrine and self-employment in so far as they are associated with low cortisol levels. Hormone cortisol may act as a contingent for a dual influence of epinephrine and self-employment.

Following the guidelines of prior reviews, we provide inputs with respect to theory and methods used by the extant literature (Paul and Rosado-Serrano 2019; Rosado-Serrano, Paul, and Dikova 2018; Yadav and Bansal 2021).

5.1 Theory

The underlying theories applied in this area of neuro entrepreneurship come from Sociology, Psychology and Management. Table 3 exhibits that 82 of the reviewed research papers use a theoretical approach.

The most commonly used theories in neurosciences are related to Psychology. The Theory of Planned Behaviour (Ajzen 1991) and Theory of Reasoned Action (Ajzen and Fishbein 1977) have formed the base for the vast number of research papers, which explains that entrepreneurs show their entrepreneurial intention and perform entrepreneurial behaviour through their personality traits, decision making, cognition and effectuation (Zhang, Foo, and Vassolo 2021). Research papers under 'computational neuroscience' use algorithms and programming applications such as Fuzzy sets, Grey theory, Markov chain and Vector norm. Studies using the Personality theory use the Big 5 personality traits' questionnaire, including openness, conscientiousness, extraversion, agreeableness and neuroticism. While providing evidence of different underlying theories from a multidisciplinary perspective, we suggest that creation, trust and network theory from Sociology; causation and discovery theory from psychology; and theories of human capital, S-D logic and contingency from Management should be included as notions which researchers in future studies in this emerging field of study can use.

5.2 Methodologies employed by extant literature

Table 4 exhibits the limited application of a mixed design by the literature so far. Future research may focus on cross-sectional and longitudinal studies, which allow the variables to be addressed with greater precision. This will allow for their determinants, processes, and results to be studied more systematically. For instance, studies could test the connection between entrepreneurial intention and actual behaviour (such as self-employment and business creation) through a longitudinal study.

6. Future research agenda

Following the structure of popular review articles (Ruggeri, Orsi & Corsi; Rana and Paul 2020; Goyal and Kumar 2020; Paul and Dhiman 2021; Radu-Lefebvre et al. 2021), we provide detailed and specific directions for future research in the area of nuero entrepreneurship. Based on the synthesis, we infer that it is important to identify the cognitive factors exclusive and extensive to entrepreneurship. Our findings highlight the need for researchers to investigate how dynamic entrepreneurial thinking, creativity, and social trust are related variables and how their change could impact an entrepreneur's business planning activities. This calls for a more longitudinal, cross-sectional, and dynamic engagement of entrepreneurial qualities than those advocated by Alonso-Galicia et al. (2015). The second research agenda highlights the need for more robust methodological approaches toinvestigate and try to ascertain how the brain's temporal, neural, and cognitive junction could deepen researchers' understanding of entrepreneurial behaviour. Future studies' longitudinal and cross-sectional aspects could allow the range of variables to be investigated and addressed with greater precision than is currently the case. Additionally, research into neuroentrepreneurship could benefit further if future studies address more systematically additional components such as the determinants, qualities, processes, and results in this growing field of research. For instance, studies could test the connection between entrepreneurial intention and the actual behavioural aspects of entrepreneurs (such as self-employment and business creation).

Future researchers may establish deeper connections or linkages between a range of areas/ aspects already surfaced in our theoretical findings as an extension of the methodological aspect. Currently, research conducted by Tipu (2015) establishes linkages between a respectable yet limited set of areas, including entrepreneurial actions, cognitive dissonance, and moral awareness and judgement. While Baron (2000) highlights the criticality of social and psychological factors (including social competence, social perception, pursuance and social adaptability) and Tran and Von Korflesch (2016) have jointly proposed a conceptual model to capture such social entrepreneurial intention for success, the linkages between personality traits, self-efficacy and social entrepreneurial outcome expectation in what they refer to as Social Cognitive Career Theory (SCCT) and their sub-sets such as aesthetic interest, dimensions of cognitive adaptability and meekness are yet to be developed to determine their contributions or impacts on entrepreneurial cognitive adaptability. The accurate assessment of entrepreneurial behaviour could be done using qualitative methodologies such as in-depth interviews, observational approaches and self-reflective action search.

Finally, future scholarship in this area needs to focus on developing theories that gimmick the neural processes underlying entrepreneurial behaviour. Stimulus tasks may be developed in the light of the entrepreneurial decision-making process for engagement in fMRI. So far, the Stroop test has been widely used for decision-making. Gaming theory and decision theory can be utilized to develop an experimental design in neuroentrepreneurship to overcome its shortcomings in the neuroscience aspect. In addition, future scholarship in this area needs to focus on developing theories that gimmick the neural processes underlying entrepreneurial behaviour. Stimulus tasks may be developed in the light of the entrepreneurial decision-making process for engagement in fMRI. So far, the Stroop test has been widely used for decision-making. Gaming theory and decision theory can be utilized to develop an experimental design in neuroentrepreneurship to overcome its shortcomings in the neuroscience aspect.

The human brain is the black box, which needs to be unpacked through neuroimaging techniques to establish a connection between entrepreneurial behaviour and neuroscience (de Holan 2014; Nicolaou and Shane 2014; Tracey and Schluppeck 2014). However, the major challenge lies in conducting multi-disciplinary research from neuroscience and social science perspectives. Social Science scholars are generally dissuaded from conducting Biological Science related studies as there are no set platforms for undertaking such researches. This further restricts the development of new theories for understanding tshe drivers of entrepreneurial intention. Scholars may feel the need for retraining themselves to see how they can further develop the theoretical and methodological aspects highlighted for future studies in this relatively novice field of neuroentrepreneurship.

7. Conclusion

The paper has discussed the importance of the relationship between neuroscience and entrepreneurship by reviewing and critiquing 167 articles about the interface between neuroscience and entrepreneurship. This study has revealed that the brain's neural underpinnings impact entrepreneurial intention through six antecedents: molecular neuroscience, systems neuroscience, behavioural neuroscience, cognitive neuroscience, social neuroscience, and computational neuroscience. The difficulty in studying the human brains' functioning and cognitive neuroscience approaches should be used more frequently to study the mechanism of recognizing and seizing entrepreneurial opportunities. Researchers may explicate the role of cognitive factors and social psychological factors in entrepreneurial activity. However, successful entrepreneurial decision-making rests on problem-solving capacity and opportunity recognition at the junction of temporal, neural, and cognitive levels. It is at this level the role of emotions should not be neglected; rather, it is essential to acknowledge the emotional influence on the entrepreneurial decision-making process.

This review has suggested the role of various methodologies in conducting studies in neuroentrepreneurship for investigating entrepreneurial behaviour. Neuroimaging techniques of EEG, fMRI, etc., are crucial in mapping the functional areas of the brain while performing task-based studies and shall be correlated with psychological assessments via questionnaires, in-depth interviews, etc. Whether an entrepreneur is born or made can be answered by using the nuclear magnetic resonance spectroscopy method for assessing the role of genetic biomarkers and comparing it with functional brain activations.

As part of practical implications, the paper suggests introducing neural and behavioural artefacts for a target-oriented training for entrepreneurs by the use of neuroplasticity, which can be used both by institutions of tertiary education to educate potential entrepreneurs and by entrepreneurial training institutions that are targeting active entrepreneurs. Hence, the practical utilization of the results shall be of a global character. Therefore, the utilization of the results in terms of articles, presentations, and lecture notes can go beyond the scope of entrepreneurs and enterprises can use this research to improve entrepreneurial skillset and better opportunity recognition in the businesses.

Notes

1. The human nervous system is examined at several different scales, ranging from the molecules that determine the functional properties of neurons to the large systems in the brain that underlie cognition and behaviour (Bear, Connors & Paradiso 2005).
2. The term phenotype refers to observable traits of an organism (Brooker 2018).
3. Genetic programming combines the expressive high-level symbolic representations of computer programs with the near-optimal efficiency of learning of Holland's genetic algorithm (Bian, Li, and Cong 1998).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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