Philosophical Foundations, Theoretical Framework, and Research Methods of Neuro-Organizational Behavior in a Multi-Dimensional Paradigm

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Abstract

Neuro-organizational behavior refers to an emerging interdisciplinary field that explores the biological operating mechanisms underlying organizational phenomena and develops and reconstructs the organizational behavior framework from a neurophysiological perspective. Within a multidimensional paradigm, neuro-organizational behavior encompasses philosophical foundations spanning from reductionism to emergentism, a theoretical framework grounded in social contextual cognition theory, cross-level research, and reverse inference, as well as parallel research methods employing neuroimaging and ANS measurement. Future research should consider the transformative potential of neuro-organizational behavior for organizational theory and the future trajectories of research methodologies.

Full Text

The Philosophical Foundations, Theoretical Framework, and Research Methods of Organizational Neuroscience from a Multi-Paradigm Perspective

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Abstract: Organizational neuroscience is an emerging interdisciplinary field that seeks to develop and reconstruct the framework of organizational behavior from a neurophysiological perspective by exploring the biological mechanisms underlying organizational phenomena. From a multi-paradigm perspective, organizational neuroscience encompasses philosophical foundations ranging from reductionism to emergence, a theoretical framework based on Socially Situated Cognition theory, multi-level research, and reverse inference, as well as parallel research methods of neuroimaging and ANS measurement. Future research should consider the potential transformations that organizational neuroscience may bring to organizational theory and the future direction of research methods.

Keywords: organizational neuroscience; paradigm; philosophical foundation; theoretical framework; research methods

1 Introduction

The understanding that human psychology and behavior are controlled by the nervous system has long been established (Gazzaniga, Ivry, & Mangun, 2014). Over recent decades, the rapid development of neuroscience has made it possible to deeply understand how the brain influences higher-level human psychology and behavior (Wickens, 2014). With continuous breakthroughs in cognitive neuroscience technologies such as brain imaging and computational modeling, the interdisciplinary integration of neuroscience with management, economics, and organizational behavior has become an inevitable trend (Becker, Cropanzano, & Sanfey, 2011; Ashkanasy, Becker, & Waldman, 2014; Waldman, Ward, & Becker, 2017). Some scholars have even argued that just as humans cannot study the solar system without the sun, they cannot study human science without the brain (White, 1992).

Specifically, Organizational Neuroscience (ON) as an academic concept was formally born only eight years ago (Becker & Cropanzano, 2010). However, it has developed rapidly since its inception. Within just eight years, research in this field has shown explosive growth, not only in quantity but also increasingly appearing in top management and organizational behavior journals such as JOM (Journal of Management) and LQ (Leadership Quarterly) (e.g., Bagozzi et al., 2013; Balthazard, Waldman, Thatcher, & Hannah, 2012; Molenberghs, Prochilo, Steffens, Zacher, & Haslam, 2017), demonstrating remarkable momentum.

This discipline's development quickly attracted the attention of Chinese scholars. The earliest influential Chinese publication in this field was the work of Li Hao and colleagues (Li Hao, Ma Qingguo, Dong Xin, 2016), who translated Organizational Neuroscience as "neuro histology." We agree with placing "neuro" first in the translation to highlight that the purpose of applying neuroscience theories and methods is to develop and reconstruct organizational behavior, and we also believe that Organizational Neuroscience should belong to organizational behavior and management as an emerging sub-discipline. However, regrettably, in domestic physiology, the term "neuro histology" specifically refers to "Neuro Histology," a professional term already established in Chinese physiology for at least twenty years prior to its adoption in organizational behavior (e.g., Han Yuze, Tang Li, Meng Dan, Hou Liran, 1994; Qin Li, Cui Shouxin, Liu Siwei, Cheng Shaoli, Yang Shaoyi, 2005). To avoid unnecessary misunderstandings arising from translation duplication across academic fields, this paper proposes the translation "organizational neuroscience," which not only avoids overlapping terminology across disciplines but also respects and acknowledges previous efforts by domestic scholars.

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Undeniably, as an emerging discipline, organizational neuroscience holds unlimited potential for future development. Faced with the possibilities that high-tech technologies offer for exploring brain mysteries, organizational neuroscience scholars have been eager to apply various cutting-edge technologies to organizational behavior research (Ashkanasy et al., 2014). However, behind the phenomenon of "neuromania" (Tallis, 2011) lurk certain crises.

On the one hand, mainstream organizational neuroscience research still habitually treats identifying brain localization of cognitive and emotional functions as an important research goal, interpreting human behavior in complex organizational contexts purely from the perspective of brain neural activity (Healey & Hodgkinson, 2014; 2015). In other words, such research remains biologically oriented, implicitly assuming that organizational individuals are "biological beings," when in fact they are "social beings" with socially embedded essential attributes. Consequently, such research detaches from the complex social and organizational contexts in which subjects are situated, placing them instead in isolated laboratory settings to explore brain functions, thereby ignoring the complexity, sociality, and integrative nature of organizational behavior and management processes.

On the other hand, faced with rapidly evolving neuroscientific technologies, organizational neuroscience researchers have inevitably fallen into certain methodological pitfalls in their eagerness to try the latest technologies (Jack, Rochford, Friedman, Passarelli, & Boyatzis, 2019). Some scholars, overly infatuated with technology and blindly pursuing cutting-edge techniques, mistakenly equate technological advancement with research leadership (Balthazard & Thatcher, 2015). For instance, functional magnetic resonance imaging (fMRI), one of the most widely used technologies in organizational neuroscience research, is not only limited to laboratory studies but also requires subjects to remain in a confined space with their heads immobilized. Such restrictions on physical activity and speech pose significant limitations for organizational behavior research (Cooke, Peel, Shaw, & Senior, 2007). fMRI also compromises external validity by limiting face-to-face interpersonal interaction between individuals (Becker & Menges, 2013). Moreover, the fact that fMRI can only be used for individual-level research greatly limits the discipline' s development potential for group- and organizational-level studies (Jack et al., 2019). Similar adaptability issues exist for all cognitive neuroscience technologies (Senior, Lee, & Butler, 2011).

Thus, there is an urgent need to systematically review and summarize the advantages and disadvantages of various neuroscientific research methods to provide a reference for methodological selection in future organizational neuroscience research. Furthermore, the true driving force behind theoretical construction and disciplinary development in organizational neuroscience lies not only in the cutting-edge nature of its methodological "toolkit" but also in the scientific nature of its disciplinary paradigm and development philosophy (Healey et al., 2014; Bagozzi & Lee, 2019). Undoubtedly, without the various research tools and techniques of cognitive neuroscience, organizational neuroscience could not have achieved such rapid development. Likewise, without organizational behavior, the external ecological validity of organizational neuroscience research would be impossible to guarantee (Healey et al., 2014, 2015). Therefore, neither organizational behavior nor cognitive neuroscience alone can reflect on the major issues of this interdisciplinary field from their own disciplinary perspectives.

From the history of scientific development, significant progress in any discipline cannot be separated from the guidance of paradigms (Mathieu & Chen, 2011; Shepherd & Challenger, 2013). Currently, although several review studies have examined the development trajectory, research hotspots, and research tools of organizational neuroscience (e.g., Butler, O' Broin, Lee, & Senior, 2016; Jack et al., 2019; Li Hao et al., 2016), there remains a lack of high-level reflection and analysis from a paradigm perspective. An organizational neuroscience paradigm can provide clear philosophical foundations, theoretical frameworks, and research methods for the field' s development, thereby avoiding unnecessary research pitfalls (Bagozzi et al., 2019; Healey et al., 2014). Given the aforementioned problems in the development of organizational neuroscience, it is imperative to conduct deep reflection and systematic review of the philosophical foundations, theoretical frameworks, and research methods of this emerging discipline from a multi-paradigm perspective.

2 Paradigm and Organizational Neuroscience Paradigm

The concept of paradigm, first proposed by American philosopher of science Kuhn (1962) in *The Structure of Scientific Revolutions*, refers to a series of basic consensus reached by researchers in a discipline regarding its research objects, theoretical systems, framework structures, research methods, and application of results (Kuhn, 1970). In Kuhn' s view, any discipline at a particular time and space is governed by a specific paradigm. Although Kuhn provided more than twenty different elaborations of paradigm, he never offered a clear and precise definition. Nevertheless, given the importance of philosophy of science for disciplinary development and research, paradigm theory has generated enthusiastic responses and profound influence in academia (Ritzer, 1975).

Paradigms have four key characteristics. First, paradigms are prescriptive. This prescriptiveness not only determines the formulation of research questions, research sequencing, experimental selection, and content but also defines certain standards for research methods and the scientific validity of research conclusions (Kuhn, 1970). Second, paradigms are hierarchical. Masterman (1970) built upon Kuhn' s work to divide paradigms into three types: Metaphysical Paradigm, Sociological Paradigm, and Artifact Paradigm. The metaphysical paradigm refers to the overall worldview pursued by a discipline at the philosophical level, representing the broadest sense of paradigm. The sociological paradigm refers to the overall framework composed of elements recognized by researchers within a discipline, including a complete set of rule systems such as disciplinary theories and theorems. The artifact paradigm refers to paradigms in the sense of tools, constituting a system of operationalized content of abstract paradigms. In short, sociological and artifact paradigms provide theoretical frameworks and research methods for a discipline, while the metaphysical paradigm connects the other two through philosophical-level reflection (do Vale Borges, 2014; Hassan, 2013). Third, paradigms are supra-conscious. Paradigms play a decisive role invisibly within any theory, doctrine, or ideology (Masterman, 1970). Paradigms are deep-level common elements hidden behind disciplines. They unite the scientific community composed of researchers in a discipline, dominate and limit researchers'thoughts and behaviors, and unconsciously guide and lead disciplinary development. Fourth, paradigms are developmental. No paradigm can dominate "all under heaven" forever. Scientific development and progress rely on the mutual replacement of incommensurable paradigms (Kuhn, 1970). As an important concept in Kuhn' s paradigm system, incommensurability refers to the characteristic that old and new paradigms cannot communicate with each other (Hung, 2017). During a specific period, only one paradigm can occupy a dominant position, and disciplinary development and evolution are achieved through the "conquest" of old paradigms by new ones (Ritzer, 1975).

Because organizational neuroscience absorbs the essence of three disciplines—neuroscience, psychology, and organizational behavior—its paradigm characteristics possess dual attributes of both natural and social sciences. Based on Masterman' s (1970) three-level classification of paradigms—defining the metaphysical paradigm of philosophical foundations, the sociological paradigm of theoretical architecture, and the artifact paradigm of operational research methods—this paper analyzes the organizational neuroscience paradigm (for the connotations and disciplinary contributions of the three paradigms of organizational neuroscience, see Table 1). In short, the organizational neuroscience paradigm takes emergence as its philosophical foundation (Bagozzi et al., 2019; Healey et al., 2014), Socially Situated Cognition theory as its theoretical cornerstone (Healey et al., 2014, 2015), and neuroimaging technologies as its main research methods, supplemented by measurement of neurophysiological indicators such as neurotransmitters and hormones (Jack et al., 2019; Massaro & Pecchia, 2019; Senior et al., 2011). These three components together constitute the paradigm system of organizational neuroscience. From a dynamic evolutionary perspective, research over the past five years indicates that organizational neuroscience has shown incommensurable replacement of reductionism by emergence at the metaphysical paradigm level (Healey et al., 2015), and a shift from neuroimaging-dominated to coexisting neuroimaging and ANS (Autonomic Nervous System) measurement methods at the artifact paradigm level (Cropanzano, Massaro, & Becker, 2017).

3 The Metaphysical Paradigm of Organizational Neuroscience

Simply put, the metaphysical paradigm is the philosophical paradigm, that is, the method of scientific thinking activities for understanding the external world formed under the guidance of ontology and epistemology (Masterman, 1970; Morgan, 2007). Ontology aims to explore the extent to which objective entities exist beyond individual subjective cognition, while epistemology concerns the extent to which research objects can be known through objective data or quantification (Jones & Gatrell, 2014).

Two prominent metaphysical paradigms have existed in the history of organizational neuroscience: reductionism and emergence. Both reductionism, followed in its early stages, and emergence, subsequently adopted as the mainstream metaphysical paradigm, belong to the category of monism in ontology (Bagozzi et al., 2019). Both acknowledge that objective entities (i.e., individuals' physiological mechanisms) exist beyond individuals' subjective consciousness and that individuals' cognition, attitudes, and behaviors can be explained by neurophysiological-level information, although they differ fundamentally in their explanatory mechanisms of the "physiology-behavior" chain. In epistemology, both acknowledge that understanding of human cognition, attitudes, and behaviors can be enhanced through quantitative research on physiological mechanisms (Healey et al., 2015).

Reductionism, derived from early phrenology and localizationist thought in neuroscience, holds the core idea that "everything can be reduced" (Putnam, 1973). According to reductionism, relationships between high- and low-level elements and between parts and wholes are linear and additive; linear combinations of low-level elements can explain high-level behavior, and the sum of parts can constitute the whole (Cummings, 1998). As an interdisciplinary theory originating from complexity science, emergence essentially emphasizes that "the whole is greater than the sum of its parts" (Holland, 1998). In this regard, emergence shares similarities with psychology' s "holism" or "Gestalt Psychology" (Liu Jinyang, 2014): they all emphasize qualitative differences between high and low levels and between parts and wholes. In other words, from low to high levels and from parts to wholes, new "qualities" "emerge" as complexity increases. Phenomena at high levels or wholes are neither mere arrangements of low-level or partial entities nor can they exist independently of low-level or partial entities (Holland, 1998).

Due to the limitations of its own disciplinary development, when organizational neuroscience was first established, Becker et al. (2011) regarded reductionism as the philosophical foundation of organizational neuroscience. Reductionism posits absolute explanatory relationships between brain structure, function, and individual behavior. In other words, complex individual behavior can be reduced downward layer by layer to the brain regions that determine cognition, attitudes, or behaviors; simultaneously, research on brain structure can not only reverse-engineer brain functions but also directly explain individuals' attitudes and behaviors (Becker et al., 2011). That is, neurophysiological structure, as the ultimate origin of individual cognition, attitudes, and behaviors, not only determines individual behavior but also constitutes the root of individual differences. For example, in research on goal-directed behavior, researchers designed and used fMRI to detect and identify the prefrontal cortex as the brain region responsible for individual planning and goal selection, and directly interpreted the achievement status of individuals' cognitive or behavioral goals based on the functions and various state indicators of the prefrontal cortex (Miller, 2000).

However, as research deepened, organizational neuroscience scholars discovered that numerous neuroscience studies show high-level individual behavior is not completed independently by a single brain region but results from the coordinated action of multiple brain regions. Moreover, the relationships between single brain structures and functions, between coordinated actions of multiple brain regions and brain functions, and between brain functions and individual behavior are not simple linear correspondences as advocated by reductionism (Clayton, 2004; Holland, 1998; Cacioppo, Berntson, & Nusbaum, 2008). Consequently, through a series of studies on intelligence emergence and brain neural networks, neuroscience has confirmed that the process from "neurons" to "mind" within individuals cannot be explained by simple localized "reduction" or linear superposition. This process involves not only complex coordination among multiple brain regions but also qualitative changes in brain functions after such coordination, "emerging" properties that simple combinations of brain regions do not possess (e.g., Bressler & Menon, 2010; Calvin, 1994; Park & Friston, 2013; Friston, 2013; Quartz & Sejnowski, 1997). These discoveries have prompted increasing numbers of organizational neuroscience scholars to question the "physiology-behavior" chain explanatory mechanism based on reductionism (Ashkanasy et al., 2014; Healey et al., 2015; Lindebaum & Zundel, 2013). Considering that the research focus of organizational neuroscience is not to explore individual brain structures or localizations corresponding to organizational behaviors but to deepen understanding of brain structures and their relationships with individual cognition and behavior, thereby providing direction for individual- and even group-level research (Healey et al., 2014), organizational neuroscience scholars have ultimately proposed that emergence should replace reductionism as the philosophical foundation of the metaphysical paradigm in organizational neuroscience (Healey et al., 2014; Hodgkinson, 2013; Hodgkinson & Starkey, 2012).

Under the philosophical foundation of emergence, individual brain functions result from complex coordinated actions among multiple brain regions, while individual behaviors emerge from complex coordinated actions among multiple brain functions. Through this layered emergent mechanism of the "physiology-behavior" chain, organizational neuroscience clarifies the misconception of linear deterministic relationships between brain structure and function and between brain function and individual behavior under reductionism. For example, in a study exploring the neural mechanisms behind regret-based decision-making, regret decisions result from the joint action of related brain regions such as the orbitofrontal cortex, amygdala, and dorsal anterior cingulate cortex (Coricelli et al., 2005). Based on reductionism, this conclusion could be interpreted as the mechanical additive combination of these three brain regions directly determining regret decisions, with the combination of these brain regions being the primary cause of regret decisions. However, according to emergence, regret decisions "emerge" bottom-up through the organic interaction among these brain regions; simple mechanical superposition of brain functions cannot produce the cognitive outcome of regret decisions.

The proposal of emergence can not only explain the "physiology-behavior" relationship at the individual level but also help interpret the "individual behavior-group behavior" relationship. Although in the field of organizational neuroscience, Healey et al. (2015) have only theoretically demonstrated the possibility of applying emergence to individual-to-group behavior, treating organizational individuals as "neurons" in the brain and viewing group behavior emergence and evolution as the result of complex coordinated actions among multiple individuals' minds, the application of emergence to the "individual behavior-group behavior" relationship has already been confirmed by other natural sciences. According to research on Collective Mind and Collective Behavior, scholars of collective behavior have extended the emergence process from "neurons" to "mind" within individuals to the dynamic evolution process from "individual mind" to "group mind" through numerous large-scale animal swarm behavior experiments (e.g., Cavagna et al., 2010; Couzin, 2007, 2009), thereby validating the applicability of emergence at the dynamic level of "individual behavior-group behavior."

4 The Sociological Paradigm of Organizational Neuroscience

The sociological paradigm of organizational neuroscience refers to the comprehensive set of all norms that provide theoretical and practical guidance for organizational neuroscience research, including theoretical foundations, research content, and research criteria.

4.1 Theoretical Foundation–Socially Situated Cognition Theory

Since the purpose of organizational neuroscience research is to reanalyze, reinterpret, and understand organizational behavior based on organizational theory and with the aid of neural-level data information (Ward & Becker, 2015), the research focus and endpoint of organizational neuroscience lie in "organization" rather than "neuro" (Healey et al., 2014). It is evident that studying organizational behavior solely from the neural level cannot encompass the entire content of organizational neuroscience. Moreover, although the metaphysical paradigm of emergence lays a macro philosophical foundation for interpreting neural-level data, as a representative of bottom-up micro-perspective theories, emergence, like reductionism, treats individuals as isolated rational beings while ignoring the role of complex organizational contexts on individuals (Ashkanasy, 2013). Therefore, it is necessary to combine top-down macro-perspective theories from organizational theory with the aforementioned bottom-up micro-perspective theories to explore the comprehensive effects of social contexts on individual cognition (Kozlowski & Klein, 2000). Furthermore, the influence of social and organizational contexts on individual cognition and behavior has long been a topic of concern and exploration for both organizational neuroscience and organizational behavior as a whole (Johns, 2006, 2017, 2018). To address the aforementioned problem of detachment from social and organizational contexts in organizational neuroscience research, Healey et al. (2014) proposed that Socially Situated Cognition theory (hereinafter SSC) should serve as the guiding theoretical framework for organizational neuroscience research.

The core argument of SSC is that individual cognition does not originate from any single element within the individual but from the interaction between the individual and social contexts such as organizations (Semin & Smith, 2013; Smith & Semin, 2004, 2007). In other words, individual cognition is rooted in a comprehensive system composed of brain, body, mind, and social environment. To better examine and confirm the role of the brain in organizational neuroscience research, Healey, Hodgkinson, and Massaro (2018) conducted a series of studies to answer questions such as whether the brain can operate independently of the body and external context and whether the brain is the ultimate determinant of behavior. The research shows that the completion of cognitive tasks in organizations is the result of the brain' s nervous system relying on the body, social interactions, and individuals' comprehensive cognition of the external world. In this process, the brain plays the role of a "management agency" or "regulatory department," combining the top-down influence of social, organizational environmental, and human factors on organizational behavior with the bottom-up influence of neural factors on organizational behavior. In short, although the brain is one of the most direct causes of behavior, it is not the ultimate cause or determinant, thereby validating the core argument of SSC.

According to SSC, the four levels of neural, individual, group, and organization are not isolated but highly intersecting and interactive. The intertwining and interaction between individual factors composed of brain, body, and mind and environmental factors composed of social, cultural, and organizational contexts jointly trigger certain behaviors in organizations. In this process, neurophysiological-level research is only one of the main mechanisms for explaining workplace behaviors. It is not difficult to find that although belonging to two different levels of paradigms, the sociological-level Socially Situated Cognition theory and the philosophical-level emergence both emphasize and recognize the interactive relationships among the four levels of "neural-individual-group-organization," together constituting indispensable core components of the multi-paradigm system of organizational neuroscience (Healey et al., 2015).

4.2 Research Content

The research content of organizational neuroscience includes both research directions and research objects. In terms of research directions, the research hotspots of organizational neuroscience basically show no difference from those of organizational behavior (Li Hao et al., 2016). Chinese scholar Li Hao et al. (2016) summarized that current research directions in organizational neuroscience include leadership, teams, organizational justice, organizational change, cognition and attitudes, decision-making, and organizational culture. Among these, leadership research has developed the fastest. Rock and Schwartz (2006) went further by directly proposing neuroleadership (Rock, Siegel, Poelmans, & Payne, 2012), separating it from organizational neuroscience as an independent field.

In terms of research objects, although organizational neuroscience includes four-level analyses of neural, individual, group, and organization, whether at lower levels of individual cognition, emotion, and motivation, or higher levels of inter-individual cooperation and conflict, or even higher-level organizational phenomena, all involve the study of individual neural systems (Bagozzi et al., 2019). This is precisely the greatest highlight of organizational neuroscience research: providing necessary and important supplements to traditional organizational behavior research through neural and physiological experiments on individual neural systems.

4.3 Research Criteria

The research criteria of organizational neuroscience include two components: a multi-level research model and a reverse inference problem-solving strategy. First, organizational neuroscience research has cross-level characteristics. So-called cross-level means that among the four levels of "neural-individual-group-organization," organizational neuroscience research should include at least the "neural" level and one of the other three levels. Bagozzi et al. (2019) pointed out that cross-level research in organizational neuroscience should organically combine objective neurophysiological indicator measurement with individuals' self-reported subjective perceptions. On the one hand, it explores the neural and physiological foundations of behavior and cognition; on the other hand, it employs traditional organizational behavior research methods such as observation and questionnaires. For example, Hannah, Balthazard, Waldman, Jennings, and Thatcher (2013) organically combined questionnaire-based psychological measurement with quantitative electroencephalography (qEEG) physiological measurement to study leaders' self-complexity. The results showed that these two distinct research methods reached the same conclusion regarding leaders' adaptive decision-making. The role of qEEG measurement was to provide direct evidence for questionnaire self-report results to verify the robustness of findings. Similarly, Meng Liang (2016) used event-related potential (ERP) methods to experimentally study the relationship between task selection in work task design and individuals' intrinsic motivation levels. This study did not rely solely on ERP technology to measure subjects' electrophysiological activity of brain neurons but also combined classical self-report methods to simultaneously verify hypotheses at both individual and neural levels, interpreting the data based on self-determination theory.

Second, corresponding to the deductive forward inference method most commonly used in organizational behavior, organizational neuroscience research should adopt reverse inference for inductive derivation (Butler et al., 2016; Jack et al., 2019). Due to the complexity and strong professional specificity of knowledge in the neuroscience field, brain regions and cognitive functions at the neural level do not have a one-to-one correspondence; often, one brain region corresponds to multiple cognitive functions. Therefore, when designing and implementing neural-level experiments, organizational neuroscience researchers must derive research hypotheses based on existing research conclusions from cognitive neuroscience through reverse inference, rather than following traditional organizational behavior research steps of first proposing hypotheses and then drawing experimental conclusions (Senior et al., 2011; Jack et al., 2019). For example, in organizational neuroscience research on managerial decision-making, researchers must first rely on cognitive neuroscience findings regarding brain regions highly related to managerial decision-making, namely the dorsolateral prefrontal cortex (DLPFC) and frontopolar cortex (FPC) (see Laureiro-Martínez, Brusoni, Canessa, & Zollo, 2015), before they can propose and verify new research hypotheses. Therefore, unlike traditional organizational behavior research that uses deductive reasoning from general to specific, neural-level experiments in organizational neuroscience represent an inductive research process from specific to general.

5 The Artificial Paradigm of Organizational Neuroscience

The artificial paradigm of organizational neuroscience belongs to the operational and technical level of the paradigm system, including all operable research methods that can be applied to organizational neuroscience research, encompassing both traditional organizational behavior methods such as questionnaires, observation, and interviews, as well as certain cognitive neuroscience research methods (Bagozzi et al., 2019). This section aims to summarize and review the new "toolkit" of organizational neuroscience—research methods unique to cognitive neuroscience. First, we review the most classic neuroimaging methods in the organizational neuroscience research method system, followed by a review and analysis of increasingly valued neurophysiological indicator measurement methods.

5.1 Neuroimaging Methods

Neuroimaging methods are currently the most frequently used research methods in organizational neuroscience research (Lindebaum, 2013; Poldrack, 2006). At the birth of organizational neuroscience, various neuroimaging methods were recommended for use in organizational neuroscience research (Senior et al., 2011). As research deepened, research tools with high invasiveness and high ethical risks to humans, such as CT (Computed Tomography) and PET (Positron Emission Computed Tomography), are no longer recommended for continued use in organizational neuroscience research (Balthazard et al., 2015). Currently, neuroimaging methods available for organizational neuroscience research include functional magnetic resonance imaging (fMRI), electroencephalography (EEG), magnetoencephalography (MEG), event-related potential (ERP), and transcranial magnetic stimulation (TMS) (Balthazard et al., 2015; Senior et al., 2011).

Senior et al. (2011) and Gazzaniga et al. (2014) provided detailed distinctions among the above five neuroimaging methods. First, although various neuroimaging tools can be applied to measure brain neural activity, they each have different emphases in spatiotemporal resolution capabilities. For example, fMRI has precise spatial resolution but can only provide temporal records in seconds; MEG, EEG, and ERP, although only involving brain region-to-cerebral cortex activity in spatial resolution, can provide temporal records in minutes.

Second, various neuroimaging methods each have their own strengths in technical principles and application scope (as shown in Table 2). fMRI derives brain region activation levels by measuring blood oxygen concentration changes in cerebral blood flow; EEG, ERP, and MEG directly measure electrical or magnetic signals of brain neural activity; TMS' s greatest advantage lies in its ability to non-invasively produce local stimulation in the brain through magnetic pulses to temporarily alter local brain physiological characteristics. As the most mature research method, fMRI has been successfully used to conduct a series of organizational neuroscience studies. For example, Balthazard et al. (2012), Boyatzis et al. (2012), and Molenbergh et al. (2015) used fMRI technology to measure brain activity differences in leaders or followers under transformational versus non-transformational leadership, resonant versus dissonant leadership, and charismatic versus non-charismatic leadership styles.

EEG has become the most recommended research method due to its advantages of high safety, low cost, portability, and non-invasiveness (Balthazard et al., 2012). Currently, scholars have achieved fruitful research results based on EEG, especially quantitative EEG (qEEG). For example, Hannah et al. (2013) showed that connectivity in frontal lobes differentially affects adaptive decision-making in leaders with varying self-complexity. Waldman, Wang, Hannah, and Balthazard (2017) demonstrated that neural activity in the brain' s default mode network (DMN) positively predicts ethical leadership behavior. Waldman, Wang, Hannah, Owens, and Balthazard (2018) found that high connectivity within the right prefrontal neural network is negatively correlated with abusive supervision. Compared with fMRI, EEG' s greatest advantage is its applicability to face-to-face interaction studies between subjects, thereby making group-level organizational neuroscience research possible. Currently, California has used EEG to develop technology suitable for group context research—Team

Neurodynamics (TND) (Advanced Brain Monitoring, 2014)—for real-time study of group task-solving processes, such as research on work engagement in work groups. In contrast, traditional questionnaire methods not only rely entirely on subjects' subjective perceptions for data acquisition but also have time lags, as questionnaires are often completed after group events occur (Waldman, Wang, Stikic, Berka, & Korszen, 2015).

Similar to EEG, MEG is also applicable to "leader-member" mechanism and interactive research at the work group and organizational levels, especially providing possibilities for better understanding how the brain responds to and utilizes contextual information in organizational contexts (Braeutigam, 2014). However, MEG is not only costly but also has no substantial difference from EEG in spatiotemporal resolution capabilities. Therefore, researchers tend to use EEG instead of MEG (Jack et al., 2019).

The premise for TMS application in organizational neuroscience lies in its ability to cause non-invasive virtual lesions in subjects. Through such artificial lesions, researchers can selectively interfere with specific cortical regions (Gazzaniga et al., 2014). TMS' s greatest characteristic is its strong context-dependent feature, that is, the excitability of cortical layers depends on the degree of artificial stimulation (Siebner, Hartwigsen, Kassuba, & Rothwell, 2009). However, although TMS claims to be non-damaging to subjects, it may still cause psychological and physiological discomfort during actual operation (Jack et al., 2019), and the entire virtual lesion process is very brief, posing great challenges to research precision (Gazzaniga et al., 2014). Additionally, TMS' s limitation lies in its applicability only to research on subcortical regions of the cerebral cortex, while many brain regions related to social cognition and emotional functions located in cortical sulci (e.g., medial parietal lobe, orbitofrontal lobe, amygdala, etc.) are not sensitive to TMS technology. This means TMS can only be used to study isolated brain regions rather than coordinated actions among multiple brain regions (Jack et al., 2019). Therefore, scholars currently have controversial views on TMS' s application prospects in organizational neuroscience, with some even pointing out that it is not suitable for organizational context research (Massaro & Becker, 2015). However, other scholars note that with technological advancement, repetitive TMS (rTMS) technology can extend the duration of virtual lesions, and deep TMS can expand TMS' s research scope, thereby providing guarantees for organizational research (Krause, Enticott, Zangen, & Fitzgerald, 2012).

5.2 Autonomic Nervous System (ANS) Measurement Methods

Autonomic Nervous System (ANS) measurement studies autonomic neurophysiological responses triggered by the brain but manifested in the body (Massaro et al., 2019; Peterson, Reina, Waldman, & Becker, 2015). Unlike neuroimaging methods that capture instantaneous brain physiological responses under unconscious conditions, ANS measurement studies individuals' unconscious physiological responses under conscious conditions (Peterson et al., 2015). It can be said that neuroimaging methods and ANS measurement methods constitute a complete neurophysiological measurement system by respectively exploring physiological responses of the "brain" and the "body."

The application of ANS measurement methods to organizational behavior research can be traced back to the 1980s (Ganster, Crain, & Brossoit, 2018). In recent years, ANS measurement methods have been strongly recommended for organizational neuroscience research due to their applicability to field studies and unique cost advantages (Massaro et al., 2019). Referring to the classification systems of Akinola (2010) and Peterson et al. (2015), ANS measurement methods include neuroendocrine activity (NA) measurement, cardiovascular activity (CA) measurement, and electrodermal activity (EDA) measurement. All ANS measurement methods can only distinguish human body regions outside the brain spatially but provide quite long continuous temporal records (minutes, hours to days) (Gazzaniga et al., 2014).

Table 3 summarizes various ANS measurement indicators. As shown, endocrine activities in the human body are composed of various neurotransmitters and hormones, including cortisol, oxytocin, testosterone, adrenaline, and acetylcholine (ACH).

Cortisol, oxytocin, and testosterone are all important indicators of individual stress and emotional responses, but each has different emphases. Cortisol is an important indicator of individual stress response and negative emotions (Peterson et al., 2015). In particular, cortisol can measure individuals' stress responses in uncontrollable situations or situations with social-evaluative threat characteristics (Akinola, 2010). Research shows that rapid increases in cortisol in high job demand situations not only bring short-term benefits to individual decision-making (Akinola & Mendes, 2012) but also affect individuals' risk preferences in behavior (Kandasamy et al., 2014); chronic elevation of cortisol negatively impacts employees'physical health and job performance (Lundberg, 2005; Melamed et al., 1999).

Oxytocin is often used to study individuals' tendency to seek social affiliation in stressful situations (Akinola, 2010). Oxytocin occupies an important position in individuals' stress responses. Taylor (2006) even pointed out that the existence of cortisol and oxytocin reflects that individuals' internal stress responses and external affiliation-seeking behavioral tendencies are equally important when facing stress. Oxytocin is also used in stress relief research because it enhances interpersonal interactions (e.g., Heinrichs, Baumgartner, Kirshbaum, & Ehlert, 2003; Light et al., 2000; Light, Grewen, & Amico, 2005). For instance, increased oxytocin can enhance trust levels, cooperation motivation, conformity, and group norm compliance among individuals, while decreased oxytocin negatively affects out-group individuals (Balthazard et al., 2015).

Testosterone is particularly suitable for studying individuals' stress responses in competitive situations (Akinola, 2010). Research shows that testosterone levels are related to dominance behaviors, defensive behaviors, status-seeking, risk-seeking, and other social behaviors and high performance in competitive situations (Bergmann & Kliesch, 2010). For example, Zyphur, Narayanan, G. Koh, and D. Koh (2009) studied the mismatch between testosterone levels and individual status; the higher the individual' s testosterone level and the lower their status in the group, the lower their comfort level in the group and the worse the group performance.

Adrenaline is closely related to individual alertness, concentration, and work pressure (Beugré, 2010). In particular, adrenaline is regarded as an important physiological indicator for judging individual workload intensity and workaholism behavior (Van Wijhe, Schaufeli, & Peeters, 2010). Research shows that increased adrenaline is often accompanied by high work pressure because it not only helps improve individual attention and innovation capabilities, thereby enhancing job performance (Sormaz & Tulgan, 2003), but also encourages individuals to develop sedentary work habits (Johansson, Johnson, & Hall, 1991), exhibit more tension, headaches, and insomnia symptoms during non-work time, and have more difficulty recovering from high workloads (Sonnentag & Zijlstra, 2006).

Acetylcholine plays an important role in human non-neuronal cells (Wessler, Kirkpatrick, & Racké, 1998). Numerous attention and cognitive behavior experiments have shown that acetylcholine is closely related to individuals' learning and memory (especially short-term memory), attention control, and spontaneous activities and exploratory behavior in new situations (Klinkenberg, Sambeth, & Blokland, 2011; Yu Ping, Qu Chunhuan, Li Xinwang, Guo Chunyan, 2008). Currently, few organizational neuroscience studies on human emotions or behaviors use acetylcholine, but its advantages in studying cognitive activities such as working memory, attention, exploration, and exploitation will secure it an important position in future organizational neuroscience research.

Cardiovascular activity measurement mainly refers to monitoring heart rate, blood pressure, and heart rate variability. Research shows that indicators such as heart rate and blood pressure are closely related to individual stress, subjective well-being, tension, frustration, and emotional arousal (Berka, Behneman, Kintz, Johnson, & Raphael, 2010). For example, perceived organizational support significantly moderates the relationship between procedural justice and individual cardiovascular activity; high levels of perceived organizational support and procedural justice significantly reduce individuals' heart rate and blood pressure (Rineer, Truxillo, Bodner, Hammer, & Kraner, 2017). Heart rate variability (HRV) is recommended for organizational neuroscience research on emotions, stress, cognitive states, behavior monitoring, and behavior change (Massaro et al., 2019). To date, HRV has been widely used in research on work stress and work-related rumination (Ganster et al. 2018). For instance, by having subjects wear wrist sensors (measuring heart rate from 8 PM to 10 PM for three consecutive workdays) to explore the relationship between work rumination and HRV, results showed that subjects who engaged in more work rumination during leisure time had relatively lower heart rate variability (Cropley et al., 2017).

The significant negative correlation between workday stress and work rumination and nocturnal HRV was also validated in Vahle-Hinz, Bamberg, Dettmers, Friedrich, and Keller (2014).

Electrodermal activity is strongly recommended for studying implicit attitudes and emotions in organizational neuroscience due to its advantages of low measurement cost and relatively easy implementation in workplace field studies (Becker et al., 2013). Numerous studies have shown that electrodermal activity is an important indicator for research on emotional arousal, physiological arousal, stress, tension, attention, and emotional intensity (Akinola, 2010; Kouchaki & Wareham, 2015).

6 Overview of Domestic and International Research in Organizational Neuroscience

Although organizational neuroscience was born less than ten years ago, a review of current domestic and international research already reveals characteristics of the "multi-paradigm" framework proposed in this paper. Therefore, this section provides a review focused on the application of the "multi-paradigm" framework in organizational neuroscience research.

6.1 Overview of International Organizational Neuroscience Research

Overall, international organizational neuroscience research has conducted in-depth studies across metaphysical, sociological, and artificial paradigms, constituting the prototype of the "multi-paradigm" framework proposed in this paper.

First, research on the metaphysical paradigm has mainly focused on the early proposal of reductionism as the philosophical foundation and the recent shift toward emergence. Reductionism originated from Becker and Cropanzano (2010) pointing out that the psychological mechanisms and brain functions of organizational individuals can be reduced to the molecular level. This viewpoint was deepened in the research of Becker et al. (2011). Becker et al. formally proposed that neurophysiological-level organizational behavior research could be conducted based on reductionist thinking. However, this viewpoint was questioned by scholars represented by Lindebaum (2013, 2014). Scholars collectively argued that the aggregation of low-level physiological structures is not equivalent to high-level individual behavior. As organizational neuroscience scholars deepened their research on the "physiology-behavior" mechanism, Healey and Hodgkinson (2014, 2015) ultimately proposed at the theoretical level the replacement of reductionism by emergence at the philosophical level.

Second, research on the sociological paradigm has mainly concentrated on proposing the theoretical foundation of Socially Situated Cognition theory (SSC) and the research criteria of cross-level research models and reverse inference. Due to typical interdisciplinary characteristics, early organizational neuroscience research suffered from serious disconnection from social contexts and the problem of equating organizational neuroscience research entirely with cognitive neuroscience research models applied to organizational behavior (Lindebaum, 2014). To compensate for the neglect of social context factors in early research, Healey et al. (2014, 2015) constructed the theoretical foundation of organizational neuroscience based on SSC; to deeply study the comprehensive influence of individuals' internal and external factors on behavior, Bagozzi et al. (2019) proposed a cross-level research model combining neural-level measurement with self-report questionnaires.

Third, research on the artificial paradigm has mainly focused on exploring how to apply various non-invasive cognitive neuroscience research methods to healthy organizational individuals, that is, advancing organizational neuroscience research from an operational practical perspective. Overall, the artificial paradigm has evolved from comprehensively borrowing various cognitive neuroscience methods (e.g., Akinola, 2010; Becker et al., 2013; Peterson et al., 2015; Senior et al., 2011) to selecting, deleting, and adding various alternative tools according to actual research needs (e.g., Balthazard et al., 2015; Jack et al., 2019; Massaro et al., 2019). After extensive tool comparisons and empirical research testing (e.g., Rineer et al., 2017; Wang et al., 2016; Waldman et al., 2018), EEG, fMRI, and ANS measurement methods will occupy important positions in future organizational neuroscience research.

6.2 Overview of Domestic Organizational Neuroscience Research

Unlike international research, domestic scholars first cognized organizational neuroscience as a branch of neuro-management (Ma Qingguo, Wang Xiaoyi, 2006), and later developed it into viewing it as an independent and complete discipline (Liu Tongjiu, 2013; Liu Yingjie, 2012). Overall, current domestic organizational neuroscience research is in its infancy as a whole. Even so, limited domestic organizational neuroscience and psychological research provides important references for constructing the "multi-paradigm" framework.

First, at the metaphysical paradigm level, although only Li Hao et al. (2016) discussed the relationship between reductionism and emergence in the organizational neuroscience field, following the principle that emergence and holism are essentially consistent, a large body of domestic research has explored the relationship between reductionism and holism philosophically (e.g., Gui Qiquan, 2015; Liu Jinyang, 2014; Zhao Guangwu, 2002). By distinguishing reductionism and holism in terms of research objects, research paths, and theoretical foundations, these studies provide support for constructing the metaphysical paradigm of this study.

Second, at the sociological paradigm level, domestic scholars have conducted a small number of empirical studies adhering to the social embeddedness and cross-level research models of organizational neuroscience. For example, Meng Liang (2016) simultaneously used individual behavioral experiments and ERP technology based on self-determination theory to study the relationship between task selection and feedback mechanisms in work task design and individuals' intrinsic motivation, proposing a cognitive processing model of intrinsic motivation that supplements the mechanism of intrinsic motivation occurrence in self-determination theory from a neurophysiological perspective. Yang Yan (2013) combined safety management theories and methods to conduct EEG experimental research on unsafe behaviors of miners in coal mining enterprises under fatigue states. Additionally, in terms of research directions, domestic research aligns with international research, with neuroleadership playing a leading role. As early as 2012, Xie Ye and Huo Guoqing reviewed the background, process, and theoretical development of neuroleadership, summarizing research progress from three perspectives: the genetic basis of leadership, brain imaging research related to "leader-follower" dynamics, and neurochemical research related to leadership. Zhang Lei (2017) reviewed neuroleadership research from perspectives of leadership traits, emotion management, leadership behaviors, and contingency leadership, and pointed out future research trends in leadership selection, assessment, training, and development. Domestic cognitive psychology research also provides important references for organizational neuroscience research. A large number of studies exploring the physiological mechanisms of personality traits and psychological processing variables such as personality traits (Guo Fengbo, Zhang Zhen, Yuan Sheng, Jing Yiming, Wang Yiwen, 2016; Huang Yamei, Zhou Renlai, Wu Mengying, 2015), self-esteem (Wang Yinan, 2016), attachment (Chen Wenfeng, Wang Zhengyan, Wang Yan, 2009), trust (Xie Yalan, 2015), and social exclusion (Yu Jihua, 2015) indicate research directions for domestic organizational neuroscience.

Finally, at the artificial paradigm level, there are currently few domestic studies introducing organizational neuroscience research methods, with only Ma Qingguo et al. (2006) conducting comparative analyses of the basic principles, experimental environments, and popularity of brain activity measurement technologies represented by fMRI and EEG, and Lei Ming (2017) summarizing resting-state and functional leadership brain mechanisms and research on neurotransmitters and hormones represented by oxytocin and testosterone. Additionally, in terms of methodological application, domestic research also shows a trend of emphasizing neuroimaging methods while giving equal importance to ANS measurement methods. For example, Meng Liang (2016) and Yang Yan (2013) both used ERP technology to study the brain mechanisms of workplace individual intrinsic motivation and employee fatigue, respectively. Qi Xingliang (2016) explored the relationship between the "pituitary-hypothalamus-adrenal axis" and work characteristics and work recovery needs by extracting cortisol from subjects' hair. Pan Ailing, Xu Yaoshan, and Li Yongjuan (2017), as well as Zhang Hongchuan et al. (2016), respectively designed research conceptions on the impact of ego depletion on workplace safety and the cognitive mechanisms of humble leadership on self-construal based on HRV and brain imaging technologies.

Based on the overall publication situation in Chinese academic journals, organizational neuroscience research in China can keep pace with international frontiers in both sociological and artificial paradigms, not only aligning with international research in research directions and using both neural-level research and self-report methods in research criteria but also showing a parallel trend of neuroimaging and ANS measurement methods in research methods. However, current domestic research mostly concentrates on theoretical review studies and research conceptions, with empirical studies truly combining cognitive neuroscience technology with organizational behavior research being rare. Nevertheless, the proposal of numerous organizational neuroscience research conceptions (e.g., Hu Weiping et al., 2015; Lou Yixue, Cai Ayan, Yang Jiemin, Yuan Jiajin, 2014; Pan Ailing et al., 2017; Zhang Hongchuan et al., 2016) not only confirms domestic scholars' strong interest in organizational neuroscience but also indicates the broad research prospects of this discipline in China.

In summary, organizational neuroscience is a model of organizational behavior "drawing nutrients from other disciplines to build theory (Zhang Zhixue, Ju Dong, Ma Li, 2014)," marking that organizational behavior research has entered a stage of exploration based on neuroscience models. The philosophical-level metaphysical paradigm, the theoretical-level sociological paradigm, and the methodological- and technological-level artificial paradigm, through their organic combination, jointly constitute the three-dimensional architecture of the organizational neuroscience paradigm. Specifically, at the philosophical paradigm level, emergence lays the philosophical foundation for association and explanation of the "neural-cognition-behavior" relationship chain; at the theoretical paradigm level, Socially Situated Cognition theory (SSC) provides the theoretical foundation for the accurate research positioning of organizational neuroscience; at the methodological and technological level, neuroimaging methods and ANS measurement methods provide an alternative toolkit for organizational neuroscience. However, it must be acknowledged that the entire disciplinary development of organizational neuroscience is still in its infancy. From a multi-paradigm perspective, there remain many issues worthy of attention and deep reflection for the future development of this discipline.

7.1 Placing Organizational Neuroscience Research in a Three-Dimensional and Multi-Level "Context"

So-called "context" refers to situational or environmental characteristics that influence research objects. In the history of organizational science development, context has been divided into "omnibus context" and "discrete context" (Johns, 2006). The former refers to broad environments, including large amounts of "fleshed-out" information such as time, place, people, and the ins and outs of events, while the latter refers to specific contextual variables that can directly affect behavior or moderate variable relationships. Discrete contexts are nested within omnibus contexts, and their effects are transmitted through discrete contextual variables or interactions among variables. According to the sociological paradigm' s Socially Situated Cognition theory, neurophysiological factors intertwine with individual, organizational, and environmental factors, and brain and nervous system operations cannot exist in isolation from contextual factors. Therefore, combining neural-level research with classic individual, group, and organizational-level research in organizational behavior and conducting organizational neuroscience research in rich and multi-level organizational contexts should become an important direction for future research.

First, expand and innovate existing organizational context theories by treating "neurophysiological states" as the "internal context" when individuals emit or implement certain organizational behaviors. For example, in a study on emotion regulation, Healey et al. expanded the original three-layer context-related cues of task, social, and cultural in Trait Activation Theory (TAT) to four layers of neurophysiological, task, social, and cultural context-related cues based on TAT, thereby enriching the connotation of context relevance (Healey, Hodgkinson, & Massaro, 2017). This idea of incorporating or treating the "neurophysiological state" of research objects as the "context" for certain organizational behaviors is expected to propel organizational neuroscience into a new historical stage. Second, Affective Event Theory (AET) can serve as a breakthrough for cross-level penetration and integration between the "neurophysiological level" and other classic organizational behavior research levels. AET systematically explains the structure, causes, and mechanisms of individuals' emotional reactions at work (Research Group of Renmin University of China, 2017). Based on neuroscience research on emotions, variables at the "neurophysiological level" may either broaden the occurrence conditions of emotional events by influencing individuals' internal attributions when experiencing certain emotional reactions or predict the impact of emotional events on individuals before they form final attitudes and behaviors (McColl-Kennedy et al., 2017). Therefore, the original "event → emotion → attitude and behavior" can be expanded to "event → neurophysiological reaction → emotion → attitude and behavior." This not only enriches AET's theoretical framework but also is expected to become a new research area in organizational neuroscience. Additionally, relying on mature organizational behavior theories, "neurophysiological" measurement can be organically combined with subjective reports of psychological processes. For example, according to the Cognitive Appraisal Theory of Emotion and Attribution Theory of Emotion, individuals' cognitive appraisals often occur before emotion generation (Duan Jinyun, Fu Qiang, Tian Xiaoming, Kong Yu, 2011), while traditional research mostly uses questionnaires for subjective reports of cognitive appraisals. If "neurophysiological" level data are introduced, they can corroborate data from traditional questionnaire methods, obtaining more and more direct data and evidence on the association between cognitive appraisal and emotion, thereby potentially verifying and expanding many classic theories from new perspectives.

7.2 Fully Utilizing the Principle of Neuroplasticity to Conduct Applied Basic Research in Organizational Neuroscience

Given that current organizational neuroscience research is still in its primary stage, research almost entirely focuses on exploring and determining the neural localization and causes of phenomena at individual, group, and organizational levels—that is, conducting basic research. Even so, we should not overlook the ultimate mission and responsibility of organizational neuroscience research: serving organizational management practice. The research topics of organizational neuroscience should strive to explore the potential counter-effects and application value of research on individual cognition, behavior, and organizational management practice—that is, the possibility of improving employees' cognitive abilities through organizational neuroscience research (Clark & Parasuraman, 2014). This possibility depends on neuroscience research on neuroplasticity—that is, how individuals' neural circuits can be reshaped through training and other methods (Bavelier, Levi, Li, Dan, & Hensch, 2010). Therefore, neuro-enhancement and neurofeedback should be future research areas in organizational neuroscience. Specifically, neuro-enhancement refers to using modern neuroscience technologies to enhance employees' mental and cognitive functions such as memory, attention, creativity, and willpower (Stikic, Berka, & Korszen, 2015). Neurofeedback refers to converting EEG signals into easily understandable forms such as sounds or animations, through which subjects can learn to selectively enhance or inhibit signals in certain frequency bands through training, thereby achieving the purpose of regulating brain functions (Monderer, Harrison, & Haut, 2002). Neurofeedback is particularly suitable for combining with organizational training to improve employees' cognitive functions. For example, Laureiro-Martínez et al. (2015) found in their research on managerial decision-making that leaders' decision-making performance improved by increasing the activity of brain regions related to attention regulation. This discovery not only opens up new directions for future applied basic research in organizational neuroscience but also provides practical ideas for reference for future customized management training. Stikic et al. (2015) studied the possibility of applying neuro-enhancement and neurofeedback in organizational research. Stikic et al. pointed out that for research in the organizational field, any pharmacological and invasive neuro-enhancement technologies should not be used, and currently, the only neuro-enhancement and feedback technology with hope for application in the organizational field is "brain training" for organizational individuals to achieve optimal cognitive states for specific tasks and maintain these optimal states through organizational individuals' self-regulation. Throughout this process, special attention should be paid to the use of "neurological markers" that can identify "optimal cognitive states."

7.3 Strengthening Integrated Application of Research Methods to Achieve Complementary Advantages

Given that each research method has its inherent strengths and weaknesses, comprehensively applying two or more research methods in the same study to leverage strengths and avoid weaknesses and achieve complementary advantages will be another future research trend in organizational neuroscience (Jack et al., 2019). This integrated application among methods includes both integration and complementary advantages among various different neuroimaging methods and integration between neuroimaging methods and ANS measurement methods. For example, the combination of fMRI and EEG can overcome the low temporal resolution of fMRI and compensate for the low spatial resolution of EEG, thereby providing possibilities for research with "dual high" temporal and spatial resolution (Huster, Debener, Eichele, & Herrmann, 2012). The combination of fMRI and TMS can simultaneously leverage fMRI' s high spatial localization and TMS' s ability to create virtual lesions. On the one hand, TMS methods can be used in real-time during task performance to stimulate specific brain regions identified by fMRI; on the other hand, it can also study connectivity issues between specific target brain regions and other brain regions during task performance and task interruption (Neggers et al., 2004). Moreover, since EEG provides continuous electrical activity records of the whole brain, the integrated application of TMS and EEG can help researchers obtain neural activity signals outside the specific brain regions of interest to TMS (Miniussi & Thut, 2010). Additionally, neuroimaging methods can be combined with ANS measurement methods to explore and solve certain practical problems in organizations. For example, in research on virtual teams, researchers hypothesized that the text-based communication methods (text messages, WeChat, emails, etc.) adopted among team members are important reasons for virtual teams' decision-making errors and confirmation bias (Kahneman, 2003). Since both cognitive and emotional responses to information are important components of the decision-making process, to verify this hypothesis, Minas, Potter, Dennis, Bartelt, and Bae (2014) simultaneously used EEG, EDA, and EMG (electromyography) methods to explore the decision-making obstacles caused by text information in virtual team decision-making from the perspective of information processing physiological mechanisms. In this study, EEG' s role was to capture individuals' cognitive responses to decision-related information statements, while EDA and EMG' s roles were to measure group members' emotional responses to information statements. The research showed that information in text messages that contradicted individuals' original decision preferences was identified as "irrelevant" information by individuals' neural mechanisms, while information consistent with individuals' original decision preferences received full processing and elaboration by neural mechanisms. Therefore, the above hypothesis was supported by research results.

7.4 Striving to Explore New Methods and Technologies While Avoiding Blind Pursuit of Novelty

The issue of low sample size and corresponding statistical power is the greatest criticism currently facing organizational neuroscience research (Button et al., 2013; Lindebaum et al., 2013; Lindebaum, 2016). Although researchers have pointed out that the human neurophysiological system differs from the subjective cognitive system and that large sample sizes are unnecessary due to greater similarity among individuals, Lindebaum (2016) and Funder (2014) still pointed out that organizational neuroscience must conduct direct retests based on original experimental designs or retests with expanded sample sizes to improve the reliability of research results.

In fact, the sample size and representativeness issue is only an important challenge facing neuroimaging methods. For ANS measurement, since experimental costs are relatively low and samples are relatively easy to obtain, the above sampling problems do not exist (Zyphur et al., 2009; Massaro et al. 2019). However, in the field of organizational neuroscience, the currently widely applied research methods are still only fMRI and EEG, both of which belong to neuroimaging methods. Therefore, expanding and applying other technological means to organizational neuroscience to enhance research internal and external validity is urgent. For example, as a representative of optical imaging technology in recent years, functional near-infrared spectroscopy (fNIRS) is based on the principle that active brain regions scatter more light than inactive brain regions. Researchers can use this to measure individual nervous system activity. More valuably, fNIRS has the same precise spatiotemporal resolution as fMRI, but its cost is only a few tenths of fMRI (Gazzaniga et al., 2014). Therefore, this technology will have great potential in the field of organizational neuroscience. In addition, newly explored improved transcranial stimulation technologies (Transcranial Stimulation, TCS) and experimental methods for non-invasively accessing deep brain regions will bring infinite hope for future non-invasive research on deep brain structures and functions (Reardon, 2016).

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Note: Figure translations are in progress. See original paper for figures.