JNphi

Neurophenomenological Oeuvre in Large-Scale Networks: The Neural Dynamics of Subjective Experience

Nathazsha Gande

Abstract

Neurophenomenology is a research program that seeks to integrate the fields of neuroscience and phenomenology for the purpose of investigating the nature of human experience. Contemporary neurocognitive models pertaining to self-regulation and execution suggests that individuals interpret objects they perceive and approach as definite in their experiential encounter. Yet, a comprehensive analysis on the phenomenology of awareness and behaviour reveals that during the process of detecting or interacting with objects, we experience them in a convoluted manner that underlies an adversarial association of default and executive control networks. In this regard, numerous studies have invested in specific tasks involving creative-thinking that engage large-scale networks during artistic performance to understand the intricate cognitive processes of goal-oriented, self-generated thinking when subjects interact with objects and the world around them. This perspective provides a cognitive neuroscience lens on first-person narrative and third-person neural data co-development through the use of neurofeedback, aiming to enhance our understanding of the dynamic interplay between large-scale neural networks and acknowledges the challenges associated with the concurrent acquisition of both phenomenological and neuroscientific data. By doing so, research gaps and explanations for apparent discrepancies are elaborated, supporting executive function with a more in-depth phenomenological understanding of ourselves.

Key Words: neurophenomenology, neurofeedback, default-control network, philosophy of mind, executive function

DOI: 10.5281/zenodo.10200290

Introduction

Neuroscience has accomplished a great deal in clarifying how and why the brain comes up with innovative and valuable conceptions. When it comes to researching the neural underpinnings of creative conception and execution in executive function, far more cognitive scientists are coming to the realization that it is necessary to make

Corresponding author: Nathazsha Gande
Address: Derner School of Psychology, Adelphi University, 1 South Avenue, Garden City, New York, 11530, USA
e-mail ✉ nathazsha@gmail.com
Received: XX May 2023; **Accepted:** XX August 2023

methodical use of introspective phenomenological accounts (Beaty *et al.,* 2003, 2015). Yet, there are still a variety of epistemological and methodological hurdles to overcome in order to successfully incorporate such first-person input further into experimental methods of cognitive neuroscience. The primary problem is the potential for prejudice or inaccuracy in first-person narratives (Nisbett and Wilson,1977; Hurlburt and Heavey, 2001). As for the second, it is natural to worry that writing an introspective or phenomenological account of an event would change the experience itself. This is an obstacle because it is essential to have the capacity to discriminate between these two different alternatives. The challenge is intricately connected to a number of more fundamental conceptual and epistemological questions concerning the relationship between “meta-awareness” and first-order experience (Schooler, 2002). The "explanatory gap" that occurs between the first-person domain of subjective experience and the third-person domain of the brain is the final impediment. This disconnect arises from the fact that the brain, the body, and behaviour are all investigated from an objective, third-person vantage point (Roy et al, 1999). Despite helpful large-scale networks of creative cognition and experimental evidence on the brain correlates of executive function, this gap still needs to be addressed appropriately. Due to these obstacles, the reliability of first-person accounts of experience is still an open and contentious topic in the field of cognitivism.

The study of phenomenology seeks, in part, to provide a direct description of human experience phenomena, free of any metaphysical preconceptions derived from mental, scientific, traditional, sociocultural, or any other conceptual framework. This commitment to direct description of human experience phenomena is at the heart of phenomenology. Nonetheless, Descartes argues that the phenomena in question cannot be represented adequately outside of the "subject-object" milieu of a subjective mind struggling to capture the objective world, a dualism that allows for even the most extreme skepticism. These are attributed to "empty heads oriented towards the universe" (Merleau-Ponty, 1962) or simply to "Dasein" in phenomenological terms (Heidegger, 1927) rather than human experience per se (with its implication of a personal, inner subject experiencing a transcendental, outer world). One of the most important, if not the most important, findings of phenomenology is the existence of this structure in our intentional engagement to the world. Though this may be the case, the process of consciously deciding how to respond to stimuli and interact with the outside world: a collection of control mechanisms that are used for a variety of purposes that work to regulate an individual’s ideas and actions—that is, executive function (EF)—is what is being described, at least in the sense that this scientific truth in deliberate interaction is manifested in the physical substrate of the human brain.

One must not mistake the scientific truth that this intentional relationship is physically realized within the brain with the phenomenological fact that the accurate account of our intended interaction with the outside world rejects that we are private, interior subjects. Instead, phenomenology and cognitive research should have a “data-to-model” link, since neuroscience seeks to explain how the brain’s physical processes conspire to construct the phenomena of human experience. Insofar as phenomenology is devoted to describing these occurrences precisely, it offers the most exhaustive and precise representation of the data that, in the end, must therefore be understood well by models of neural activity (Varela,1996). The purpose of a phenomenological analysis of a particular facet of human behaviour is to offer an in-depth description of the features of that behavior, to which any physical and or biological explanation ought to be capable of recreating.

This paper is concerned with higher-order neurocognitive processes of subjective experience including, decision making, mind-wandering, performance planning, and future-thinking, all of which regulate the forms of thinking and behaviours that lead to successful creative outcomes in the real world (Anderson, 2002; Zelazo and Carlson, 2012), which is evident with creativity. It is with contention that studying large-scale functional networks that display a linked activity sequence at rest and when it is engaged in cognitive tasks can be faithfully reproduced by the most salient phenomenological qualities of artistic phenomena. In particular, discussing how the default and executive network regions are dynamically coupled along with divergent thinking is dependent on the cooperation of networks that are normally at odds with one another, which is associated with cognitive control and improvised thought. This would provide a constructive view that is essential to the phenomenological qualities in the place of the ‘knowing’, involved in the dexterous acquisition of objects, as well as ‘interacting’ with the object in our visual field. This is fundamental in our perception of them; by which the subject infers meaning to the object. In other words, we are exposed to the unfiltered information of external and internal sensory experiences.

The ability to rationalize, make connections, and create opinions about these perceptions gives us the freedom to either appreciate and embrace the object at hand, or reject and despise it. According to Merleau-Ponty’s existential phenomenology, to infer meaning is a property of *being-in-the-world* rather than *knowing-the-world*, leaving it open to interpretation as to whether it arises from the unconscious, personality, genes, or any other form of causal component chosen by other philosophies (Merleau-Ponty, 1996). It is possible that in doing so, the objects we interact with in our daily lives reflects an internal concentration of top-down control in spontaneous cognition and EF in ourselves during the real-time execution of a goal-directed task. By implementing this behaviour in a concept that is, at least in principle, consistent with neuroscientific data regarding the function of the brain, these accounts of perception and action get close to satisfying the dual constraints of neurophysiological feasibility and phenomenological accuracy that should guide all works dedicated to discovering the physical bases of the human experience.

Self-Generated Thought, Large-Scale Networks and Creative Cognition: A Metatheoretical Relation

> *At the still point of the turning world. Neither flesh nor fleshless;Neither from nor towards; at the still point, there the dance is, But neither arrest nor movement.* –*T.S. Eliot*

The ability to mentally recreate another time, location, or viewpoint is fundamental to human cognition and allows us to transcend the limitations of our immediate surroundings. These internally created processes have numerous positive outcomes, but they can also have significant negative outcomes for certain people (Ruby, 2015). The processing of sensory data is unnecessary for many mental operations (like creative thinking), and during these actions, we focus on our mental models, ignoring or even suppressing any external sensory data that could get in the way (Puente-Diaz, 2023). Constructive processes rely on memory or previously stored knowledge rather than direct sensory input that characterize the cognitive activities we call planning, mental simulation, and creative idea production. Internally directed thought might be either impromptu or purposeful. When we are relaxed or our minds wander off on their own, we are engaging in spontaneous internal cognition. Yet, goal-directed internal cognition is a portion of an activity that is itself goal-directed, which relies heavily on internally-focused attention (Smallwood, 2013). Maintaining an internalized stream of thought requires directing one's attention inside, despite a barrage of external stimuli. To protect ongoing internal processes from outside interruption, it has been claimed that an internal attention focus entails detaching attention from perceptual input (Dixon *et al.,* 2014). Hence, keeping one's attention on anything within oneself might be understood as an exercise of an individual's executive control (Benedek *et al.,* 2014; Schooler, 2006).

The fields of cognitive neuroscience and neuroimaging have begun to provide light on the neural circuits that are related with focused inner and outward attention respectively. The regions of the superior parietal and intraparietal regions are critical nodes in the dorsal attention network (DAN), which has been connected several times to attention that is directed externally. There is also the possibility that occipital areas are part of the DAN that perhaps make up their own distinct visual network (Yeo *et al.,* 2011). For tasks with a specific end in mind, the DAN helps guide cognition upwards toward those sensory cues (Benedek *et al.,* 2016). Yet, introspective focus is typically linked to the brain's "Default Mode Network" (DMN) (Buckner *et al.,* 2008).

The medial prefrontal cortex, posterior cingulate, medial temporal lobes, and posterior inferior parietal cortex make up the DMN's central areas. Activation of the DMN has been linked to purposeful introspection and imaginative activities, suggesting an indirect linkage between internal attention and the DMN since the DMN reliably deactivates throughout all types of external tasks (Gusnard and Raichle, 2001) This indicates that when internal cognition is occurring, one's attention is disconnected from the outside world and is instead being used to process and maintain one's own self-generated thought (Smallwood and Schooler, 2006; Smallwood, 2010; Schooler *et al.,* 2011; Smallwood *et al.,* 2012).

Recent research has shown that self-generated thought (SGT) can have simultaneous advantages and drawbacks, and that it can be connected to both executive control and executive failure, challenging the long-held view that it is a unifying phenomena (Cancer *et al.,* 2023; Simola *et al.,* 2023). Several varieties of SGT can exhibit unique phenomenological features, pointing to the involvement of diverse cognitive correlates in the genesis of varied lines of thought. This shows that individual variations in thought content accounted for differences in the brain substrates of SGT are determined by resting state functional Magnetic Resonance Imaging (fMRI) and electrophysiological studies aiming to elucidate the neural correlates of self-generated cognition (Li *et al.,* 2023). One study compared brain activity during a visuospatial planning task and a self-reflective assessment of an autobiographical planning task. They discovered that the DAN was involved in the visuospatial task, the DMN in the introspective task, and that both tasks also activated a frontoparietal control network (FPCN) (Spreng *et al.,* 2010). Task-related coupling of FPCN with DMN was also linked with introspective planning, whereas task-related coupling of FPCN with DAN was connected with visuospatial planning. This suggests that internal-external multitasking is facilitated by interactions between the DMN, FPCN, and DAN, and that the time-varying information processing between these networks is responsive to differences in task-specific attention. It seems that the outcomes of each research task vary based on the task itself and the participant group, rendering it hard to generalize the results.

Yet, when it comes to creative, artistic-oriented tasks, humans have an instinct for recognizing truly original artistic creations, but there is no universal metric by which to rate them. This is most evident in the creative tasks of live music performance. According to the established psychological literature that defines creativity, it must involve both originality and usefulness (Runco and Jaeger, 2012). Creativity is a tough issue to tackle since it is hard to measure factors like originality, quality, and audience suitability (Guilford, 1950; Baer, 1998). Whilst there have been many approaches taken in an attempt to understand creativity, only examining the process of creative thought can truly capture the moment when an idea becomes a finished product. Changes in spectral and temporal brain activity have been seen across groups of people with varying degrees of improvisatory training. These changes have been measured using time-sensitive methods such as electroencephalography and event-related potentials (EEGs and ERPs), and they have been observed in a variety of groups (Vuust *et al.,* 2012; Przysinda *et al.,* 2017; Goldman *et al.,* 2022). Research on event-related potentials (ERPs) show that musicians' reactions to unexpected musical occurrences vary greatly depending on their level of improvisatory training and also evolve over the course of time. Musicians with improvisatory training may detect the unexpected as soon as 200 milliseconds (ms) after the situation happened, whereas classical musicians continue to exhibit sensitivity until 800 ms after the start of a piece (Przysinda *et al.,* 2017). According to research by (Goldman *et al.,* 2023) experienced jazz instrumentalists had faster reaction times to functional abnormalities. In this sense, composing music, performing it, and especially improvising, as it is done in jazz, all need artists to be innovative since they must come up with new musical ideas on the spot, in real-time that is relevant to real-world circumstances. Because of this, jazz improvisation has been held up as a prime example of improvised innovation in Western tradition for quite some time (Sawyer, 1992). The study of jazz improvisation is only one area where neuroscientific methods have become progressively more common in recent years to which improvisational music is often held up as the gold standard of creative spontaneity.

Another study compared spontaneous improvisation to controlled performance on the keyboard. The results showed that during jazz improvisation, there is a network of activations and deactivations in the medial prefrontal cortex (MPFC) and dorsolateral prefrontal cortex (Limb and Braun, 2008) as they changed from performing memorized repertoire to improvised lines. When compared to performing memorized sequences, improvising results had an increase in DMN activation and a simultaneous decrease in Executive Control Network (ECN) activation. Instrumental experts generally inject thoughts that match the present situation with minimum cognitive control needed, hence their decrease in ECN activation was read as reduced estimation (Berkowitz, 2010; Harris *et al.,* 2017). *Hypofrontality*, which has been linked to 'flow' (Dietrich, 2004), is the term the authors used to describe this inactive condition. Enhanced performance has been connected to the phenomenological concept of achieving a flow-state incarnation, which is characterized by a state of deep immersion in a single activity with limited reflection on the task's significance or the individual's role in the task's completion, though the intention of creating sound is deliberate (Gande, 2022).

Since then, functional MRI has been the primary tool for correlating behavioral performance during improvisation with brain activity in neuroimaging investigations of musical innovation (Donnay *et al.,* 2014; Pinho *et al.,* 2014). Neuroimaging research on jazz improvisation and artistic tasks can shed light on the broader field of neuroscience by revealing the neural mechanisms behind the spontaneous development of auditory-motor sequences (Berkowitz and Ansari, 2008). Thus, it lends weight to the idea that SGT is a multifaceted phenomena, and they point out how considering SGT content improves our grasp of the neurocognitive mechanisms representing the neural dynamics of an individual's subjective experience in performing a particular task. This indicates that this idea of creative thought and execution is founded on a pervasive dualism that dichotomizes subject and object, nature and consciousness, reason and emotion, spontaneity and deliberation. To observe that the behaviors we learn influence the outcomes we witness, and that the meanings we espouse determine the worth we assign to certain items. A "philosophy as science" paradigm is incapable of accurately reflecting aesthetic and experiential realities. It is evident that the definition of meaning derived from "linguistics as a science" fails to adequately describe how humans express themselves and the multifaceted character of meaning that is both experienced and expressed through action in real-time performance. In this vein, performing a creative task can mean different things to different people, but most people agree that it involves making something new and helpful (Runco and Jaeger, 2012). To this end, we might define creative cognition as a series of mental operations that facilitates the birth of original and practical concepts. Here, we zero in on the mental procedures involved in the generation and assessment of original concepts across several artistic fields. How can we describe the phenomenology of a calm state of mind during an artistic task? It is much simpler to attain the state of euphoric comfort when one closes their eyes and remove themselves from potential external distractions (Twemlow *et al.,*1982).

When the mind is left to its own devices, however, it is not uncommon for it to encounter a nonstop onslaught of critical ideas, emotions, or moods. SGT that a person has on their own are the result of introspective processing that takes place with little to no outside influence (Polychroni *et al.,* 2022). Thoughts of one's own creation can emerge naturally in the mind, and research shows they can derive from goal-oriented processing and self-regulation of thinking (Novakovic-Agopian *et al.,* 2018). According to a plethora of recent cognitive and neuroscientific studies, humans devote a disproportionate amount of their mental resources to self-generated thought (Simola *et al.,* 2023; Xu *et al.,* 2023; Northoff *et al.,* 2023; Kane *et al.,* 2007; Killingsworth and Gilbert, 2010), an intrinsic mode of cognition distinguished by its independence from the limitations imposed by the surrounding environment (Smallwood, 2013). The benefits of original thought are numerous, and its prevalence helps us face future difficulties, find solutions to issues, and find our way in the social environment (Smallwood and Schooler, 2006; Baars, 2010; Unsworth and McMillan, 2013). In the same frame of mind, phenomenological content may play a part in deciding the benefits and drawbacks associated with self-generated cognition coupled with EF.

On the other hand, one may argue that these conceptual concerns are not only important, but also, on a deeper level of analysis, could lead to fruitful research themes for future study. This is an alternative viewpoint to the one presented in the previous paragraphs. Phenomenology, philosophy of mind and cognitive neuroscience can be seen as a metatheoretical endeavor, wherein philosophers' first- order theoretical work is to get as close as they can to the phenomenon that is being studied. The second-order work of phenomenologists and experimentalists is to be concerned with the conceptual framework of first-person, real-time theories in the phenomenon itself (Lutz and Thompson, 2003).

One of philosophy's goals is to break down the material and human world into its constituent components in order to better understand the 'whole' of which they are a part. This practice has the potential to create a divide between ourselves and the things we hold dearest as human beings. Because of this, a philosophical approach will center its attention less on the reality of spontaneity and deliberateness of thought and more on the concepts that are used to understand it. Both levels of investigation are intertwined in practice. Empirical researchers have a vested interest in methodological concerns and a predisposition to establish implicit conceptual background assumptions, while philosophers give fresh abstract introspections to experimentalists and may subsequently develop empirical propositions altogether. Nevertheless, hardly any present work provides a combined phenomenological and cognitive neuroscience viewpoint as to how phenomenology, executive function and self-generated thought may evolve together in creative output. Yet, developmentalists have seldom attempted to explore the link between these abilities as indicators of shared and/or separate neurological substrates, instead relying on broad assumptions about how the brain works. Quite naturally, philosophers of mind always deal with their own, highly conceptual issues, but they also aim to build a more complete and integrated framework that may guide and motivate empirical inquiry.

Selecting specific, increasingly well-researched topic phenomena and exploring what can be learnt about them from the empirical literature has shown to be intriguing and rewarding from a philosophical standpoint.

The Bridge of First-Person Narrative and Third-Person Data

> *In the case where the self is merely represented and ideally presented (vorgestellt), there it is not actual: where it is by proxy, it is not. –Georg Wilhelm Friedrich Hegel, The Phenomenology of Mind*

Our idea of ourselves is not ourselves. In the first-person domain, by seeing oneself as the subject, one must construct a representation of oneself that is filled with definitions. This is not "genuine" since it has not been abstractly processed to achieve a unification of subject and substance, existing in and for itself. While we search for our true selves, we use an external, object-based interpretation of ourselves, relying on our perceptions of who and what we are and the experiences that have shaped our lives. In an attempt to understand ourselves, the primary subfields of cognitive neuroscience seek to define the nature of the human mind, personality, and awareness. This strategy uses random sampling, calibration methods, and data analysis to isolate the mechanisms that are most likely to be constant throughout the population. It is ironic, though, that when we investigate the phenomena of mental processes, which are by definition subjective, we refuse to treat them as such. We overlook the most distinguishing aspect of our minds by failing to elaborate on the subjectivity that is its most distinctive trait.

To solve the complex nature of consciousness, Varela (1996) developed a research program known as "Neurophenomenology" (Chalmers, 1995). This idea was opportunistic in character, with a vision towards filling up the interpretive gap between neurobiological and phenomenological aspects of consciousness rather than researching the complex topic as a whole. Without rejecting the need for a robust research methodology in the gathering of first-person data, neurophenomenology promotes a combined exploration of scientific investigation and subjective experience in scientific inquiry. The integration of these two data processing kinds is seen as valuable on two fronts:

a) Experientially enhanced neural activity exposes the individual to otherwise hidden mental or behavioural processes. It is also conceivable that this will provide for more time for self-reflection and observation.

b) The subjective report serves as a substantial restraint on the neuroscientist's study and explanation of physiological data pertinent to subjective experience. Phenomenological analysis, which bridges the gap between physiology and the human experience, is anticipated to reveal previously hidden nuances in neurological data.

This allows us to specify our models of phenomenology and the corresponding brain activity thanks to the joint limitations provided by alternative views of consciousness. A modest but increasing body of literature has emerged in recent years to investigate the overlap between phenomenology and neuroscience. Studies on visual acuity (Lutz, 2002), meditation (Hobson, 2009), the onset of epileptic seizures (Le Van Quyen and Petitmengin, 2002), and works on elucidating mental processes that coincide with the DMN activation (Panksepp and Solms, 2012) all demonstrate to this pattern (Garrison *et al.,* 2013). There are, however, several obstacles that must be overcome before first-person data can be effectively integrated into the experimental methods of cognitive neuroscience. In lieu of this, the enhancement and regulation of neural activity is a fundamental aspect of Neurofeedback, previously known as electroencephalographic (EEG)

biofeedback. This form of neurofeedback involves instructing the brain to adopt novel ways of functioning, with or without the use of an external stimulation or task (Marzbani *et al.,* 2016). This would ensure that participants in a neurofeedback setting must acquire the ability to voluntarily modulate their brain dynamics. Recently, there has been an increased availability of products on the market that can measure various brain and body processes with the aim of bettering health and maximizing mental performance. This has resulted in a renewed interest in the subject of applied neuroscience, and notably in neurofeedback among researchers of related disciplines. The traditional focus on electroencephalography has been welcomed in neurofeedback research by a wide variety of other neuroscience methods, such as measuring brain activation with (fMRI) (Sulzer *et al.,* 2013; Emmert *et al.,* 2016), functional near-infrared spectroscopy (fNIRS) (Tsujii *et al.,* 2013) and magnetoencephalography (MEG) (Florin *et al.,* 2014; Okazaki *et al.,* 2015). It moreover prompts researchers to re-examine problems that were left unanswered by older counterparts due to the absence of adequate research methods, instruments, and paradigms.

Even so, it continues to be hard to draw a meaningful connection between qualitative data and neural data, despite the fact that significant progress has been made in this area (Lutz, 2002; Depraz and Cosmelli, 2003; Petitmengin, 2007). The time scale of neuronal and subjective events is still at the crux of the question. Ideation and recollection processes operate on a larger scale of seconds, whilst most neural events could only last a few hundred milliseconds (Bagdasaryan and Quyen, 2013). A spoken report can only be as precise as the speaker’s own approximation of time. Furthermore, subjective evaluations are never collected simultaneously with neural data, but rather at various points throughout the experiment or at its conclusion. Due to their separate methods of data collection, reports and neuronal recordings may only be contrasted or connected. The quantity of information gleaned from such comparisons is severely limited by the time lag seen between experience and the accompanying brain activity, as temporal accuracy is an essential characteristic for neural processes. A causal connection between the approaches appears to be required when the individual's narrative is meant to steer the inquiry and interpretation of neural data. Similarly, associative learning demonstrated that progressive dependency between personal experience and brain events is necessary for benefiting from neural input for a deepened introspection of evaluation (Sulzer *et al.,* 2013).

These restrictions on the neurophenomenological method highlight the need for an experimental process or a specific task that would empower a more precise mapping of neurological and individual data. As neurofeedback is predicated on the principle of combining first-person narratives to third-person data, it is well suited for investigations within the neurophenomenology research paradigm.

Real-Time Neurofeedback Loop in Neurophenomenological Inquiry

> *"We can only live in (if not for) the present moment by analysing the pleasure of watching a dance, by breaking it down into movements that become jerks as they are arrested frame by frame, and music as it is frozen note by note". – Diskin Clay, Meditations: Introduction*

Neurofeedback allows researchers to establish a continuous link between the phenomenological nature of subjective experience and a real-time characterisation of large-scale brain activity. The arrangement captures the subject's present state of neural activity across numerous cortical locations, indicating fleeting shifts in their perception and cognition. The time between processing and presenting the neural variable to the participant is less than 0.5 seconds. The participant is tasked with keeping track of any and all mental activities or experiential shifts that could be related to the signal's ebb and flow. The subject's primary objective while attempting to detect the link between the two is to direct mental activity in a way that the brain signal hits either a higher or lower criterion. In order to accomplish this goal, the subject must keep track of whether or not a shift in thought processes is accompanied by a corresponding shift in the signal level. This kind of intentional modification of the signal adds the subject's continuous firsthand experience to the neural data, which in turn influences the subject's own neural activity. Similar to how the subject may be influenced by scientifically provided data, the subject may alter his or her approach to the problem within the next cycle of real-time processing, during the subsequent

0.5s. This creates a two-way causal loop between the subject and the data.

In this manner, the constant feedback-loop helps the subject monitor brain control and judge the overall effectiveness of their chosen technique (i.e., recalling memories from their childhood, performance effectiveness etc.). Insights into excitation, focus, loss of concentration, self-awareness, and self-regulation can be cultivated by consistent introspective practice throughout training sessions (Kaplan, 2023). Progressively, the connection between the cognitive shift and its neurological correlates is first comprehended, then refined via experimentation and failure until it can be reliably and consistently exploited. The subject is trained to manipulate many electrodes implanted at different cortical regions in an effort to alter oscillatory bandwidths, spiking activity, and synchronization levels (Patil *et al.,* 2023). At the end of the day, the subject can choose which electrode gives the most accurate readings of their intentionally created mental events and whichever frequency band or other characteristic is the most amenable to their manipulation. The relative limitations of phenomenology and neuroscience are an essential aspect of this scenario. The epistemological problem of connecting brain and interpersonal data is overcome by the repetitive nature of real-time EEG-neurofeedback, which brings together and mutually determines information from first and third-person viewpoints.

This causal connection provides a framework for making sense of data that combines subjective and neuroscientific measures. Moreover, it is challenging to obtain a delay-free simultaneous analysis of subjective experience with the gathering of neural activity. Because the subject is an active part of the experiment, neurofeedback provides a new aspect of real-time data correspondence (Bagdasaryan and Quyen, 2013). Due to the incorporation of first-person narrative into the larger stream of neural data, there is no need to shift between impersonal and subjective information. The methodological issue of a dishonest, inaccurate, or prejudiced report may be avoided, which is a further plus. Subjective descriptions, whether verbal or in writing, are not required for the implementation of the neurofeedback paradigm but may be helpful in elucidating the optimal cognitive approach.

Although our understanding of the neural substrates underpinning neurofeedback is limited, the aforementioned studies in the previous sections provide a crucial signal that a cognitive approach requiring attentional processes (Sulzer *et al.,* 2013) and specialized tasks is optimal for initiating neural control. This finding reveals the association involving higher-level cognitive activity and shifts in neural activity patterns, suggesting the importance of top-down influences on self-aware mental processes during neurofeedback. This is generally acknowledged that the temporary and continual orchestration of large-scale neural networks in substantial support of frontal, parietal, and limbic regions is necessary for the function of neural mechanisms involved in perception and cognition. Large-scale systems have been theorized to play a key role in the creation and maintenance of “cognitive-phenomenal states” (Varela, 1995; Varela *et al.,* 2001; Rudrauf *et al.,* 2003) by ”driving” many levels of neural activity across macroscopic, mesoscopic, and microscopic time and space. Several investigations have found co-integration links between different spatial and temporal dimensions by employing unit recordings or functional imaging (Fröhlich and McCormick, 2010; Buzsaki and Wang, 2012).

There is the potential for an interplay to take place between the activity of small-scale interactions that give rise to emergent phenomena and the activity on a larger-scale that evolve as a result of these interactions. The importance of neural oscillations in orchestrating dynamic multi-scale exchanges is becoming increasingly evident in this setting (Fries, 2005; Le Van Quyen, 2011). Additionally, the flow of cognitive processing appears to somehow be reflected in the hierarchical interconnections across regions. It has been demonstrated, for instance, that synchronization on varying oscillatory bandwidths is responsible for the top-down and bottom-up effects between frontal and parietal cortices (Buschman and Miller, 2007). A putative neurophysiological mechanism behind neurofeedback function may be theorized of these thoughts on “downward causation”, due to the connection seen between numerous scales as expressed in distinct oscillatory rhythms (Gruzelier, 2014). When it comes to neurofeedback, it is important to engage in higher-order cognitive activities and tasks (i.e., observation and reflection) which require activation of wider regions that involve more distinct sub-processes (Brandmeyer and Delorme, 2020). Ergo, oscillatory activity enforces this, leading to efficient connectivity across decentralized networks and a regulated flow of data acquisition. Inside this, the overarching interactions are coupled together through concurrent oscillations of varying frequencies that cause adaptations in neuronal excitability which can be seen as a cascade from the first large-scale activity generated by mental exertion, all the way down towards the level of individual neurons. While downward causation is the basis for the conception of neural control, it is crucial to note that in terms of physiology, top-down and bottom-up processes are constantly defined and interconnected (Borrett *et al.,* 2000). It is possible to conceptually isolate and practically quantify these impacts independently. However, these two forms of causation between neuronal and mental processes exist organically and cannot be separated.

ISSN 1307-6531, JNphi, Since 2007 www.jneurophilosophy.com

Default and Executive Network Coupling during Artistic Execution

One of what makes us human is our capacity for original thought, which has led to great advancements in a wide range of fields, from science and the arts to everyday problem solving. While creativity has long been viewed as a mysterious entity (Boden, 2007; Hennessey, 2010), researchers have made significant strides in understanding its neurological and psychological underpinnings in recent decades. Neuroimaging research has shown that the default and executive networks work together to facilitate creative thought across a variety of domains (Beaty *et al.,* 2016; Ellamil *et al.,* 2012; Mayseless *et al.,* 2015). In this regard, such goal-oriented, self-generated cognitive processes are also involved in creative cognition, especially when mental resources must be confined to satisfy narrow task requirements. Functional magnetic resonance imaging (fMRI) and functional connectivity studies of fMRI data have been used in an increasing number of studies to analyze the dynamic interactions between large-scale brain systems like the DMN and ECN during creative cognition and artistic performance (Lutz and Thompson, 2003; Pinho *et al.,* 2014). Despite these advancements, cognitive science still has a long way to go before it can provide a clear explanation for the emergence of creative cognition from neurocognitive mechanisms. There is a remarkable gap concerning the specific contributions of various brain areas to creative cognition and how these contributions change over time and across different stages of the creative process, such as innovation activities and appraisal. Some fundamental concerns include: whether the DMN involves generation and the ECN underpins evaluation (Beaty *et al.,* 2016; Mayseless *et al.,* 2015) whether or not the steps of generating and evaluation occur in cycles (Kleinmintz *et al.,* 2019) or both (Goldschmidt, 2016) and also whether either network has been more strongly linked to artistic performance.

In many conditions, the DMN and ECN may compete for limited resources, despite the fact that they are normally anti-correlated, in the sense that there is a tendency for one network to deactivate when the other one operates (Beaty *et al.,* 2021; Anticevic *et al.,* 2012). Nonetheless, in a wide variety of creative activities, including "verbal divergent thinking", researchers have discovered enhanced connectivity between default and executive control areas (Mayseless *et al.,* 2015; Shofty *et al.,* 2022), improvisatory melodies (Pinho *et al.,* 2014) and writing fictional literature (Ellamil *et al.,* 2012).

Individuals with stronger connections between the DMN and ECN areas are shown to be better at divergent thinking (Beaty *et al.,* 2015) and those who respond with more bright ideas (with the most original answers) had higher connectivity between the two functional networks (Green, 2016). Furthermore, the degree of connectivity between areas of the ECN, DMN, and salience network (SN) has recently been used to predict participants' creative performance (Beaty *et al.,* 2018). There have been attempts to assign a cognitive meaning to this pattern of activity by looking at the kinds of tasks that are usually performed in these brain regions. It has become plausible that the DMN underpins the spontaneous activation of varied ideas, accessible via associative processes (Beaty *et al.,* 2021), given the network's role in recall and creative thinking (Andrews-Hanna *et al.,* 2014). And yet, the ECN may oversee and direct this unprompted action through top-down control, for instance, while carrying out certain tactics in a creative endeavour (Benedek and Jauk, 2019). Considering that these networks collaborate during daydreaming (Fox and Beaty, 2019) and future thinking (Gerlach *et al.,* 2014), they might work together to maximize one's capacity for creative problem-solving, which can be characterized as "self-generated yet goal-directed thought." (Beaty *et al.,* 2016).

Similarly, researchers have considered the networks in terms of the generating and evaluation stages of creative cognition, attributing innovative thinking to the DMN and concept evaluation and refinements to the ECN (Beaty *et al.,* 2016; Ellamil *et al.,* 2012; Kleinmintz *et al.,* 2019). There is less understanding of the specific cognitive mechanisms that these regions employ to facilitate creative thought that there is some empirical evidence for the hypothesis that certain regions of the ECN may dampen down the activity of the DMN, therefore blocking the flow of distraction and low-quality thoughts and making room for more fruitful ones (Bagdasaryan and Quyen, 2013). On the other hand, the ECN's 'sub-networks' may underlie distinct creative activities (Pe˜na *et al.,* 2019) and have distinct connections well with the DMN (Beaty *et al.,* 2021; Dixon *et al.,* 2018). With these advancements, there are still many unanswered concerns, especially regarding the role that these networks play in the development of creative cognition. It is not presently clear if the DMN and ECN each play a more or less significant role in the various phases of creative cognition such as idea formation and judgment (Sowden *et al.,* 2015; Kleinmintz *et al.,* 2019). Moreover, the operation and interaction throughout the duration of mental processes and their underlying brain areas during creative pursuits would greatly contribute to our knowledge of creative cognition and execution. The "serial order effect," for one, was discovered via studies of 'temporal dynamics' of creative thought through which the caliber of one's thoughts improve over the course of time (Johns *et al.,* 2001). The conventional view of this effect attributes it to a gradual propagation of engagement from the stimulus idea to the ideas that are becoming increasingly creative, that can be deemed original. New research has shown that this may be owing to the selective use of inhibition and receptivity to innovative ideas (Bai *et al.,* 2021; Wang *et al.,* 2017). By analyzing the interplay of many brain areas, functional connectivity solutions may fill in the gaps left by traditional fMRI studies. The function of the default and control networks in the context of a divergent thinking task was investigated through one such research (Beaty *et al.,* 2015). Participants were given a set of everyday items and were instructed to come up with a new use for them or to just recall their attributes according to the activity paradigm. By examining the brain's functional connections in their entirety, researchers discovered a web of cerebral areas related with divergent thinking, encompassing an important portion of the DMN and ECN. In-depth analysis later revealed strong causal links between these network nodes as they interacted when the task is executed. Additionally, a fluid connectivity study looked at how networks changed over time and discovered that coupling between the DMN and ECN occurred late in the activity of participants. Even further, works have demonstrated that the 'default-control' connection of behavior during various idea generation tasks provides additional backing to the notion that creative cognition requires an enhanced collaboration of both the default and control networks (e.g., Green, 2016). Most importantly, these results point to the importance of collaboration between systems engaged in original thinking and cognitive regulation in the creative process. Additional support for the collaborative function of default and control networks is provided by studies of improvised music. However, the significance of these networks in previous melody-improvisatory experiments were unclear, as was the case with divergent thinking research. Consequently, quite several brain areas, including those in the default and control networks, were shown to be active during improvisation tasks, according to a review of the relevant literature (Beaty *et al.,* 2015).

Limb and Braun (2008) found that during artistic improvisation, experienced artists' dorsolateral prefrontal cortex and other regions of their ECN deactivated to a greater extent than their medial pre-frontal cortex. This trend was also documented in an investigation of impromptu rap artists (Liu *et al.,* 2012) suggesting that both instrumentation as well as verbal improvisational tasks include spontaneously, self-generated practices. Given the "spur of the moment" nature of improvisation and the apparent absence of opportunity for preparation, it stands to reason that the deactivation of areas of the ECN during improvisation would be representative of the default network's leanings toward spontaneous generation, at the expense of executive function. In contrast, creating, interpreting, and adopting melodic episodes in the moment during improvisational activity has already been described as a complicated and intellectually difficult process in its own right (Pressing, 1988). Taking into account the neuroimaging findings for both cross-domain (i.e., divergent thinking) and intra-domain (i.e., musical improvisation) creative thinking, individuals may construct their own mental experiences, drawing on their own prior knowledge rather than their immediate surroundings for inspiration. By modeling future occurrences, reliving the past, or envisioning the thoughts of someone else, SGT (also called mind-wandering or daydreaming) allows people to temporarily disengage from the present (Smallwood, 2013). These results lend credence to the idea that goal-oriented, self-generated thinking may be an integral part of creative cognition. They also enrich the existing creativity literature by illuminating situations on the DMN and ECN degrees of activation. In this respect, Liu *et al.,* (2015) found that while performers are given the opportunity to improvise on the go with no restrictions, participants show more default activity and less control activity. However, when creatives are given a task with modifying their ideas to achieve a certain outcome (such as conveying a certain emotion), the DMN tends to function more closely with the executive control areas (Pinho *et al.,* 2014).

Collectively, these findings suggest that the activation of the ECN network depends on how much imaginative thought is confined to achieve pre-determined objectives. The artistic persona may also be studied to provide light on the function of the DMN and the place of self-generated cognition in the process of creative innovation. Part of the five terms, known as the "Big Five" aspects of personality is a propensity to participate in innovative, artistic, and amorphous cognitive processes, and this desire is exemplified through an "Openness to Experience" character that adheres a phenomenological undertaking (McCrae and Costa Jr, 1997). With Graph Theoretic Analysis of Resting State fMRI, a pair of investigations explored whether 'openness' was associated with optimal transfer of information through the large-scale topology of the DMN and accompanying areas (Medaglia, 2017; Rutter *et al.,* 2013). 'Openness' was a strong predictor of better DMN performance across the two experiments. Therefore, the default network demonstrated better information efficiency as 'openness' grew. This suggests that highly 'open' individuals are more adept at effectively engaging their neurocognitive assets that comprise their DMN which accounts for their susceptibility to idea generation. This makes the justification quite apparent: Phenomenology can only be grasped fully with an understanding of the frameworks and mechanisms of thought, as well as other philosophies that govern it. Those schools of thought speculate on the worth of the human experience and the meaning that comes with it. Taken together, phenomenological inquiry therefore necessitates familiarity with philosophical principles that form the basis of our interpretations of human experience that can cast a cognitive meaning on the function of the DMN, ECN and the role of self-generated cognition in the innovation process.

Conclusions, Limitations and Future Directions

The preceding discussion of the neuroscientific literature emphasizes the importance of both original thinking and the control-default network to the creative process. It has been suggested that the self-generated mental processes linked with the DMN and ECN are crucial to the generation of original concepts. The capacity to take inspiration from and creatively reassemble mental images is a basic process underpinning creative thinking and execution, and this idea has been supported by behavioral studies revealing the persistent engagement of SGT and EF in creative thought and execution (Eberhart *et al.,* 2023; Saleh Al Rasheed and Hanafy, 2023). New research additionally indicates that cognitive control mechanisms are essential to creative problem solving, especially when ideas must be limited to achieve certain objectives (Beaty *et al.,* 2016; Tromp, 2023; Gong *et al.,* 2023). The capacity of subjects to draw on their individual and unique understanding of their experiences and to record those experiences in a systematic way that is consistent with the interpersonal criteria of science is crucial to the successful curiosity of such empirical concerns. To accomplish this goal, we need to refine our methodological description and practical philosophy of the experience-awareness process (Varela, 1996; Depraz and Cosmelli, 2003). Since the relationship between cognitive science and phenomenology currently continues to be thoroughly researched (Varela, 1995; Wojnar and Swanson, 2007; Goleman, 2003); neuroscientists well-versed in disciplined introspective phenomenologies might form the backbone of a prototypical neurophenomenological alliance. In experimental inquiry methods, the task being assessed should be forced in the same way that it is in real-world applications.

By exploring artistic activities that align with one's interests, there is a potential for heightened neural activity as individuals engage in regular practice of their chosen craft. The technological and experimental configurations of neurofeedback establish a linkage among scholarly as well as personal subjective data groups, amalgamating them into a single information stream. This experimental setup can help bring together the fields of neuroscience and first-person accounts. In contrast to other physiological organs that enable the processing of sensory input of a specific medium, the human organism does not possess a mechanism to subjectively perceive its own ongoing cerebral processes. Neurofeedback offers the individual an opportunity to observe their own neural processes, that is known to contain valuable insights in regards to self-control. The aforementioned context integrates harmoniously with the concept of adaptive systems as introduced by Varela in the "enactive" paradigm (Thompson and Varela, 2001). This paradigm posits that an individual acts as both an initiator and a product of what surrounds it (Varela, 1991). The application of neurofeedback involves the simulated realization of a self-governing body that governs its own neural processes and awareness through the interplay between internal representations of experience and the sensory feedback of neural activity from the outside world. By including the subject's input, neuroscientists are able to explore the phenomenon of a characterization with selection involving large-scale neural activity and the mind's thoughts, a central tenet of the enactive hypothesis. In this vein, neurofeedback's capacity to offer real-time data enables for rapid analysis of various sources of data, therefore conceptually unifying introspective and neural data. The significance of comprehending the neural markers of effective autonomous control is likely influenced by neural computation that operates hierarchically. There exists an exchange of benefits between phenomenology and empirical evidence, by which the significance of self-regulatory processes in relation to mental experiences cannot be undervalued from the standpoint of psychology (Girn *et al.,* 2020).

Through the process of training, a subject's ability to introspect is enhanced, resulting in an improved capacity for awareness of themselves and self-regulation. The above phenomenon has the potential to alter one's self-perception, resulting in increased control and autonomy, particularly in individuals with developing personalities or specific clinical presentations. The proposed comprehensive outlook in neurofeedback holds profound effects in the world at large. The ability to intentionally regulate biological processes encompasses the ability to exert influence across diverse neural mechanisms that govern mental and behavioral processes. As a result of this, the utilization of self-regulation has the potential to facilitate the attainment of enhanced awareness of oneself, self-discovery along with heightened mental abilities. Moreover, neurofeedback is known to have clinical advantages (Marzbani *et al.,* 2016). The acquisition of the ability to modulate certain areas of the brain or elicit particular patterns of neural activity could potentially offer a non-invasive, introspective approach to treating various ailments in the future (Gunkelman and Johnstone, 2005). Taken together, the amalgamation of goal-directed and self-generated thought may be valuable for creative thinking. A crucial avenue for forthcoming neuroimaging investigations involves ascertaining the pertinent facets of self-generated cognition that are germane to innovative creation tasks. As previously mentioned, SGT may encompass impromptu cognition, including mind-wandering (Smallwood, 2013). However, the precise degree to which innovative, goal-directed thinking is enhanced by such spontaneous processes stands uncertain. It is worth noting that according to other studies on behavior, mind wandering has the potential to interfere with the generation of creative ideas (Hao *et al.,* 2015). Subsequent investigations ought to provide a more distinct distinction of the role of cognitive control in the process of generating innovative ideas. In the article by Beaty *et al.,* (2016), the research mentioned previously suggests that in situations where the creation of ideas is restricted to fulfill specific objectives, creativity may be enhanced by controlled processing (Beaty *et al.,* 2016). Likewise, Pinho *et al.,* (2015) observed enhanced collaboration between the control and default network regions in pianists while improvising phrases that centered on an anticipated emotional state (Pinho *et al.,* 2015). The application of EF may prove advantageous in situations where individuals endeavour to adapt their thoughts to align with the requirements of a predetermined creative challenge. Despite the significance of cognitive regulation and SGT in fostering innovative thinking, the manner in which these networks collaborate to facilitate intricate artistic actions continues to be a subject of exploration and intrigue for forthcoming research.

Abbreviations

The following abbreviations are used in this manuscript:

EF	Executive Function
DMN	Default Mode Network
ECN	Executive Control Network
SN	Salience Network
DAN	Dorsal Attention Network
FPCN	Frontoparietal Control Network
SGT	Self-Generated Thought
EEG	Electroencephalography
ERP	Event-Related Potential
fMRI	functional Magnetic Resonance Imaging
fNIRS	functional near-infrared spectroscopy
MEG	magnetoencephalography

Acknowledgements

I would like to extend my gratitude to the reviewers for taking the time to meticulously review the manuscript, as well as providing constructive feedback which was instrumental in refining the paper.

Data availability

None declared.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

Conflict of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Anderson P. Assessment and development of executive function (EF) during childhood. Child neuropsychology 2002; 8(2):71–82.

Andrews-Hanna J.S and Spreng R.N. The default network and self-generated thought: Component processes, dynamic control, and clinical relevance. Annals of the new York Academy of Sciences 2014; 1316(1):29–52.

Anticevic A, Cole M.W, Murray J.D, Corlett, P.R, Wang X.J, Krystal J.H. The role of default network deactivation in cognition and disease. Trends in cognitive sciences 2012; 16(12):584–592.

Baars B.J. Spontaneous repetitive thoughts can be adaptive: Postscript on “mind wandering”. Psychological bulletin 2010; 136(2):208-210.

Baer J. The case for domain specificity of creativity. Creativity research journal 1998; 11(2):173–177.

Bagdasaryan J and Quyen M.L.V. Experiencing your brain: neurofeedback as a new bridge between neuroscience and phenomenology. Frontiers in human neuroscience 2013; 7:680. https://doi.org/10.3389/fnhum.2013.00680

Bai H, Leseman P.P, Moerbeek M, Kroesbergen E.H, Mulder E. Serial order effect in divergent thinking in five-to six-year-olds: Individual differences as related to executive functions. Journal of Intelligence 2021; 9(2):20. https://doi.org/10.3390/jintelligence9020020

Beaty R.E, Benedek M, Barry Kaufman S, Silvia P.J. Default and executive network coupling supports creative idea production. Scientific reports 2015; 5(1):10964.

Beaty R.E, Benedek M, Silvia P.J, Schacter, D.L. Creative cognition and brain network dynamics. Trends in cognitive sciences 2016; 20(2):87–95.

Beaty R.E, Kenett Y.N, Christensen A.P, Rosenberg M.D, Benedek M, Chen Q, Fink A, Qiu J, Kwapil T.R, Kane M. Robust prediction of individual creative ability from brain functional connectivity. Proceedings of the National Academy of Sciences 2018; 115(5):1087–1092.

Beaty R.E, Zeitlen D.C, Baker B.S, Kenett Y.N. Forward flow and creative thought: Assessing associative cognition and its role in divergent thinking. Thinking Skills and Creativity 2021; 41:100859.

Benedek M and Jauk E. Creativity and cognitive control. The Cambridge handbook of creativity, 2019.

Benedek M, Jauk E, Sommer M, Arendasy M, Neubauer A.C. Intelligence, creativity, and cognitive control: The common and differential involvement of executive functions in intelligence and creativity. Intelligence 2014; 46:73–83.

Benedek M, Jauk E, Beaty R.E, Fink A, Koschutnig K, Neubauer A.C. Brain mechanisms associated with internally directed attention and self-generated thought. Scientific reports 2016; 6(1):22959.

Berkowitz A. The improvising mind: Cognition and creativity in the musical moment. Oxford University Press, 2010.

Berkowitz A and Ansari D. Generation of novel motor sequences: the neural correlates of musical improvisation. Neuroimage 2008; 41(2):535–543.

Boden M.A. Creativity in a nutshell. Think 2007; 5(15):83–96.

Borrett D, Kelly S, Kwan H. Phenomenology, dynamical neural networks and brain function. Philosophical Psychology 2000; 13(2):213–228.

Brandmeyer T and Delorme A. Closed-loop frontal midlineθ neurofeedback: A novel approach for training focused-attention meditation. Frontiers in Human Neuroscience 2020;14:246.

Buckner R.L, Andrews-Hanna J.R, Schacter D.L. The brain’s default network: anatomy, function, and relevance to disease. Annals of the New York Academy of Sciences 2008; 1124(1):1–38.

Buschman T.J and Miller E.K. Top-down versus bottom-up control of attention in the prefrontal and posterior parietal cortices. Science 2007; 315(5820):1860–1862.

Buzs ́aki G and Wang X.J. Mechanisms of gamma oscillations. Annual review of neuroscience 2012; 35:203–225.

Cancer A, IanNello P, Salvi C, Antonietti A. Executive functioning and divergent thinking predict creative problem-solving in young adults and elderlies. Psychological Research 2023; 87(2):388–396.

Chalmers D.J. Facing up to the problem of consciousness.Journal of consciousness studies 1995; 2(3):200–219.

Cross P and Goldman A. Interval patterns are dependent on metrical position in jazz solos. Musicae Scientiae 2023; *27*(2):299-312.

Depraz N and Cosmelli D. Empathy and openness: Practices of intersubjectivity at the core of the science of consciousness. Canadian Journal of Philosophy Supplementary Volume 2003; 29:163–203.

Dietrich A. The cognitive neuroscience of creativity. Psychonomic bulletin & review 2004; 11:1011–1026.

Dixon M.L, Fox K.C, Christoff K. A framework for understanding the relationship between externally and internally directed cognition. Neuropsychologia 2014; 62:321–330.

Dixon M.L, De La Vega A, Mills C, Andrews-Hanna J, Spreng R.N, Cole M.W, Christoff K. Heterogeneity within the frontoparietal control network and its relationship to the default and dorsal attention networks. Proceedings of the National Academy of Sciences 2018; 115(7): E1598–E1607.

Donnay G.F, Rankin S.K, Lopez-Gonzalez M, Jiradejvong P, Limb C.J. Neural substrates of interactive musical improvisation: an fmri study of 'trading fours' in jazz. PLoS one 2014; 9(2):e88665.

Eberhart J, Paes T.M, Ellefson M.R, Marcovitch S. Discussion: Special issue 'executive functions and play'. Trends in Neuroscience and Education 2023; 30: 100198. https://doi.org/10.1016/j.tine.2023.100198

Ellamil M, Dobson C, Beeman M Christoff K. Evaluative and generative modes of thought during the creative process. Neuroimage 2012; 59(2):1783–1794.

Emmert K, Kopel R, Sulzer J, Br ̈uhl A.B, Berman B.D, Linden D.E, Horovitz S.G, Breimhorst M, Caria A Frank S. Meta-analysis of real-time fmri neurofeedback studies using individual participant data: How is brain regulation mediated? Neuroimage 2016;124:806–812.

Florin E, Bock E, Baillet S. Targeted reinforcement of neural oscillatory activity with real-time neuroimaging feedback. Neuroimage 2014; 88:54–60.

Fox K.C and Beaty R.E. Mind-wandering as creative thinking: Neural, psychological, and theoretical considerations. Current opinion in behavioral sciences 2019; 27:123–130.

Fries P. A mechanism for cognitive dynamics: neuronal communication through neuronal coherence. Trends in cognitive sciences 2005; 9(10): 474–480.

Fr ̈ohlich F and McCormick D.A. Endogenous electric fields may guide neocortical network activity. Neuron 2010; 67(1):129–143.

Gande N. Neural phenomenon in musicality: The interpretation of dual-processing modes in melodic perception. Frontiers in Human Neuroscience 2022;16:823325. https://doi.org/10.3389/fnhum.2022.823325

Garrison K.A, Santoyo J.F, Davis J.H, Thornhill T.A, Kerr C.E, Brewer J.A. Effortless awareness: using real time neurofeedback to investigate correlates of posterior cingulate cortex activity in meditators' self-report. Frontiers in Human Neuroscience 2013; 7:440.https://doi.org/10.3389/fnhum.2013.00440

Gerlach K.D, Spreng R.N, Madore K.P, Schacter D.L. Future planning: default network activity couples with frontoparietal control network and reward-processing regions during process and outcome simulations. Social cognitive and affective neuroscience 2014; 9(12):1942–1951.

Girn M, Mills C, Roseman L, Carhart-Harris R.L, Christoff K.Updating the dynamic framework of thought: Creativity and psychedelics. Neuroimage 2020; 213:116726. https://doi.org/10.1016/j.neuroimage.2020.116726

Goldman A, Gervis M, Griffiths M. Emotion mapping: Exploring creative methods to understand the psychology of long-term injury. Methodological Innovations 2022;15(1):16–28.

Goldschmidt G. Linkographic evidence for concurrent divergent and convergent thinking in creative design. Creativity research journal 2016; 28(2):115–122.

Goleman D. Healing emotions: Conversations with the Dalai Lama on mindfulness, emotions, and health. Shambhala publications, 2003.

Gong Z, Nanjappan V, Lee L.H, Soomro S.A, Georgiev G.V. Exploration of the relationship between culture and experience of creativity at the individual level: A case study based on two design tasks. International Journal of Design Creativity and Innovation 2023; 11(3):185-208.

Green A.E. Creativity, within reason: Semantic distance and dynamic state creativity in relational thinking and reasoning. Current Directions in Psychological Science 2016; 25(1):28–35.

Gruzelier J.H. EEG-neurofeedback for optimising performance. iii: a review of methodological and theoretical considerations.Neuroscience & Biobehavioral Reviews 2014; 44:159–182.

Guilford J.P. Creativity. American psychologist 1950; 5(9):444-454.

Gunkelman J.D and Johnstone J. Neurofeedback and the brain. Journal of Adult Development 2005;12(3):93–98.

Gusnard D.A and Raichle M.E. Searching for a baseline: functional imaging and the resting human brain. Nature reviews neuroscience 2001; 2(10):685–694.

Hao N, Wu M, Runco M.A, Pina J. More mind wandering, fewer original ideas: Be not distracted during creative idea generation. Acta psychologica 2015; 161:110–116.

Harris D.J, Vine S.J, Wilson M.R. Is flow really effortless? the complex role of effortful attention.Sport, Exercise, and Performance Psychology 2017; 6(1):103.

Heidegger M. (1962). Being and time, Harper & Row. New York, 1927.

Hennessey B.A. The creativity—motivation connection.The Cambridge handbook of creativity, 2010.

Hobson J.A. Rem sleep and dreaming: towards a theory of protoconsciousness. Nature Reviews Neuroscience 2009; 10(11):803–813.

Hurlburt R.T and Heavey C.L. Telling what we know: describing inner experience. Trends in cognitive sciences 2001; 5(9): 400–403.

Johns G.A, Morse L.W, Morse D.W. An analysis of early vs. later responses on a divergent production task across three time press conditions. The Journal of Creative Behavior 2001; 35(1):65–72.

Kane M.J, Brown L.H, McVay J.C, Silvia P.J, Myin-Germeys I, Kwapil T.R. For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. Psychological science 2007; 18(7):614–621.

Kaplan C. EEG neurofeedback as an instrument to explore introspective correlates of cortical activity. 2023. https://dspace.cuni.cz/handle/20.500.11956/179880

Killingsworth M.A and Gilbert D.T. A wandering mind is an unhappy mind. Science 2010; 330(6006):932–932.

Kleinmintz O.M, Ivancovsky T, Shamay-Tsoory S.G. The two-fold model of creativity: the neural underpinnings of the generation and evaluation of creative ideas. Current Opinion in Behavioral Sciences 2019; 27:131–138.

Le Van Quyen M. The brainweb of cross-scale interactions. New ideas in psychology 2011; 29(2):57–63.

Le Van Quyen M and Petitmengin C.Neuronal dynamics and conscious experience: an example of reciprocal causation before epileptic seizures. Phenomenology and the Cognitive Sciences 2002; 1(2):169–180.

Li HX, Lu B, Wang Y.W, Li X.Y, Chen X, Yan C.G. Neural representations of self-generated thought during think-aloud fmri. NeuroImage 2023; 265:119775.

Limb C.J and Braun A.R. Neural substrates of spontaneous musical performance: An fmri study of jazz improvisation. PLoS one 2008; 3(2):e1679.

Liu S, Chow H.M, Xu Y, Erkkinen M.G, Swett K.E, Eagle M.W, Rizik-Baer D. A, Braun A R. Neural correlates of lyrical improvisation: an fmri study of freestyle rap. Scientific reports 2012; 2(1):1–8.

Liu Y, Lv D, Ying Y, Arndt F, Wei J. Improvisation for innovation: The contingent role of resource and structural factors in explaining innovation capability. Tech-novation 2018; 74:32–41.

Lutz A. Toward a neurophenomenology as an account of generative passages: A first empirical case study. Phenomenology and the cognitive sciences 2002; 1(2):133–167.

Lutz A and Thompson E. Neurophenomenology integrating subjective experience and brain dynamics in the neuroscience of consciousness. Journal of consciousness studies 2003;10(9):31–52.

Marzbani H, Marateb H.R, Mansourian M. Neurofeedback: a comprehensive review on system design, methodology and clinical applications. Basic and clinical neuroscience 2016; 7(2):143.

Mayseless N, Eran A, Shamay-Tsoory S.G. Generating original ideas: The neural underpinning of originality. Neuroimage 2015;116:232–239.

McCrae R.R and Costa Jr P.T. Personality trait structure as a human universal. American psychologist 1997;52(5):509.

Medaglia J.D. Graph theoretic analysis of resting state functional mr imaging. Neuroimaging Clinics 2017; 27(4):593–607.

Merleau-Ponty M. Phenomenology of perception. Motilal Banarsidass Publishe, 1996.

Merleau-Ponty M and Smith C. Phenomenology of perception, volume 2012. Routledge London, 1962.

Nisbett R.E and Wilson T.D. Telling more than we can know: Verbal reports on mental processes. Psychological review 1977; 84(3):231.

Northoff G, Vatansever D, Scalabrini A, Stamatakis E.A. Ongoing brain activity and its role in cognition: Dual versus baseline models. The Neuroscientist 2023; 29(4):393-420.

Novakovic-Agopian T, Kornblith E, Abrams G, Burciaga-Rosales J, Loya F, D'Esposito M, Chen A.J. Training in goal-oriented attention self-regulation improves executive functioning in veterans with chronic traumatic brain injury. Journal of neurotrauma 2018; 35(23):2784–2795.

Okazaki Y.O, Horschig J.M, Luther L, Oostenveld R, Murakami I, Jensen O. Real-time meg neurofeedback training of posterior alpha activity modulates subsequent visual detection performance. NeuroImage 2015; 107:323–332.

Panksepp J and Solms M. What is neuropsychoanalysis? clinically relevant studies of the minded brain. Trends in cognitive sciences 2012;16(1):6–8.

Patil A.U, Lin C, Lee S.H, Huang H.W, Wu S.C and Huang C.M. Review of eeg-based neurofeedback as a therapeutic intervention to treat depression. Psychiatry Research: Neuroimaging 2023; 329:111591.

Pe˜na J, Sampedro A, Ibarretxe-Bilbao N, Zubiaurre-Elorza L, Ojeda N. Improvement in creativity after transcranial random noise stimulation (trns) over the left dorsolateral prefrontal cortex. Scientific reports 2019; 9(1):1–9.

Petitmengin C. Towards the source of thoughts: The gestural and transmodal dimension of lived experience. Journal of consciousness Studies 2007; 14(3):54–82.

Pinho A.L, de Manzano O, Fransson P, Eriksson H, Ull´en F. Connecting to create: expertise in musical improvisation is associated with increased functional connectivity between premotor and prefrontal areas. Journal of Neuroscience 2014; 34(18):6156–6163.

Pinho A.L, Ull ́en F, Castelo-Branco M, Fransson P, de Manzano O. Addressing a paradox: dual strategies for creative performance in introspective and extrospective networks. Cerebral Cortex 2015; 26(7): 3052–3063.

Polychroni N, Herrojo Ruiz M, Terhune D.B. Introspection confidence predicts eeg decoding of self-generated thoughts and meta-awareness. Human BrainMapping 2022; 43(7):2311–2327.

Pressing J. Nonlinear maps as generators of musical design.Computer Music Journal 1988; 12(2):35–46.

Przysinda E, Zeng T, Maves K, Arkin C, Loui P. Jazz musicians reveal role of expectancy in human creativity. Brain and cognition 2017; 119:45–53.

Puente-D ́ıaz R. Metacognitive feelings as a source of information for the creative process: A conceptual exploration. Journal of Intelligence 2023;11(3):49.

Roy J.M, Petitot J, Pachoud B, Varela F.J. Beyond the gap: An introduction to naturalizing phenomenology. In Naturalizing phenomenology: Issues in contemporary phenomenology and cognitive science. Stanford University Press, 1999.

Ruby F.J.M. Understanding the varieties of self-generated thought. PhD thesis, University of York, 2015.

Rudrauf D, Lutz A, Cosmelli D, Lachaux J.P, Le Van Quyen M. From autopoiesis to neurophenomenology: Francisco varela's exploration of the biophysics of being. Biological research 2003; 36(1):27–65.

Runco M.A and Jaeger GJ. The standard definition of creativity. Creativity research journal 2012; 24(1):92–96.

Rutter L, Nadar S.R, Holroyd T, Carver F.W, Apud J, Weinberger D.R and Coppola R. Graph theoretical analysis of resting magnetoencephalographic functional connectivity networks. Frontiers in computational neuroscience 2013; 7:93.

Saleh Al Rasheed L and Hanafy A.A.M. Effects of brain-based instruction on executive function and habits of mind among young children at-risk for learning disabilities. Applied Neuropsychology: Child 2023; pp.1–8. https://doi.org/10.1080/21622965.2022.2161904

Sawyer K. Improvisational creativity: An analysis of jazz performance. Creativity research journal 1992; 5(3):253–263.

Schooler J.W. Re-representing consciousness: Dissociations between experience and meta-consciousness. Trends in cognitive sciences 2002; 6(8):339–344.

Schooler J.W, Smallwood J, Christoff K, Handy T.C, Reichle E.D and Sayette M.A. Meta-awareness, perceptual decoupling and the wandering mind. Trends in cognitive sciences 2011; 15(7):319–326.

Shofty B, Gonen T, Bergmann E, Mayseless N, Korn A, Shamay-Tsoory S, Grossman R, Jalon I, Ram Z. The default network is causally linked to creative thinking. Molecular Psychiatry 2022; 27(3):1848–1854.

Simola J, Silander T, Harju M, Lahti O, Makkonen M, P ̈atsi L.M, Smallwood J. Context independent reductions in external processing during self-generated episodic social cognition. Cortex 2023; 159:39–53.

Smallwood J. Why the global availability of mind wandering necessitates resource competition: Reply to mcvay and kane (2010). Psychological Bulletin 2010; 136(2):202–207.

Smallwood J. Distinguishing how from why the mind wanders: a process–occurrence framework for self-generated mental activity.Psychological bulletin 2013; 139(3):519.

Smallwood J and Schooler J.W. The restless mind. Psychological bulletin 2006; 132(6):946.

Smallwood J, Brown K, Baird B, Schooler J.W. Cooperation between the default mode network and the frontal–parietal network in the production of an internal train of thought. Brain research 2012; 1428:60–70.

Sowden P.T, Clements L, Redlich C, Lewis C. Improvisation facilitates divergent thinking and creativity: Realizing a benefit of primary school arts education. Psychology of Aesthetics, Creativity, and the Arts 2015; 9(2):128.

Spreng R.N, Stevens W.D, Chamberlain J.P, Gilmore A.W, Schacter D.L. Default network activity, coupled with the frontoparietal control network, supports goal-directed cognition. Neuroimage 2010; 53(1):303–317.

Sulzer J, Haller S, Scharnowski S, Weiskopf N, Birbaumer N, Blefari M.L, Bruehl A.B, Cohen L.G, DeCharms R.C and Gassert R. Real-time fmri neurofeedback: progress and challenges. Neuroimage 2013; 76: 386–399.

Thompson E and Varela F.J. Radical embodiment: neural dynamics and consciousness. Trends in cognitive sciences 2001; 5(10):418–425.

Tromp C. Integrated constraints in creativity: Foundations for a unifying model. Review of General Psychology 2023; 27(1):41–61.

Tsujii T, Komatsu K, Sakatani K. Acute effects of physical exercise on prefrontal cortex activity in older adults: a functional near-infrared spectroscopy study. Adv Exp Med Biol 2013; 765:293-298.

Twemlow S.W, Gabbard G.O, Jones F.C. The out-of-body experience: A phenomenological typology based on questionnaire responses. American Journal of Psychiatry 1982;139(4):450–455.

Unsworth N and McMillan B.D. Mind wandering and reading comprehension: examining the roles of working memory capacity, interest, motivation, and topic experience. Journal of Experimental Psychology: Learning, Memory, and Cognition 2013; 39(3):832.

Varela F.J, Lachaux J.P, Rodriguez E, Martinerie J. The brainweb: phase synchronization and large-scale integration. Nature reviews neuroscience 2001; 2(4):229–239.

Varela F.J. Organism: A meshwork of selfless selves. Organism and the Origins of Self. Dordrecht: Springer Netherlands, 1991.

Varela F.J. Resonant cell assemblies: a new approach to cognitive functions and neuronal synchrony. Biological research 1995; 28:81–81.

Varela F.J. Neurophenomenology: A methodological remedy for the hard problem. Journal of consciousness studies 1996; 3(4):330–349.

Vuust P, Brattico E, Sepp ̈anen M, Tervaniemi M. The sound of music: differentiating musicians using a fast, musical multi-feature mismatch negativity paradigm. Neuropsychologia 2012; 50(7):1432–1443.

Wang M, Hao N, Ku Y, Grabner R.H, Fink A. Neural correlates of serial order effect in verbal divergent thinking. Neuropsychologia 2017; 99:92–100.

Wojnar D.M and Swanson K.M. Phenomenology: an exploration. Journal of holistic nursing 2007; 25(3):172–180.

Xu X, Xia M, Pang M. Do authentic people generate more creative solutions to help others? the mediating role of dispositional and situational perspective-taking. Thinking Skills and Creativity 2023; 48:101254. https://doi.org/10.1016/j.tsc.2023.101254

Yeo B.T, Krienen F.M, Sepulcre J, Sabuncu M.R, Lashkari D, Hollinshead M, Roffman J.L, Smoller J.W, Z ̈ollei L, Polimeni J.R. The organization of the human cerebral cortex estimated by intrinsic functional connectivity. Journal of neurophysiology 2011; 106(3):1125–1165.

Zelazo P.D and Carlson S.M. Hot and cool executive function in childhood and adolescence: Development and plasticity.Child development perspectives 2012; 6(4):354–360.