

Review Article

Neural Foundations of Creativity: A Systematic Review



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ABSTRACT

When considering the importance of the human cognitive function of creativity, we often overlook the fact that it is due to human creativity and to the constant search for new sensory stimuli that our world has, throughout the years, been one of innovation in every aspect of our existence—in the sciences, the humanities, and the arts. Almost everything that surrounds us is the result of human creativity, therefore it is not difficult to understand that although neuroscientific research has led to valuable perceptions into the probable underpinnings of this multifaceted ability, the precise neurological substrates that underlie creativity are yet to be determined. Despite the establishment of a strong link between creativity and divergent thinking, other brain networks have been implicated in this mental process. The following review underlines recent studies on the neural foundations of creativity. A comprehensive analysis of the upmost important facts will be presented, with emphasis on concepts, tests, and methods that have been used to study creativity, and how they have outlined a pathway to the key understanding of this unique human ability.

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Fundamentos neurales de la creatividad: una revisión sistemática

RESUMEN

Al considerar la importancia de la creatividad en la función cognitiva humana, sucede con frecuencia y pasamos por alto el hecho de que es precisamente debido a la creatividad humana que a través de los años nuestro mundo ha estado en constante innovación en cada aspecto de nuestra existencia: en la ciencia, las humanidades y las artes. Casi todo lo que nos rodea se debe a la creatividad humana; por lo tanto, no es difícil entender que, aunque la investigación neurocientífica ha conducido a percepciones valiosas sobre los fundamentos probables de esta capacidad multifacética, estos estudios no han permitido conclusiones

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claras y tienen todavía mucho por determinar para comprenderla mejor. A pesar de que se ha establecido un fuerte vínculo entre la creatividad y el pensamiento divergente, científicos han identificado otras redes cerebrales implicadas en este proceso mental. La presente revisión subraya los estudios recientes sobre los fundamentos neuronales de la creatividad. Se presenta un análisis comprensivo con énfasis en los conceptos, las pruebas y los métodos que se han utilizado para estudiar la creatividad y la forma en que han proyectado una vía para la comprensión fundamental de esta capacidad humana única.

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Introduction

In the last decade, although studies in neuroscience have provided important insights about the neural basis of creativity, these studies have not yet led to clear assumptions regarding the neural correlates due to the complicated construct of the topic.¹ Neural correlates in the fundamental human capacity of creativity have become increasingly important in research,² nonetheless hard to document or replicate due to its abstract and multiform definitions that likely involve other cognitive brain processes.³ Therefore, although specific neural processes are assumed to mediate creativity, their scientific exploration has been extremely challenging.⁴ There is no single measure method that can apprehend the multifactorial complexion of this cognitive function. Research in creativity is puzzling for a number of reasons; more specifically, the study of creativity becomes complicated when identifying tasks that will be able to measure creativity without other cognitive processes that can trigger brain responses.⁵ For example, rather than being yes or no answer tasks,⁶ creativity tasks involve verbal or written/drawing responses that may lead to brain activity related to working memory, attention and language.⁷ Furthermore there is also a problem due to the conceptual meaning of creativity and the difficulties overcoming the fact that creativity isn't predicible and can't be prompted volitionally.

The problem can be approached at the level of large-scale systems using neuroimaging methods and standardized psychometric tests.^{8,9} Brain imaging methods including positron emission tomography (PET), functional magnetic resonance imaging (fMRI) and electroencephalography (EEG and event related potentials [ERP]) have provided important implications regarding the neural basis of creativity.^{10,11} Notwithstanding the lack of consensus, developing literature and neuroimaging studies have led to suggest that divergent thinking is neural correlate of creativity and a central component of the ability.¹² Specifically these studies yield information about the role of the prefrontal cortex, the default mode network and central executive processes associated with internally directed attention and spontaneous cognition.¹³

This review discusses definitions and evidence about the neural basis of creativity in an attempt to explain the neural mechanisms underlying this mental process, elucidating the current difficulties, the need to study other approaches and to reveal how functionally linked neural areas may cooperate in its production. By reviewing creativity, this article hopes

to clarify that this cognitive process is one that cannot be completely apprehended by current theoretical proposals.

An Approach to Unravelling the Meaning of Creativity

Over the years there has been many definitions of creativity. Wallas¹⁴ proposed that creativity was a mental process that included phases such as preparation, incubation, illumination and verification. Torrance¹⁵ defined creativity as "a process of becoming sensitive to problems, deficiencies, gaps in knowledge, disharmonies; identifying the difficulty; searching for solutions, or formulating hypotheses about the deficiencies: testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results." Bronowski¹⁶ defined creativity as the ability to find unity in what appears to be diverse or finding the thread that unites. On the other hand, Boden¹⁷ formalized a mathematical Creative Systems Framework based on creative conceptualization and process. Heilman¹⁸ defined creativity as "the ability to understand, develop and express in a systematic fashion, novel orderly relationships." Lastly, Schmidhuber¹⁹ proposes a model based on intrinsic motivation and creativity based on maximizing intrinsic reward for active creation of innovating sequences that allow prediction.

It's noteworthy to understand that creativity is influenced by the development of new social institutions, economic growth²⁰ and time. The creative potential exists in everyone, but it's greatly influenced by experiences, social and environmental contexts.²¹ Curiosity, experience and the senses are all key in the construct of creativity.²² Experience can be considered as a basis by which humans influence the world we live in more effectively by constantly creating new and different ways of sensing our environment.²³ Considering the relationship between sensory-driven information and mind-driven information²⁴ it can be stated that creativity is a multimodal process that comprises sensory areas such as visual, tactile, olfactory, auditory, gustatory, physical and also cognitive, emotional and verbal information.²⁵

There is a general agreement that creativity is a multifaceted phenomenon²⁶ that involves the ability to create or work on something that is innovative, beneficial, practical and generative.²⁷ However, creativity can be also observed, considered, and studied as a part of a process, rather than an only ability.²⁸ Creativity in the brain does appear to work in a series of networks of cognitive functions such as attention, flexibility,

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