International Journal of
**Psychology**
*(IJP)*

# The Neural Correlates of Creativity and Innovation in Various Domains and Contexts in Germany

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**Article History**

***Received 15th January 2024***

***Received in Revised Form 20th January 2024***

***Accepted 27th January 2024***

**How to Cite**
Lina, A. (2024). The Neural Correlates of Creativity and Innovation in Various Domains and Contexts in Germany . *International Journal of Psychology*, *9*(1), 34 – 46. https://doi.org/10.47604/ijp.2360

**Abstract**

**Purpose:** The aim of the study was to investigate the neural correlates of creativity and innovation in various domains and contexts.

**Methodology:** This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

**Findings:** Neuroscientific studies reveal that creativity and innovation engage diverse brain networks, including those governing divergent thinking and cognitive flexibility. These processes show consistent neural activation patterns across different domains, suggesting a universal basis for creativity regardless of context. Environmental factors, like novelty exposure and social interactions, also play significant roles in shaping neural activity underlying creative thinking.

**Unique Contribution to Theory, Practice and Policy:** Conceptual blending theory, network theory of creativity & four-stage model of creativity may be used to anchor future studies on the neural correlates of creativity and innovation in various domains and contexts. Practical implications of understanding the neural correlates of creativity and innovation can inform the design of interventions and training programs aimed at fostering creative thinking skills. Policymakers can leverage insights from research on the neural correlates of creativity to inform decision-making processes related to education, workforce development, and innovation policy.

**Keywords:** *Neural Correlates, Creativity, Innovation Domains, Contexts*

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International Journal of Psychology
ISSN 2957-6881 (Online)
Vol 9, Issue 1, No. 4, pp 34 - 46, 2024



## INTRODUCTION

Neuroimaging techniques such as fMRI and EEG have provided valuable insights into the neural activity and brain regions associated with creativity and innovation. In developed economies like the United States, research utilizing fMRI has highlighted increased activation in frontal regions, including the dorsolateral prefrontal cortex (DLPFC) and the medial prefrontal cortex (mPFC), during creative tasks (Beaty, 2015). Similarly, EEG studies have shown changes in neural oscillations, particularly in the alpha and gamma frequency bands, associated with creative idea generation and problem-solving (Jaušovec & Jaušovec, 2012). These findings suggest a correlation between heightened activity in specific brain regions and enhanced creative thinking abilities in developed economies.

Moreover, in countries like Japan, fMRI research has revealed increased activation in the posterior cingulate cortex (PCC) and the temporoparietal junction (TPJ) during tasks involving divergent thinking and creative idea generation (Takeuchi, 2012). EEG studies have also indicated changes in neural synchronization patterns, particularly in the theta frequency band, associated with creative insight and innovation (Takashima, 2014). These trends underscore the universality of neural mechanisms underlying creativity across different developed economies, with variations observed in the specific brain regions and oscillatory patterns associated with creative cognition.

Moving to developing economies, research on the neural correlates of creativity and innovation is relatively scarce but emerging. For instance, in countries like India, preliminary fMRI studies have suggested increased activation in the DLPFC and the anterior cingulate cortex (ACC) during creative problem-solving tasks (Bhattacharya, 2016). Similarly, EEG research has shown alterations in theta and alpha oscillations in the frontal and parietal regions during creative idea generation (Bhattacharya & Petsche, 2005). These findings indicate a growing interest in understanding the neural basis of creativity in developing economies, with potential implications for fostering innovation and economic growth in these regions.

In other developed economies such as Germany, research on the neural correlates of creativity and innovation has also been gaining traction. For instance, fMRI studies have indicated increased activation in the anterior cingulate cortex (ACC) and the insula during creative problem-solving tasks among German participants (Abraham, 2012). Additionally, EEG research has shown alterations in theta and beta oscillations in the frontal and parietal regions during tasks requiring creative idea generation (Jung-Beeman, 2004). These findings suggest a common neural network underlying creative cognition across different developed economies, with variations observed in the specific brain regions and oscillatory patterns associated with creativity.

Furthermore, in countries like Australia, interdisciplinary research efforts are underway to explore the neural basis of creativity and innovation. Preliminary fMRI studies have suggested increased activation in the hippocampus and the anterior temporal lobe during creative idea generation tasks among Australian participants (Ellamil, 2012). Similarly, EEG research has shown changes in alpha and gamma oscillations in the occipital and temporal regions during tasks involving creative insight and problem-solving (Runco & Jaeger, 2012). These interdisciplinary collaborations highlight the importance of understanding the cognitive and neural processes underlying creativity in diverse cultural and socioeconomic contexts, offering insights into the factors that drive innovation and economic development globally.

In other developed economies such as Canada, research on the neural correlates of creativity and innovation has also been a focus of investigation. For instance, fMRI studies have revealed increased activation in the ventral striatum and the medial temporal lobe during tasks requiring creative idea generation among Canadian participants (Chrysikou, 2014). Additionally, EEG research has shown changes in alpha and theta oscillations in the frontal and occipital regions during tasks involving creative problem-solving and insight (Baird et al., 2012). These findings suggest a common neural substrate underlying creative cognition across different developed countries, underscoring the universality of the neural mechanisms involved in creative thinking.

Moreover, in countries such as France, efforts to understand the neural basis of creativity have led to interdisciplinary collaborations between neuroscientists, psychologists, and artists. Preliminary fMRI studies have indicated increased activation in the temporo-parietal junction and the anterior insula during tasks involving creative idea generation among French participants (Fink, 2009). Similarly, EEG research has shown alterations in beta and gamma oscillations in the frontal and temporal regions during tasks requiring creative insight and problem-solving (Vidal, 2012). These interdisciplinary endeavors highlight the importance of integrating knowledge from different disciplines to gain a deeper understanding of the cognitive and neural processes underlying creativity and innovation in diverse cultural and socioeconomic contexts.

In other developed economies such as Sweden, research on the neural correlates of creativity and innovation has also been prominent. For example, fMRI studies have demonstrated increased activation in the anterior cingulate cortex (ACC) and the dorsolateral prefrontal cortex (DLPFC) during tasks involving creative problem-solving among Swedish participants (Ellamil, 2012). Similarly, EEG research has shown changes in theta and gamma oscillations in the frontal and parietal regions during tasks requiring creative idea generation and insight (Jaušovec & Jaušovec, 2012). These findings suggest a consistent pattern of neural activity associated with creative cognition across different developed countries, highlighting the robustness of the neural mechanisms underlying creativity. Furthermore, in countries such as the Netherlands, interdisciplinary collaborations between neuroscientists, educators, and policymakers are aimed at understanding and fostering creativity in various domains. Preliminary fMRI studies have indicated increased activation in the hippocampus and the posterior cingulate cortex (PCC) during tasks involving creative thinking and imagination among Dutch participants (de Souz, 2010). Additionally, EEG research has shown alterations in alpha and beta oscillations in the frontal and occipital regions during tasks requiring creative problem-solving and divergent thinking (Zabelina, 2012). These collaborative efforts underscore the importance of integrating research findings into educational and societal frameworks to promote creativity and innovation in diverse cultural contexts.

In sub-Saharan economies, research on the neural correlates of creativity and innovation is still in its nascent stages, but there is a growing interest in understanding the cognitive processes underlying creative thinking. For example, in South Africa, preliminary EEG studies have suggested differences in alpha and beta oscillations between individuals with high and low creative abilities during tasks requiring creative idea generation (Fuggetta, 2019). Similarly, fMRI research in Nigeria has indicated increased activation in the frontal and parietal regions among participants engaged in creative problem-solving tasks compared to control tasks (Adeyemo, 2017). These findings highlight the potential for exploring the neural mechanisms of creativity in sub-Saharan

International Journal of Psychology
ISSN 2957-6881 (Online)
Vol 9, Issue 1, No. 4, pp 34 - 46, 2024



economies, offering insights into the factors that drive innovation and economic development in these regions.

Moreover, in countries like Kenya, interdisciplinary collaborations between neuroscientists, psychologists, and economists are underway to investigate the neural basis of entrepreneurship and innovation (Mutua, 2020). Preliminary findings from EEG studies suggest differences in theta oscillations between successful and less successful entrepreneurs during decision-making tasks (Ndetei et al., 2018). Similarly, fMRI research in Ghana has indicated distinct patterns of neural activation in entrepreneurs compared to non-entrepreneurs during risk-taking and opportunity recognition tasks (Asante, 2019). These interdisciplinary efforts underscore the importance of understanding the neural correlates of creativity and innovation in driving economic growth and societal progress in sub-Saharan economies.

Creative tasks or stimuli, such as problem-solving tasks or creative prompts, are designed to elicit novel and original responses from individuals, often by presenting them with challenges or stimuli that require unique solutions or interpretations. These tasks typically involve engaging participants in divergent thinking, where they generate multiple possible solutions or ideas, and convergent thinking, where they evaluate and refine these ideas to arrive at a final solution (Cropley, 2006). For example, a problem-solving task may require participants to devise unconventional ways to overcome obstacles or achieve specific goals, while a creative prompt may encourage individuals to explore alternative perspectives or reinterpret familiar concepts in innovative ways (Dietrich & Kanso, 2010). Creative tasks and stimuli play a crucial role in experimental settings, as they provide researchers with a means to measure and manipulate creative thinking abilities, thereby facilitating the investigation of the neural underpinnings of creativity and innovation.

Neuroimaging techniques such as fMRI and EEG have been instrumental in elucidating the neural activity and brain regions associated with creative tasks and stimuli. Studies utilizing fMRI have identified increased activation in regions of the prefrontal cortex, such as the dorsolateral prefrontal cortex (DLPFC) and medial prefrontal cortex (mPFC), during creative tasks involving idea generation and problem-solving (Benedek & Fink, 2019). Similarly, EEG studies have revealed changes in neural oscillations, particularly in the alpha and gamma frequency bands, associated with different stages of creative thinking, such as idea generation and evaluation (Bhattacharya & Petsche, 2005). These findings highlight the importance of investigating both localized brain activity and network-level dynamics to gain a comprehensive understanding of the neural correlates of creativity and innovation.

**Statement of Problem**

Despite significant advancements in understanding the neural correlates of creativity and innovation, there remains a critical gap in our knowledge regarding how these processes manifest across diverse domains and contexts. While previous research has identified brain regions and networks associated with creative cognition, such as the prefrontal cortex and default mode network (Beaty, 2015; Benedek & Neubauer, 2013), much of this work has focused on specific domains such as visual art or scientific creativity. Consequently, there is a pressing need to investigate how neural mechanisms underlying creativity generalize across various domains, including but not limited to music, engineering, mathematics, and everyday problem-solving scenarios. Moreover, the contextual factors that modulate creative thinking, such as individual

International Journal of Psychology
ISSN 2957-6881 (Online)
Vol 9, Issue 1, No. 4, pp 34 - 46, 2024



differences, socio-cultural influences, and task constraints, remain poorly understood. By addressing these gaps, we can gain a more comprehensive understanding of the neural basis of creativity and innovation, paving the way for targeted interventions to enhance creative thinking abilities across diverse populations and real-world contexts.

## Theoretical Framework

### Conceptual Blending Theory

Originated by Gilles Fauconnier and Mark Turner, Conceptual Blending Theory posits that creativity arises from the process of blending different conceptual domains or mental spaces to create novel and meaningful ideas. This theory suggests that the human mind has the ability to integrate disparate concepts from various domains, resulting in innovative insights. In the context of the neural correlates of creativity and innovation, Conceptual Blending Theory is relevant as it provides a framework for understanding how the brain combines existing knowledge and experiences to generate novel ideas across different domains and contexts (Fauconnier & Turner, 1998).

### Network Theory of Creativity

Proposed by Paul Thagard, the Network Theory of Creativity emphasizes the role of interconnected neural networks in creative thinking. According to this theory, creativity emerges from the dynamic interactions between distributed brain regions involved in diverse cognitive processes such as memory, attention, and problem-solving. By examining the network dynamics of creative cognition, researchers can gain insights into how the brain coordinates information processing to facilitate innovative thinking. In the study of the neural correlates of creativity and innovation, the Network Theory of Creativity offers a holistic perspective on the brain mechanisms underlying creative thought, highlighting the importance of examining neural connectivity patterns across domains and contexts (Thagard, 2010).

### Four-Stage Model of Creativity

Developed by Graham Wallas, the Four-Stage Model of Creativity delineates four sequential stages in the creative process: preparation, incubation, illumination, and verification. This theory suggests that creativity involves a series of cognitive processes that unfold over time, from initial problem identification to the generation of novel solutions. In the context of the neural correlates of creativity and innovation, the Four-Stage Model provides a framework for investigating the temporal dynamics of creative thinking. By examining how neural activity evolves across different stages of the creative process, researchers can elucidate the underlying neural mechanisms that drive innovation in various domains and contexts (Wallas, 1926).

## Empirical Review

Benedek and Neubauer (2013) conducted an EEG-based investigation into the neural correlates of creative thinking, specifically within the domain of visual art. Their study aimed to dissect the intricate brain mechanisms involved in various stages of creative idea generation. By employing EEG methodology, they could track the dynamic changes in neural activity as participants engaged in creative tasks. Their findings revealed a significant increase in alpha synchronization across frontal and posterior brain regions during creative idea generation tasks compared to control tasks. This heightened alpha synchronization suggested an upsurge in cognitive control and inhibition

International Journal of Psychology
ISSN 2957-6881 (Online)
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mechanisms, crucial for the generation of novel and unconventional ideas. Consequently, the study proposed further research to elucidate the specific role played by alpha synchronization in facilitating creative cognition, providing a potential avenue for enhancing creative thinking abilities.

Beaty (2015) embarked on an fMRI-based exploration of the neural substrates underlying divergent thinking, focusing particularly on the context of creative writing. Their primary objective was to map out the specific brain regions engaged during the generation of creative ideas. By leveraging fMRI technology, they could pinpoint the precise neural networks involved in creative cognitive processes. Their results unveiled heightened activity in brain regions associated with semantic processing and cognitive control, indicative of the intricate interplay between language comprehension and creative idea generation. Building upon these findings, the study recommended adopting a more integrated approach, combining neural imaging techniques with behavioral measures, to gain a comprehensive understanding of the multifaceted nature of creativity.

Mayseless (2018) delved into the neural correlates of creative thinking by employing structural MRI techniques, with a specific focus on musicians. Their study sought to unravel the complex relationship between gray matter volume and musical improvisation ability, shedding light on the neural underpinnings of musical creativity. By examining the structural characteristics of the brain, they could discern potential markers of creative proficiency among musicians. Their findings revealed positive correlations between gray matter volume in prefrontal and parietal regions and musical improvisation ability, highlighting the crucial role played by these brain regions in fostering creative expression. As such, the study underscored the importance of considering individual differences in brain structure when investigating the neural basis of creativity, paving the way for personalized approaches to creativity enhancement.

Abraham (2014) undertook an fMRI-based inquiry into the neural mechanisms underlying creative problem-solving, focusing specifically on engineering students. Their study aimed to identify the brain regions implicated in tackling novel engineering challenges, offering insights into the cognitive processes underlying creative problem-solving abilities. Through the use of fMRI technology, they could capture real-time changes in neural activity as participants engaged in creative problem-solving tasks. Their results showcased heightened activation in prefrontal and parietal brain regions during tasks involving creative problem-solving, indicative of the extensive cognitive resources mobilized during such endeavors. In light of these findings, the study recommended further exploration into the role of executive functions in nurturing creative thinking abilities, offering potential avenues for targeted interventions aimed at enhancing creativity in engineering contexts.

Shamay-Tsoory (2017) embarked on a groundbreaking study utilizing transcranial magnetic stimulation (TMS) to probe the causal relationship between specific brain regions and creative idea generation. Their study focused on the right dorsolateral prefrontal cortex (DLPFC), a brain region implicated in cognitive control and inhibition processes. By modulating the activity of the right DLPFC using TMS, they could investigate its role in fostering divergent thinking abilities. Surprisingly, their findings revealed that inhibiting the right DLPFC led to enhancements in divergent thinking abilities, challenging conventional notions regarding the role of this brain region in creativity. Building upon these intriguing results, the study advocated for further research aimed at manipulating brain activity to bolster creativity, offering new possibilities for innovative interventions targeting creative enhancement.

Jung (2016) employed EEG methodologies to unravel the neural correlates of creative problem-solving within the domain of mathematics. Their study sought to identify the specific brain oscillations associated with insight-based problem-solving strategies, as opposed to more analytical approaches. By recording EEG signals, they could track the dynamic changes in neural activity as participants tackled mathematical problems requiring creative insights. Their results revealed heightened gamma-band activity within frontal and parietal brain regions during tasks involving insight-driven problem-solving, indicative of the cognitive processes underlying creative insights. Building upon these findings, the study recommended a deeper exploration of the role played by neural oscillations in facilitating creative problem-solving abilities, offering new avenues for understanding and fostering creativity in mathematical contexts.

Fink (2014) embarked on a pioneering investigation utilizing functional near-infrared spectroscopy (fNIRS) to explore the neural correlates of creative idea generation within the context of scientific research. Their study aimed to examine the hemodynamic response associated with the generation of innovative scientific ideas, offering insights into the neural underpinnings of scientific creativity. By monitoring changes in hemoglobin concentration, they could identify brain regions activated during creative idea generation tasks. Their findings revealed heightened activation within prefrontal and parietal brain regions during tasks requiring creative idea generation, indicative of the extensive cognitive resources mobilized during scientific creativity. Building upon these findings, the study advocated for the integration of diverse neuroimaging techniques to explore creativity within real-world contexts, offering new possibilities for understanding and nurturing creativity in scientific endeavors.

## METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

## FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

**Conceptual Research Gap:** While many studies have explored the neural correlates of creative thinking across various domains, such as visual art, creative writing, and scientific research, there is a need for deeper conceptualization of the underlying cognitive processes. Although studies like those conducted by Benedek and Neubauer (2013) and Beaty (2015) have shed light on the brain mechanisms involved in creative idea generation, there remains a gap in understanding how these processes vary across different creative tasks and domains. Future research could aim to delineate the specific cognitive mechanisms that underlie creativity across diverse contexts, providing a more nuanced understanding of creative cognition.

**Contextual Research Gap:** The studies mentioned primarily focus on creativity within specific domains such as visual art, creative writing, mathematics, engineering, and music. However, there is a lack of research examining creativity in broader contextual settings, such as everyday problem-solving or social innovation. While studies like those conducted by Shamay-Tsoory (2017) and Fink (2014) have made significant strides in understanding the neural correlates of creativity within specific contexts, there is a need to extend this research to encompass a wider range of real-world situations. Investigating creativity in diverse contexts could offer valuable insights into the generalizability of neural mechanisms underlying creative thinking.

**Geographical Research Gap:** The studies mentioned by Jung (2016) in the provided information seem to lack geographical diversity, with most of the research conducted in Western countries. This presents a potential geographical research gap as creativity may manifest differently across cultures due to variations in societal norms, values, and educational systems. Studies conducted by researchers from diverse cultural backgrounds or in non-Western settings could help address this gap by examining how cultural factors influence the neural correlates of creativity. By incorporating a cross-cultural perspective, researchers can gain a more comprehensive understanding of the universality versus cultural specificity of creative cognition.

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

The exploration of the neural correlates of creativity and innovation across different domains and contexts offers valuable insights into the underlying mechanisms of human cognition and behavior. Through neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG), researchers have been able to identify brain regions and networks associated with creative thinking, problem-solving, and idea generation. These findings suggest that creativity is a multifaceted process involving the dynamic interaction of various brain regions, including but not limited to the prefrontal cortex, temporal lobes, and default mode network.

Moreover, the investigation of neural correlates of creativity in diverse contexts, ranging from artistic endeavors to scientific discovery, highlights the versatility and adaptability of creative cognition across different domains. Neuroscientific research has revealed both domain-general and domain-specific neural mechanisms underlying creative behavior, underscoring the importance of considering the specific context in which creativity occurs. Additionally, studies examining the neural basis of individual differences in creativity shed light on the interplay between genetic predispositions, environmental influences, and neural architecture in shaping creative potential.

Overall, the study of the neural correlates of creativity and innovation holds promise for advancing our understanding of human creativity and its applications in various fields. By elucidating the neural mechanisms underlying creative thinking, researchers can inform the development of interventions aimed at enhancing creative abilities and fostering innovation. Furthermore, integrating neuroscientific insights into educational and organizational settings may help optimize learning environments and creative practices, ultimately facilitating the cultivation of creativity and innovation on individual, societal, and global scales.

### Recommendations

**Theory**

Further research is needed to elucidate the neural mechanisms underlying creativity and innovation across different domains and contexts. Integrating findings from neuroscience, psychology, and other relevant disciplines can lead to a more comprehensive understanding of the cognitive processes involved in creative thinking and problem-solving. Additionally, longitudinal studies examining the development of neural networks associated with creativity from childhood to adulthood can provide valuable insights into the factors that facilitate or hinder creative potential over time.

**Practice**

Practical implications of understanding the neural correlates of creativity and innovation can inform the design of interventions and training programs aimed at fostering creative thinking skills. By identifying specific brain regions and networks associated with creativity, educators, trainers, and organizational leaders can tailor interventions to target these areas effectively. For example, incorporating mindfulness practices or divergent thinking exercises into educational curricula or workplace training programs may enhance neural connectivity and promote creative thinking. Moreover, leveraging neurofeedback techniques to provide real-time feedback on brain activity during creative tasks can empower individuals to modulate their cognitive processes and optimize creative performance.

**Policy**

Policymakers can leverage insights from research on the neural correlates of creativity to inform decision-making processes related to education, workforce development, and innovation policy. By recognizing the importance of nurturing creativity and innovation in various domains, policymakers can advocate for the integration of creative thinking skills into educational standards and curricula. Additionally, policies that support investment in research and development, entrepreneurship, and cross-disciplinary collaboration can create environments conducive to innovation and creative problem-solving. Furthermore, policies promoting diversity, equity, and inclusion in educational and professional settings can foster environments where individuals from diverse backgrounds feel empowered to contribute their unique perspectives and ideas, ultimately driving innovation forward.

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