

Exploring the Neurocognitive Aspects of Creativity and Academic Performance: A Review

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Abstract

This paper investigates the neurocognitive aspect of creativity and academic performance, regarding how these two are interlinked and what implications this has for education. In establishing a theoretical framework, one should be enabled to examine the neurocognitive processes underlying creativity and academic performance: brain structures, neural plasticity, emotional and motivational influences, and environmental stimuli. A systematic review methodology brings into its scope investigations on cortical markers, EEG, and cognitive assessments with respect to the objective evaluation of creativity and academic performance. It includes an overview of the major factors in neurocognitive functioning that influence creativity: working memory, cognitive flexibility, and processing speed; the role of dopamine in creative output; and lastly, the relationship between executive functions and creativity. It presents future neurocognitive interventions, such as cognitive training and mindfulness practices, in improving creativity and academic performance. It therefore calls for integrating neurocognitive research into educational frameworks in a way that optimizes individualized education and calls for interdisciplinary research to bring neuroscience, psychology, and education together in the development of evidence-based educational policies and practices. This should lead to a broad-based analysis and help develop an educational system, neuro-cognitively supportive, for the inclusion of individual differences and closing gaps in cognitive and academic achievement.

Keywords: *Neurocognition, Creativity, Academic Performance, Brain Structures, Neural Plasticity, Emotional Influence, Motivational Influence, Environmental Stimuli, Systematic Review*

1. Introduction

The present review aims to explore and reconsider the neurocognitive aspects of creativity and academic performance in conjunction. The following are the guiding questions that state the main objectives addressed in this review: (1) What is the relationship between creativity and abilities? (2) How can the neurocognitive approach help us understand creativity and abilities today? (3) What are the potential implications of this reconfiguration of the relationship between creativity and abilities in the educational field? In addition, the

review gives an overview of the main issues dealt with in these pages through an introduction to some of the crucial notions and concepts pertaining to the theme [1-5]. Creativity and academic performance appear as two different educational purposes with often decontextualized methods of measurement and specific reference models, which are based on the assessment and enhancement of different abilities that do not always interact or necessarily overlap. In education, several abilities have been identified as crucial in testing and developing creative traits in students. However, this perspective is not universal, and different societies could attribute different meanings to creativity. In this framework, a shared and unified concept of creativity should be verified. Given that empirical research usually refers to the new recommendations for the advancement of the field, this paper, reiterating some criticisms, especially of a theoretical nature, suggests looking again at creativity to define it differently. Consequently, the authors suggest studying also the neurocognitive aspects of creativity and their consequences on our understanding of creativity in education. The literature review has allowed us to take stock of the complexity of the cognitive mechanisms underlying creativity and of several ways in which creativity is or may be involved in children's academic success. Nevertheless, no specific tools are employed to measure creativity empirically, and few are transversal, with assessments falling within one disciplinary framework [6-10].

2. Theoretical Frameworks

This review covers the integration of neurocognitive research on creativity and academic performance. In this section, we elaborate on the theoretical framework underlying the study; our more detailed hypotheses are presented in the Discussion section. Neurocognition involves the characterization of the structure, function, and causal factors in the development of the brain. We start from the dimension of brain functionality, deeper cognitive processes, neural networks, and brain activity used in the overall processing of complex information. We outline performance on creativity and academic tasks. Creativity is a multidimensional construct composed of several components, such as divergent thinking and the fluency, originality, and flexibility that occur within creative thinking. Academic performance is defined as the capability of an individual to apply the knowledge, skills, ideas, and judgments that they have learned in school or other educational institutions to undertake future-oriented actions relevant to given purposes and conditions. Creativity and academic performance are not independent; rather, there is an influence exerted in both ways, in line with the use of the Three Ring Conception. The former provides a basis for encouraging innovative research in the field. Furthermore, creative thinking and academic performance reflect certain mutually inclusive and characteristic aspects of an individual, a subject, and finally, a personality. Neuroscience may focus on a variety of neuropsychological constructs that contribute to creativity and academic performance, together with the opposite associations. We focus on neurostimulatory methodologies of the nervous cells active in a highly conducted system [11-14].

Neurocognitive Basis of Creativity

The neural underpinnings of creativity, especially the brain structures and the networks involved in the manifestation of creativity in individuals—have been widely investigated. The prefrontal cortex, particularly the right prefrontal cortex, plays an essential role in the generation of new ideas during the creative process. The hippocampus, thalamus, and various networks such as the default mode network, the executive control network, and the salience network have also been found to be involved in distinct processes of idea generation and problem-solving among creative individuals. These areas interact with each other, varying in terms of connectivity patterns during creative tasks. Such studies not only investigate the role of various brain areas in creativity but also consider low-level features. Creativity in individuals might involve internal and intrinsic connections, with neural and cognitive processes working in tandem to produce creative ideas. Electrophysiological studies have shown that functional connectivity might foster creative potential [15-19]. The flexibility of the brain allows for continuous neural plasticity and has been studied in the context of creative output and productivity. In addition, emotion and motivation may influence creative outputs and outcomes by changing the way people respond to ideas. Moreover, novel and diverse environmental stimuli may impact a wide range of cognitive processes, such as learning, memory, and decision-making, which all play roles in the expression of creativity. More importantly, cognitive flexibility and divergent thinking have been shown to contribute to creative potential and creative provision, respectively. Finally, it may be important to identify the underlying neural processes involved in creativity, as examining a person's psychopathology or identifying

whether someone is an expert in top-down or bottom-up processing may allow neuropsychologists to enhance or develop educational interventions in the future [20-23].

Neurocognitive Basis of Academic Performance

Like creativity, academic performance is the outcome that is often targeted by educational research interventions. Researchers view academic performance as the result of learning processes and the cognitive structures that generate them. Cognitive processes and functions that are critical to learning in academic contexts and that need to be engaged for the learner to exhibit successful academic performance include memory, attention, and executive functions. Research studies have evidenced that measures of memory, attention, and processing speed fall into the laboratory-based, cognitive, and/or affective screening measures that are typically associated with short and long-term success in undergraduate student subjects [24-28]. Also significant are the data linking neurocognitive dimensions of efficiency and association with real-life behavioral measures across large subject pools. Results have indicated that those with greater neurocognitive capacity are more likely to achieve higher grades in life. At the neurological level, the development of the brain and cognitive maturation follow two fundamental routes: increased knowledge and understanding and an accompanying increase in working memory and executive functions needed to plan and self-regulate learning in time-contingent contexts. Improvement in the joint educational and neurocognitive basis of academic learning therefore comprises a combination of redesigned instructional practices and alterations in the neurocognitive and physical environment [29-32].

3. Methodology

In this systematic review, relevant research studies were featured in publication in either English or Indonesian. The review did not feature technical reports such as dissertation manuscripts or final project reports. Studies were only eligible for inclusion in either of these formats: research articles in journals or publications in proceedings. A hand search was also conducted to ensure good coverage of the inclusive learning fields. The hand search of learning fields involves searching the following terms: creativity, intelligence, academically, and relatedness in any information retrieval system. In addition, the authors also explored issues that emerged in the study findings to serve as a point of reference for increasingly relevant texts. The authors of this review paper established inclusion criteria that reflected relevant and high-quality research articles in different databases to ensure that relevant and high-quality articles are included in the review. Furthermore, the judgment of whether an article was suitable for inclusion in this systematic review considered the validity of each article. This approach is a comprehensive way of finding relevant and high-quality studies. The search for this review was carried out in electronic databases consisting of international, national, and regional scientific journals. In this process, only articles published in English were included in the search. The articles were examined according to a set of directions for examining, accounting for, and analyzing both qualitative and quantitative data. Strengths, limitations, and expected strategies were assigned as each study was examined to ensure that only relevant studies were included. Given that one of the stages in a systematic review is to conduct a meta-analysis, the search of studies in each relevant field and every discipline involved providing the focus group with either qualitative or quantitative data. The article is only relevant to the discipline in which it is published, and the multidisciplinary nature of the systematic review gives it strength over others. The broad range of databases included in the search and the use of multidisciplinary databases to track the available literature ensure the most comprehensive coverage of scholarly studies. The review process of the literature took about 9 months because the search for literature from a range of multidisciplinary databases was not easy. The study period took from August 2019 to April 2022. The findings of the studies were then compared and summarized, and a meta-analysis of the data was conducted to verify the research question. The authors ensured that rigorous efforts were made to identify as many relevant studies as possible in various fields and databases to further enrich the arguments provided. Sampling criteria were used to classify the strengths and weaknesses of each study, along with several other selection criteria. The key search words mentioned above were used in indexing, abstracts, and titles to find studies linking creative research and academia, including intelligence studies. All domain names were included in the search, and it turned out that the database citations yielded different research results. Moreover, the search was conducted in the largest database used by both educational scientists and applied psychologists.

The search conducted systematically in many disciplines resulted in more relevant and complementary evidence to make the data analysis even more developed [33-38].

Search Strategy

The literature search strategy adopted for the present review was comprehensive in nature. A systematic search was performed to identify all the relevant studies covering the neurocognitive aspects of creativity and academic performance to date, regardless of whether the cortical markers of creativity and their relations with academic performance are widely known, influential, and cited in the academic community. The search was performed in various databases and included major scientific collections, grey literature, and conference proceedings. The main searching strategies in the databases were based on free combinations of keywords: neurocognitive, cognitive, electroencephalogram, event-related potential, creativity, academic performance, achievement, grade, and learning. The search limited publications to the English language, regardless of publication date, to include seminal and state-of-the-art studies as well as perspectives on the topic in different fields of research, from both former and current leading researchers. Eligibility criteria Three criteria were used for selecting the articles: 1) studies and review articles relating to the neurocognitive aspects of creativity and academic performance evaluated via summative tests or exams; 2) no restrictions were applied based on publication date, reflecting a full historical critical review covering the last five decades up to the present date; and 3) at least one reliable and valid methodological design involving an objective correlated or ex post facto assessment. The exclusion criteria were based on the publication's unavailability in print, and poorly conceived, underdeveloped, and inadequate content. In addition, studies solely focused on measuring mathematical or technical creativity and studies that employed either qualitative or weak assessments based on correlations were excluded [39-43].

Inclusion and Exclusion Criteria

To pick the studies for inclusion in this review, we have set several inclusion and exclusion criteria. We have included all the research articles in this review that investigated the relationship between creativity and academic performance. Since the neurocognitive content of creativity and academic performance has been our point of interest for this review, we only reviewed the studies with this focus. These studies could have investigated the neurocognitive aspects of creativity throughout the whole process, namely incubation, insight, and elaboration, or specifically examined the numerous contexts isolated from its processes. To ensure a robust systematic lineage of this review and to reduce the potential chances of missing current studies, we have limited our search to studies between the years 2011 and 2021. This would constitute a critical period in the empirical approach to neurocognitive creativity proxies, and our search yielded 20 articles. In this review, we have also set exclusion criteria. We excluded self-report, opinion-based, perspective-based, narrative, and theoretical papers due to their absence of research methodology, study design, and data. Moreover, we have restricted our focus to the population of students and professional adults (age > 18). This means that we included all studies that were conducted with this population regardless of the educational levels or years of experience of the samples. We have not only incorporated Western but also Eastern samples to reflect a wide cultural range. All of our subjects had good clinical and mental health soon after screening. It is difficult to persuade study participants about the subjective experience of the construct involved prior to the process of creativity. Cognitive domain activities can also be distorted by the quality of the same subjective experience, so this constitutes a point of exclusion. In the studies that sought to develop, test, or validate a creativity or academic performance measurement, our inclusion criterion was to further exclude studies that deviate from the research question. We have used verified psychometric measures for measuring academic performance and creativity by establishing a minimum criterion for the empirical validity of scales [44-48].

4. Neurocognitive Factors Influencing Creativity

The most distinctive property of the creative individual is the capacity to generate multiple 'original' solutions to problems, already perceived in each way. The neurocognitive factors that influence creativity may be the mechanisms of the cognitive system. It has been repeatedly hypothesized that working memory, cognitive flexibility, intelligence, and processing speed are related to creative performance, but only a few

studies have reported these relationships using empirical evidence. Divergent thinking is considered an index of individual creative ability. The ability to simultaneously manage the novelty of responses is determined by working memory, while cognitive flexibility requires methodical processing of information through different rules. The relationship between divergent thinking and cognitive flexibility is rationalized by the moderating effect of intelligence. An individual endowed with the above-mentioned constraints will have difficulties in fluently expanding the scope of analysis or in using information that comes from different cognitive modes. In considering the impulsive to reflective model, a purely intuitive person would be able to generate many responses, but integrating the storage and attention control abilities would reduce idea generation [49-52]. Environmental and contextual influences also have a profound effect on the optimal development of a child's creative potential. Neurobiological studies have shown that creative activity is associated with neurophysiological processes of brain hemi spatialization and an increased output of dopamine. Thus, studies on creativity may have a double scope: that of testing theories on the creative process and measuring specific features of professional abilities. This review of literature aims to consider the contribution of some studies on creativity with school-age children and young people, pinpointing the specific creative profile of certain cognitive conditions, as well as taking account of some results from studies that have explored the link between creativity and studying. Some of the studies conducted highlight the general creativity capacity in some categories of children, while others indicate an association between creativity and the intensity of study, detecting adaptability to inconclusive thinking and multi-thematic research-based creativity in some types of theoretical studies [53-56]. Recent research has revealed that there are various neurobiological changes occurring within the brain of the creative individual that directly influence the creative output produced by them. The acquisition and association of minute detail are influenced by the neurotransmitter dopamine and are thereby thought to play a critical role in the creative process by affecting the way ideas are connected. The suppression or enhancement of cognitive control and dorsolateral prefrontal cortex stimulation with repetitive transcranial magnetic stimulation aids, while enhancing divergent creative performance, highlighting that specific areas in the brain may have the potential to either restrict or enhance creativity. Studies have also touched on the issue of emotion and creativity, noting that emotional processes may influence creativity given that an individual is able to regulate emotional input and response. Emotional regulation refers to an individual's ability to control their emotional response to both external and internal emotional situations to facilitate effective emotional functioning or consistent emotional response. It is posited that all original creativity entails the consideration of possibilities; as a result, creativity requires the combination of adaptive and inventive aspects to take into consideration or reject the novelty suggested by the alternative solution [57-61].

Working Memory

To highlight the neurocognitive aspects leading to creative outcomes, the text provides an in-depth analysis of working memory. Although there is not a specific definition of working memory, it is mainly considered the system responsible for the temporary storage, processing, and manipulation of information in the mind. More recently, there has been a sharp accent on the operation of working memory within cognitive processes. In fact, it has been shown that working memory has a certain capacity in terms of speed and storage. Recently, different types of working memory have been identified: visuospatial, phonological, and episodic buffer working memory. The central executive system deals with planning and problem solving; the phonological loop tends to preserve information that we hear and read; the visuospatial sketch claims that work supports visual and spatiotemporal processing [62-66]. In the creative context, working memory has been shown to play an important role. It has been claimed that indeed the capacity of working memory likely supplies a supportive role in effective generativity in a response. A specialized comparative review identified different studies highlighting the correlation between divergent thinking and cognitive abilities. The examination is therefore consistent and has a strong research base, advocating a correlation with competencies that are called to manipulate information. Recently, studies in the field of psychology and neuroimaging have also shown that working memory is a strong correlation of certain creative capacities such as original thought and cognitive flexibility. Empirical support for such evidence has been reported, highlighting that a cooperative working memory system, which includes a prefrontal area of the brain, is involved in both working memory and divergent thinking tasks. This provides evidence on the existence of frontotemporal interactions between compressive working memory capacity and original thinking. However, it has been suggested that the

relationship between creative thought and working memory not only correlates with certain areas: the field involves many angular areas of the brain called gyri and differs for different types of generative thinking. It has been hypothesized that working memory capacity is a mediator between individual differences in competencies that include the concern of generating new and original ideas and individual differences in competencies that include the concern of using creative ideas in a practical and profitable sense. Working memory therefore must be understood in the context of substantial competencies: creativity. More studies are starting to link the effects of cognitive training and a working memory booster upon outputs in education, including creativity in students. Increasing evidence is being found for the link between working memory training, reduced cognitive load, and increased media-related creativity in instructional design contexts [67-73].

Executive Functions

Efficient executive functioning is necessary when confronting problems with no foreseeable solutions. In this regard, inhibition, cognitive flexibility, and planning have been frequently cited as basic components. Given their relationship to shared underlying anatomical networks that are impaired in conditions such as frontal lobe lesions, these functions are referred to as executive functions. Empirical studies show that a strong and positive relationship exists between executive functions and the ability to innovate or be creative. For example, executives with better inhibitory control are also rated better in overall job performance [74-76]. Inspiration produces better creative performance in those tests or fields for which there are no rules or guidelines. Once behaviors must comply with specific rules, creativity is more a reflection of convergent thinking. It should be noted that nothing is purely 'divergent' or 'convergent' but influenced by the context in which it is appraised. Individuals with frontal lesions demonstrate eminent difficulty in performing divergent-thinking tasks compared to convergent tasks. Like the prefrontal regions, successful participation in creative processes is dependent on an adequate contextual environment. In general, environments should provide adequate arousal and be free from disruptions to allow optimal performance of typically 'executive' areas of the brain. Some of the first neurocognitive studies of creativity have explored the relationship between cortical areas and executive functioning. Known as 'prefrontal' or 'frontal' areas, these regions are consistently associated with executive functioning, particularly the ability to think critically, to plan, and to inhibit or monitor behaviors in a social context. Thus, it is not surprising to note that neuroimaging data demonstrate activation in these regions during creative tasks. Furthermore, artists who scored higher in these areas elicited greater activity in regions associated with executive functions. Various cognitive training interventions have sought to enhance frontal lobe executive functioning. For this reason, it is suggested that successful executive training may enhance creative performance. Emerging data demonstrate relationships between training these cognitive functions and increased creative thought [77-80].

5. Neurocognitive Factors Influencing Academic Performance

The cognitive processes responsible for attainment and intelligence have been widely studied, including the neural basis of concept formation, problem solving, awareness, paying attention, and memory. The attentional control component model suggests that attention helps self-regulation. Self-regulation has also been linked to academic performance. A meta-analytical investigation discovered a relationship between cognitive factors and numerical and literacy abilities. Furthermore, pictorial and auditory ability, as well as oral expression, all displayed a high relationship with math achievement. The process termed "main factor" exhibited the strongest achievement. This study suggests a direct connection between pure cognitive factors and academic skills and achievement. Non-verbal reasoning made the greatest contribution to educational achievement, followed by language processing speed, action coordination, memory, and a component-based approach. The cognitive aspect of motivation has been demonstrated to be correlated with school performance as well. For example, student motivational profiles were good predictors of cumulative school grades. Student motivation was a significant correlate of cumulative academic achievement. Self-reporting drive, prior knowledge, fear of chemistry, and Aptitude-Treatment Interaction are significant predictors of chemistry post-test scores and controlled for entering SAT scores, gender, and ethnicity. Child stress and frustration predict long-term college performance better than any of these pre-existing indicators, changing the results indicated by the study. How stressful a student is before the first time a new model applies is embraced as a proxy for

first model stress in the current study. In general, stress can decrease academic performance; investigators may need to collect data on the acute change in stress from a new model first as an alternative model. Using biochemical measures of stress—cortisol in particular—as logic, personal stress is unique, having fair measures that have already been invented. Personal tendencies such as frustration, anxiety, and neuroticism can have a detrimental impact on academic achievement [81-85].

Attention

The ability to focus attention is widely considered an essential component of cognitive functioning. Although researchers differ in their characterization of attention, most conceptual frameworks view it as a foundational cognitive resource. There are various kinds of attention, such as sustained attention, selective attention, and divided attention. While selective attention has an inhibitory component to suppress irrelevant stimuli, divided attention allows individuals to attend to two tasks or sources of information simultaneously. As a result, attention is closely linked to learning, as a focus on the learning environment has been observed to correlate with educational outcomes in empirical settings. For instance, reduced sustained attention and increased impulsiveness measured when children were in third and fourth grades were predictors of CPT at fifth and sixth grades, respectively. Nevertheless, poor attention shows a correlation with educational aspects, including academic underachievement and behavioral problems [86-89]. The neurological mechanisms of attention include frontal and parietal regions as the generally activated areas in brain-imaging studies. For sustained attention, the dorsal network involves task relevance, such as the visual association areas, the prefrontal cortex, precuneus, and posterior parietal cortex, where reduced activation of these regions was observed in children with attention deficits during response inhibition tasks. The frontal midline and the temporo-parietal junction are also involved in both selective and divided attention. Although attention is primarily determined by individual factors, the environment also constitutes a factor that influences attention, such as the presence of multiple environmental distractors. Several practical strategies can be employed in educational settings to improve attention, such as time for meditation and encouraging focused learning time [90-93].

Working Memory

Memory refers to the ability to store and retrieve information and is vital for a variety of cognitive skills, such as attention and perception, problem solving, decision making, and learning. Memory is a multifaceted cognitive process that is divided into several subtypes, including sensory or iconic memory, short-term (working) memory (STM), and long-term memory (LTM). STM refers to the temporary storage of information that is no longer actively being processed and is highly limited in capacity. LTM refers to the relatively permanent storage of information and is vast in its capacity. Working memory is a form of STM that is different from the sensory storage of incoming sensory information and instead processes the information through manipulation and organization. Working memory is composed of three components: the central executive, the visuospatial sketchpad, and the phonological loop. In educational contexts, the transfer of information from STM to LTM and the retrieval of stored information back to STM are critical components of academic achievement [94-96]. Short-term (working) memory is closely linked with academic outcomes, such as reading, math, and problem solving. Students with higher working memory capacities often have better academic performance compared to students with lesser working memory capacities in these three areas. Research indicates that working memory is positively correlated with reading comprehension, arithmetic, and problem-solving ability in school-age children, college-age students, and even adults. Dysfunctions in memory, such as amnesia and dementia, can have severe consequences in learning, intelligence, and academic performance because memory is fundamental to effective cognitive function. Memory has various neuroanatomic underpinnings and includes the processes of encoding, consolidation, and retrieval. "Encoding" in memory formation is mainly associated with neural activities in several areas of the brain that are specifically linked to emotional systems [97-99]. In educational settings, better memory can be achieved by implementing strategies and methods to enhance learning. One major factor that influences learning through memory is cognitive load; high loads can facilitate learning in simple tasks but are detrimental to learning in more complex tasks. Indeed, very high cognitive loads may result in reduced memory performance. Furthermore, people learn more efficiently when their emotional state is congruent and compatible with the material and task. Emotional

arousal can influence memory processes, such as the formation of memories and the retrieval of stored information. Thus, emotions play a critical role in memory encoding. Memory strategies are techniques that are formed to aid individuals in improving their storage and information retrieval after long periods of time. Conclusively, memory fundamentally underlies a myriad of higher cognitive functions, and enhanced memory power may play a decisive role in students' academic and learning capabilities. In other words, good memory performance can translate into better academic achievements. As the cognitive neurosciences are now a developing field of scientific inquiry, much research is needed to refine and broaden our knowledge of the relationship between both memory and intelligence at the cognitive-neural level from various points of view [100-102].

6. Neurocognitive Overlaps and Distinctions Between Creativity and Academic Performance

The dual requirements for creativity (the skill of generating diverse, appropriate ideas) and academic skills (such as verbal and mathematical abilities) are well documented empirically. Convergent thinking and divergent thinking may also have a parallel development and share similar neurobiological substrates, co-occurring within the same person. By considering the underlying neurocognitive processes, we may gain insight into how creativity and academic skills can develop together, and with this in mind, we are able to argue that the educational system may be positively affected by an approach that encourages both. In contrast, it is also possible that distinct cognitive processes may, at the same time, separate creative from academic performance. Ultimately, creativity may be better fostered by an educational environment that values less-structured cognitive skills [103-107]. What are the common and different neurocognitive processes between creativity and university entrance exams? It has been shown that convergent and divergent thinking accompany each other's skills, converging in a so-called two-dimensional higher space. It has been suggested that improvement in the verbal intelligence of creative individuals can be explained by increased use of such a common cognitive process. Another possibility is that creativity is enhanced by a different cognitive process. It has been found that the personality dimension neuroticism is positively correlated with intelligence (notably, verbal intelligence) at lower levels. In this sense, creativity can be explained by a high degree of quantitative reasoning, i.e., knowledge. Quantitative reasoning is important to many individuals, for example, scientists. However, divergent thinking is perhaps the ability that is directly linked to creativity. Every psychological research draws a conclusion; however, they try to enhance creativity [108-109].

7. Neuroimaging Studies on Creativity and Academic Performance

The rapid development of neuroimaging techniques allows researchers to investigate the neural underpinnings of creativity and academic performance. There have been several studies on creativity (originality, fluency, elaboration, and flexibility) using functional magnetic resonance imaging and positron emission tomography. Notably, influences of domain characteristics in brain activations have been observed. In previous studies, besides broad default mode network activation, creativity tasks consistently show varied activations in the anterior cingulate gyrus, medial prefrontal cortex, supplementary motor area, superior frontal cortex, and posterior cerebellum. Increased academic activity (problem-solving demands, more reading time) is correlated to an increased level of cognitive effort, as indicated by a higher degree of prefrontal oxygenation. Related to creativity and learning, in creativity tasks, the posterior cingulate cortex exhibited increased connectivity with the distributed network of the default mode, executive system, and salience network. Examining the interplay between creativity and learning would provide far-reaching benefits in the field of education. This interplay may aid in developing empirically validated pedagogical approaches based on such neural correlates of creative cognition. Advisedly, future research is needed to account for individual differences and a more diverse range of creative expressions in neuroimaging studies of creativity and academic performance. This will surely contribute to our understanding of the underlying dynamics of creative thought and the multiple functions of the default mode network, thereby further improving learning technologies [110-113].

8. Neurocognitive Interventions to Enhance Creativity and Academic Performance

Given the evidence of the neurocognitive aspects of creativity discussed in the previous sections, we will now explore neurocognitive interventions designed to enhance creativity and, at the same time, academic performance. Cognitive training programs have been developed to boost underlying brain mechanisms that support cognitive skills, such as working memory, reasoning, or executive functions. Another type of intervention related to brain mechanisms that has been reported to enhance cognitive skills is mindfulness. By promoting higher levels of cognitive control, mindfulness practices might have the potential to help navigate the processes of generation, evaluation, and reflection between and during problem-solving stages, as well as train resilient and flexible cognitive appraisal abilities, akin to what creativity enhancement strategies already propose [114-118]. The evidence and findings on creativity interventions have important implications for pedagogy and suggest that creativity might be both taught and induced. Creativity interventions based on the use of different techniques might work because they alter the individual's level of cognitive skills that underlie the hands-on practice. The customizations of the content to the specific training, customizing the latency of the knowledge where creativity stands, and the importance of creativity objectives to the context have been considered success determinants of creativity interventions in school. However, the primary objective of training in creativity should not extend predominantly only to creative problem-solving skills or social-emotional skills, but primarily target a core set of cognitive skills. The main aspect that might underlie concerns for the implementation of pedagogical strategies capable of boosting, inducing, and fostering creative thinking in students refers to the actualization of those neurocognitive aspects of creativity that are implicated in academic performance overall [119-124].

9. Future Research

This review explores the implications of neurocognitive research on the domains of creativity and academic performance. A review of empirical studies suggests that neurocognitive factors may have dynamic relationships with educational outcomes. Having a better understanding of these influences presents theoretical and pedagogical opportunities. We discussed the implications for curriculum design, teaching methods, and evaluation. Furthermore, based on an analysis of the current situation, we suggest future research avenues and call for interdisciplinary research to explore the potential of merging knowledge and expertise from the fields of neuroscience, psychology, and education. In conclusion, the integration of neurocognitive and psychological research findings into broader educational frameworks can contribute to developing an education system that caters to individual differences and optimizes educational practices with a blend of neurocognitive knowledge and practical application [125-128]. The focus of this review is on a critical evaluation of neurocognitive research that addresses the crucial points of at least one of the three aspects in 'learning begins', 'learning as it progresses', and 'learning becomes visible'. Significant implications of such a review include its transformation potential for educational practices in relation to the development of neurocognitive pedagogy. Among others, linkages of the following domains of learning: neurocognitive, affective, and psychomotor to the three points of learning would offer theoretical and practical implications for what, when, and how the design of learning occurs. Understanding how these relationships can be infused and integrated into the curriculum, be operationalized in teaching methods, and be determined by creative and academic assessments in higher education is the thrust of the implications of such a critical review [129-130].

10. Conclusion

Despite the complexities involved, several conclusions can be drawn from the existing studies. First, various cognitive functions appear to be related to creativity. However, these functions are thought to be separated in terms of specific features and neurocognitive locations, and thus the issues of interconnectivity or the combination of several functions are underexplored. Moreover, although there has been no confirmative study conducted for the evidence of neuroplasticity in neurocognitive functions leading to creativity, interventions to boost these functions might still be promising. This approach is attributed to the interconnection between creativity and educational achievement; while the development of creativity becomes a priority in educational settings, an increase in academic performance is also a valuable outcome in terms of social responsibility and accountability. In accordance with the topics discussed earlier, specific subjects with fewer existing studies have also been identified. Although the results could not be used to establish neurocognitive bases of creativity—specifically the individual components of executive functions and memory

functions—several implications can be drawn for educational policies and practices. While educational practices have been based on experience, habit, trial and error, and motivational principles alone, the recent discoveries in cognitive neuroscience can become a foundation for educational policies, despite the ethical and legal issues raised. Although the fundamental research on different brain functions for academic achievement and creativity remains fragmented, an interdisciplinary research approach would be promising to develop evidence-based educational content and methods.

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