The Neuroscientific Approach to Creativity and its Musical Applications

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Creative thinking is a skill that has given immeasurable benefits to the human race. Creative ideas are defined as those that include the ability to produce work that is both novel and appropriate (Sternberg & Lubart, 1999). This type of thinking occurs in all situations that include high-level information processing, whether they be scientific or aesthetic. Some compare a moment of creativity to the flashing of a light bulb. Others envision a controlled and logical process that takes time to develop into a novel thought or expansion of dimensionality. In science, creative thinking involves expanding on known truths to broaden human understanding of our environment. In fine arts, creativity can be the advent of a new way to express the feelings of the artist's subjective experience (Zeki, 2001). This can manifest itself as a new chord progression or set of lyrics, a new instrument, a new genre, et cetera.

The study of creativity has been long and varied in its approach. For much of human history, creativity has been regarded as a God-given gift. Countless ancient writers and musicians spoke of invoking their muse before they began their creative process. Attempts to scientifically study the phenomenon of creativity have long been met with criticism by those who believe man has neither the right nor the ability to fully comprehend this phenomenon (Sternberg & Lubart, 1999; Pfenninger, Shubik, & Adolphe, 2001).

The first step in the direction of a scientific model for the process of creativity was taken by 17th century French philosopher and mathematician, Rene Descartes. Descartes' theory of duality popularized the idea that the mind is a distinct "thinking substance" that is completely separate from the body (Pfenninger et al, 2001). Since this time, more and more attention has been paid to the scientific study of the processes of creative thinking. These include, among others, psychodynamic, psychometric, social, and confluence approaches. In the present paper, another approach will be examined; that is the application of the studies of cognitive neuroscience to the processes of creativity. This research has sought to examine information processing from a neurological perspective. Some of the most important results to come from this research are the division of creative thinking into several distinct categories based both on the brain circuits by which the information is processed, and the resulting effects of creative behavior on primitives and goals used in further creative behavior (Cariani, 2008, 2009; Dietrich, 2004)

The human brain is designed to extract two different kinds of information from the external environment, each of these involving a different neurological pathway. Information gathered through the emotional route includes relative emotional values of incoming information in order to assess its biological significance. Not surprisingly, this information is initially processed in the structures of the limbic system such as the amygdala (Dietrich, 2004). Information that is processed through the perceptual route is meant to analyze incoming stimuli in order to construct a detailed perceptual representation of the external environment. This type of cognition is responsible for sensory input and long-term memory as well. The cognitive neurological pathway passes mainly through the hippocampus and temporal, occipital, and parietal lobes (TOP).

Until this point in information processing, both of these pathways remain mostly computational. It is the integration of these two streams of data that allows for analysis and higher order functions. This system of integration begins when information reaches the prefrontal cortex. It is executive processes of the prefrontal cortex that allow us to draw conclusions, organize willed behavior, control levels of selective attention, and make decisions based on the data we receive (Dietrich, 2004). This area is also home to our behavioral flexibility and adaptability, two traits that are essential to creative thinking. It is theorized that the different types of higher brain function come from different discrete circuits by which the information reaches the prefrontal cortex.

Within the prefrontal cortex, there are two subcortices that are especially important in creative thinking. The first of these is the ventromedial prefrontal cortex (VMPFC). This construct shares a large number of intricate connections with the structures of the limbic system and is responsible for the integration and analysis of complex emotions, behavioral consequences, complex social cognition, and other functions. To establish true creative novelty it is necessary to understand the effect of an idea on others, whether within a small group or community or to society as a whole (Sternberg & Lubart, 1999). The high level functions of the VMPFC can allow creative thinkers such as environmentalists or politicians to assign levels of priority and propriety to the issues and questions they intend to address. The function of analyzing behavioral consequences is also highly useful in the production of novelty. Creative thinkers can put themselves in great danger when their behavior is judged by others to be socially unacceptable or deviant from the norm. Thus, bringing such ideas to life through art is an effective form of avoiding negative consequences (Zeki, 2001).

The second important division of the prefrontal cortex is the dorsolateral prefrontal cortex (DLPFC). This construct does not share the same connections with the limbic structures seen in the VMPFC, but is highly interconnected with the structures of the TOP and is integral in the coordination of motor functions, working memory, and temporal integration. It is in this construct that information from the emotional and perceptual pathways meet and undergo higher level processing. With the first streams of limbic computations, the DLPFC can use the previously computed salience levels to divide and sustain attention on the most pressing issue. The mechanisms of attention and selective processes are present throughout the perceptual process, even before prefrontal integration in the TOP. However, the intentional control of attention and the maintenance of concentration are functions of the prefrontal cortex (Dietrich, 2004). Thus, the DLPFC is responsible for carrying out the priorities established by the VMPFC. Once the correct questions have been identified, necessary information is held in working memory and selective attention is maintained long enough for a truly creative solution to develop.

In the realm of music, high-level emotional and social cognition is readily evident as well. A style of music that has become tremendously popular since the introduction of software sampling is the “Mash-Up.” Artists like Girl Talk, Norwegian Recycling, and the Super Mash Bros have all made their mark by slapping together beat-matched versions of several famous songs. In many cases the two or more songs being mashed will have social significance both by themselves and together. Girl Talk’s song “Too Deep,” features samples from Dr. Dre, Paul McCartney, Mariah Carey, The Smashing Pumpkins, and Alicia Keys (among others) in one cohesive and well-produced track. The artist clearly used high-level VMPFC functioning to accurately assess the social importance of his samples and predict the positive reactions of the public.

In this example the initial stages of conception and the formulation of a goal are handled by the VMPFC. However, when execution begins, much of the cognitive heavy lifting is taken care of by the functions of the DLPFC. It is relatively safe to assume that Girl Talk used working memory and selected attention to remain conscious of his goal while he chose his samples, made necessary audio adjustments, and wrote the arrangements for his album. These divisions of the prefrontal cortex perform distinct functions, but often work together in well-executed creative behavior.

The neurological constructs involved in the processes of creative thought are broadly accepted. However, several different researchers have proposed their own strategies for categorizing the different types of creativity (Cariani 2008, 2009; Dietrich 2004; Zeki, 2001; Sternberg & Lubart, 1999). Disparities between these categories are often attributed to discrete circuits by which the information was processed (Dietrich, 2004).

One theory for the categorization of different types of creativity is a two by two matrix consisting of the variable's processing mode and knowledge domain (Dietrich, 2004). According to this theory, creativity arises through one of two processing modes, spontaneous or deliberate. This is the distinction between a sudden "flash" of brilliance and carefully calculated and goal-driven behavior. Creative thoughts that are processed through the spontaneous mode are often the product of defocused attention and thus involve a different type of DLPFC function. The insights that are represented in working memory here are not chosen by selected attention. For this reason, these thoughts tend to be more disorganized, random, and abnormal. Information processed in a deliberate mode is exactly the opposite. These insights are chosen for representation in working memory by deliberate searches based on previously chosen goals. Because these insights come from circuits that have already been highly processed by the prefrontal cortex, these are much more rational and structured thoughts. These thoughts are much more likely to stand in accordance with personal values and beliefs as well as cultural and societal norms.

The second variable used in Dietrich's (2004) model for the categorization of creative behavior is knowledge domain. The distinction between the two types of knowledge, emotional or cognitive, is made based on the previously mentioned informational pathways by which the knowledge reached the prefrontal cortex.

The proposed theory separates creative thoughts into four categories based on all possible combinations of processing mode and knowledge domain. The first of these categories is the deliberate-cognitive structure. Insights of this type result from a deliberate search by selected attention and include mostly sensory information from the TOP. These insights rely on a level of expertise in the relevant area because the more information that is made available in the TOP, the more information will be incorporated into working memory while the creative process occurs. Novelty resulting from this category of creative information processing is often very systematic and scientific. An example of this in music could be using computer programming to create a digital recreation or modification of a natural audio process.

The Talk Box, a device made famous by acts like Peter Frampton and Bon Jovi, is a good example of deliberate-cognitive structures at work. With the goal of having a musician speak with the frequency of a note played on a keyboard, the inventor incorporated knowledge of linguistics, music, and the physics of sound to produce a novel and appropriate device.

The second of these categories is deliberate-emotional. Insights in this category are retrieved from affective memory, and the information that is received has been processed by the limbic structures. Because this information contains highly processed social and emotional information, the resulting creative actions are often insights into specific emotional or social experiences. A good example of the results from this circuit in the arts would be the paintings of an impressionist artist like Monet or Van Gogh. Van Gogh especially used unorthodox techniques of blending and heaping paint onto a canvas to part with realism in order to capture the emotional essence of a particular scene. This type of abstract, yet deliberate approach to conveying emotion is common to all form of artistic expression.

The third of these proposed categories is spontaneous-cognitive. This type of insight comes from information that is first processed in the TOP, and is unintentionally represented in working memory. There is evidence that this sort of thinking makes use of the basal ganglia as well, due to its involvement in both implicit learning and automatic behavioral responses. Moments of true spontaneous cognitive creativity are best represented as "eureka moments," or the cliché of a light bulb turning on. Although this is not a dependable way to accomplish the goal of creative thought, the relaxed constraints of attention can help individuals gain a new perspective on the problems that they intend to solve. Examples of this behavior in the musical world happen constantly. In jazz music, musicians are constantly improvising based on a set of established rules that are modified by a certain level of freedom. While playing a solo, an instrumentalist will likely store the chord scales and level of consonance of each degree for use in the creation of melodies. A common practice in jazz, known as quoting, happens when a soloist plays the melody of another song so that it fits over the progression of the current song. This is a good example of spontaneous-cognitive creativity because the similarities between the current and quoted song often seem to pop into consciousness without warning. This can elicit an amusing surprise response amongst listeners and players alike.

The last category in this proposed theory is spontaneous-emotional creativity. These kinds of insights are often the result of a particularly emotional epiphany or religious experience. In music, this phenomenon is not common. In his book, *Musicophilia*, neuroscientist Oliver Sacks discusses several examples of a sudden undeniable urge to create music. One case is that of a man who survived a lightning strike inside a telephone booth. There were no lasting health problems, but he experienced an undeniable urge to compose and listen to piano music. The patient noted that he felt this music moving in a way that he hadn't previously. It is quite possible that the patient's experience caused a switching of his neurological circuits. Music in his new brain was most likely assigned a vastly increased emotional salience level in the amygdala before arrival in the prefrontal cortex. While this example may not have much external validity, it illustrates how shifts in neurological circuits can dramatically change the way we perceive and use incoming information.

Dietrich's proposed theory of processing mode by knowledge domain distinctions focuses mainly on the information processing pathways involved in a creative thought. Other theories derive distinctions in creativity based on the type of novelty that emerges as a result of the creative process (Cariani, 2008, 2009). One of the main distinctions in this theory is between combinatorial systems and emergent systems. In a combinatorial system, changes in the use of goals, rules, and available information allow for creative actions to take place. While no new states are created in this type of system, alternate combinations of existing information leads to creative production. This is the way that new types of genetic DNA sequences arise. There is a finite number of available nucleotides, but novel sequences can lead to observably unique combinations of genes (Cariani, 2008). One can see this in music in several ways. New songs within established genres are created by a mostly combinatorial process. No new instruments or sound parameters are varied, but the lyrics and melodies are novel combinations of established notes, progressions, and words.

The other category in this theory is emergent creativity. Contrary to combinatorial creativity, this process does involve the introduction of new primitives in the form of states, measurements, or even goals. These actions are unique because they create the need for a new dimension of observation in order to track the behavior over time (Cariani, 2009). Examples of this type of behavior are shown in instances of epistemic emergence. This process involves the creation of new ways for an organism to sense its external environment. It was through epistemic emergence that our bodies evolved to interact with the outside world in the way they currently do (Cariani, 2008). Short-term processes, however, are not unable to produce emergent creativity. In music especially, the technological advancements of the past few decades have allowed the emergence of songs that make use of parameters and effects that stretch far beyond the realm of notes and rhythms. Synthesizers have the ability to build sound from the ground up and, therefore, they can be used to vary frequency filters, spectral effects, direct interactive relationships between video and sound. Emergent creativity represents the true paradigm shift in the universe.

The history of the study of creativity has been long and varied. Knowledge on the topic has expanded greatly since public consensus accepted a mystical or spiritual approach to novel behavior. While proponents of these approaches still exist (Pfenninger et al, 2001), the more modern approach outlined in this paper provides a much better understanding of the creative process and, therefore, more opportunity for consciously controlling and improving creative behavior. Like a new computer or phone, the brain is an instrument whose output can be maximized by a more complete understanding of the process by which it works.

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