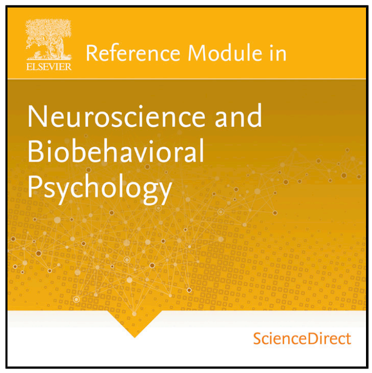

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Research Development of Creativity☆

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Glossary

Creativity A process in which one generates a contextually and culturally original and valuable product within a certain domain.

Confluence-theories approach An approach assumes that multiple components must converge for creativity to occur.

Cognitive creation approach An approach that emphasizes creative capacity as an essential property of normative human cognition and suggests that the relevant processes are open for investigation.

Cognitive neuroscience approach An approach that involves relating cognitive functions to their underlying basis in the brain.

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Insight problem An open problem that has a closed solution; it typically requires the mental restructuring of problem information, which leads to a clear and immediate understanding of how to solve the problem.

Working memory An executive and attentional aspect of short-term memory involved in the integration, processing, and retrieval of information.

What Is Creativity?

Definition of Creativity

Creativity is a process in which one generates a contextually and culturally original and valuable product within a certain domain; moreover, a creative product or outcome is the result of the interaction of personal characteristics and the environment (Yeh, 2004). Since J. P. Guilford's speech advocating the systematic study of creativity in 1950, numerous definitions of creativity have been proposed over the past six decades and creativity has been studied in a great variety of disciplines. Definitions of "creativity" have evolved from the unidimensional to the multidimensional plane and from factors related to personal characteristics to those concerning social milieus since 1950s (Yeh, 2006). In a review article, Hennessey and Amabile (2010) suggested that creativity is associated with the development of a novel product, idea, or problem solution that is valuable to the individual and/or the larger social group. Accordingly, creativity is an important ability for remaining flexible in coping with the problems and changes in our personal life as well as for enhancing the well-being of our societies.

Elements of Creativity

Creativity is comprised of certain basic elements that are nurtured through the accumulation of various life experiences. The nature of these experiences may very well be affected by personal characteristics, family environment, schooling, and even one's social milieu. Among these influential factors, personal characteristics have the most direct and greatest influence on creative performance (Yeh, 2004). Such characteristics can be divided into categories of knowledge, disposition (attitudes, tendencies and motivation), and skills. A sound knowledge base is essential to the development of creativity, and the ability to build new structures is at the core of knowledge-building. Creative thinkers require both the knowledge of a particular domain and that of cross-domains. As for their disposition, creative individuals are usually curious, willing to share ideas, brave enough to express themselves, and highly motivated to learn and achieve self-improvement; they also attempt to solve different problems and have a persistent urge to keep on trying. Finally, the skills required for creative performance include both cognitive and metacognitive skills. Creativity is the ability to transform materials into new and original forms; it is also regarded as a metacognitive process in which such metacognitive abilities as planning, monitoring, and evaluating cognitive operations are required (Yeh, 2004).

Types of Creativity

Creativity can be divided into four categories: mini c, little c, pro c, and big c. To date, most investigations of creativity have focused on big c and little c. The creativity types mini c and pro c were recently proposed. Big-c creativity consists of eminent creative contributions. The goals in studying eminent creativity are to learn about creative genius and to discuss what creative works may last forever. Typical creators who might be studied are eminent classical composers whose works have lasted for centuries, the winners of prestigious awards, or great inventors whose inventions have had a great impact on human civilization. Examples of those who are classified as big-c are Mozart, Einstein, and Darwin (Kaufman and Beghetto, 2009).

The study of little c is based on the assumption that creativity is part of human nature and can be found in average people's everyday lives (Kaufman and Beghetto, 2009). For example, a person may creatively paint his/her room to look like a blue sky. Such everyday creativity is called little c. Most studies that focus on students or children examine this type of creativity. The little-c category is important for identifying and nurturing creativity at home and in schools, the workplace, and social settings.

Mini-c creativity refers to novel intrapersonal insights about and interpretations of personal experiences or actions; it highlights the personal and developmental aspects of creativity (Kaufman and Beghetto, 2009). For example, a 4-year-old boy told his mother that he wants to have a "rocket bicycle" because it could take him to any place that he wanted to visit immediately. The little boy had a mini-c insight about combining two things he loves: rocket and bicycle. The mini-c helps to explain young children's creativity; it is useful for distinguishing between the genesis of creative expression (mini-c) and the recognizable expressions of creativity (little-c).

Pro-c represents a level of developmental progression and effort that extends beyond that of little-c but does not reach that of big c yet. People who attain professional-level expertise in any creative area are likely to have pro-c (Kaufman and Beghetto, 2009). For example, an individual of this nature might be a professional composer who makes a living composing songs for famous singers. However, not all working professionals in creative fields can reach the pro-c level. Prominent creators may require 10 years of preparation in a domain to become world-class experts.

Evaluation Indices of Creativity

The great majority of creativity studies have been based on divergent thinking tests, which are open-ended and designed to assess the ability to generate novel alternative solutions. Performance on these tests is usually scored based on three indices: fluency, cognitive flexibility, and originality. Fluency refers to the number of unique ideas or problem solutions that are generated, while flexibility refers to the number of categories that a person accesses; it reflects the capacity to switch approaches, goals, and sets. Finally, originality refers to the uniqueness of an idea; it reflects the ability to approach a problem in a novel way (Baas et al., 2008). Because fluency and flexibility are contagious and because of the development of creative theories, the recent consensus is that the evaluation of creativity must include originality (or novelty) and valuation (usefulness or appropriateness) (Mayer, 1999; Yeh et al., 2011).

Is Creativity Domain-General or Domain-Specific?

The debate over whether creativity is domain-specific or domain-general includes three important perspectives. The first perspective is that creativity is a domain-general trait; that is, creative individuals can be creative in many domains. Studies based on the psychometric approach usually assume this perspective (Silvia et al., 2009). The second perspective is that creativity is domain-specific; that is, people who are creative in one area are not necessarily creative in other areas. Studies based on socio-cultural and problem-solving theories support this domain-specific perspective; when tasks reflect the domain of expertise, expertise plays an important role in creative problem-solving (Silvia et al., 2009). The third perspective is that creativity has both specific and general components (Plucker and Beghetto, 2004). Such a hybrid model suggests that the level of specificity may change with the social context and with development through childhood into adulthood, and while some general factors may influence creative performance in all areas, only several domain-specific factors will influence creative performance in specific activities.

Development of Research Approaches and Models of Creativity

Approaches for Creativity Research

The study of creativity can be traced back to Plato, who argued that a poet is able to create only when the Muse dictates; however, more scientific and systematic studies of creativity started after the psychometric approach was proposed in 1950. The development of creativity research included seven approaches (Sternberg and Lubart, 1999): (1) The mystical approach regards a creative individual as an empty vessel that a divine being can fill with inspiration. The individual will then pour out the ideas with which he has been inspired and form a creative product. (2) The pragmatic approach primarily concerns the development of creativity, and most studies are not concerned with testing the validity of creative ideas. (3) The psychoanalytic approach hypothesizes that creativity is derived from the tension between conscious reality and unconscious drives. Case studies of eminent creative persons are examples. (4) The psychometric approach claims that creativity can be studied in everyday subjects using paper-and-pencil tasks. Such tasks usually measure creativity based on fluency, flexibility, and originality. (5) The cognitive approach seeks to understand the mental representations and processes underlying creative thought. (6) The social-personality approach focuses on personality variables, motivational variables, and social culture environment. Through correlational studies and contrasts between high- and low-creativity people, many potential traits have been identified. (7) The confluence-theories approach assumes that multiple components must converge for creativity to occur. Most recent studies are based on this assumption. Based on the recent research trend, I add the eighth approach—the cognitive neuroscience approach; this approach involves relating cognitive functions to their underlying basis in the brain. Through neuroscience instruments, brain activity during the process of creation can be specified.

While the first two approaches seem to damage the scientific study of creativity, the psychoanalytic approach can be regarded as the first major theoretical approach to studying creativity in the 20th century. Moreover, the cognitive approach and social-personality approach were developed at about the same time (Sternberg and Lubart, 1999). Recently, the cognitive neuroscience approach has started to be employed in studies concerning the creative process.

Confluence Theories of Creativity

Most studies have defined creativity from the perspective of one of the "4Ps": personality, process, place/press, and product. More recent studies, however, have interpreted creativity from a more holistic, dynamic, and multidimensional perspective due to the flourishing of the following confluence theories (Yeh and Wu, 2006).

Componential Model of Creativity

This model suggests that three components are essential for the production of original responses or works. These three components are domain-relevant skills, creativity-relevant procedures, and task motivation. Domain-relevant skills include technical skills, factual knowledge, and special talents in a given domain. Creativity-relevant procedures are composed of cognitive styles, work styles, and the application of heuristics to exploring new pathways. Task motivation is comprised of motivational variables that determine an individual's approach to a given task. The level of creativity varies as a function of the strength of each of the three components (Amabile, 1996).

Evolving System Model of Creativity

The characteristics of this model are three-fold: (1) the creative person is unique; (2) developmental change is multidimensional; and (3) the creative person is an evolving system. Creative people do not follow some well-charted path; they are unique in unexpected ways. The notion of an evolving system emphasizes that development is multi-causal and that reciprocally interactive relationships exist both among the internal elements of the system and between creative individuals and their external milieu. Additionally, the evolution of creative ideas is influenced by personal expertise, motivation, emotions, and environment. Moreover, creative individuals seek not just answers but also new questions (Gruber and Wallace, 1999).

Systems Model of Creativity

This model suggests that creativity is a process that can be observed only at the intersection of individuals, domain, and field. In this model, individuals draw on information in a particular domain and transform or extend it through their cognitive processes, motivation, or unique life experiences. The field, consisting of people who influence a particular domain, evaluates and selects new ideas. The domain, a culturally defined symbol system, preserves creative products and transmits them to other individuals and future generations. This model also emphasizes that individuals undertake creation within a particular domain and that, therefore, domain knowledge is required (Csikszentmihalyi, 1999).

Interactive Perspective of Creativity

This model emphasizes the creative results of the interaction of three core elements: the individual, other persons, and the work. The individual can be a child or a master. As for other persons, when the individual is a child, the influential other persons are family and peers, whereas when the individual is a mature adult, they are rivals, judges and supporters in the field. The work refers to relevant symbol systems in the domain or discipline. The model also suggests that three factors (symbol systems, mental skills, and ways of communicating in different domains) vary dramatically from one another (Gardner, 1993).

Investment Theory of Creativity

This theory suggests that creative people are willing and able to buy low and sell high in the realm of ideas. Buying low refers to pursuing ideas that are unknown and/or out of favor but that have growth potential. These ideas are often intensely resisted by others when they are first introduced to them. Creative people persist nevertheless and eventually sell high. This theory suggests the confluence of six distinct but interrelated resources that are required for creativity: intellectual ability, knowledge, a particular style of thinking, personality, motivation, and environment (Sternberg and Lubert, 1996).

Ecological Systems Model of Creativity Development

The *Ecological Systems Model of Creativity Development* suggests that four systems—the microsystem, mesosystem, exosystem and macrosystem—have a far-reaching impact on an individual's development of creativity (Yeh, 2004). The microsystem specifies inherent and learned personal characteristics: mainly knowledge, dispositions, and skills. These personal characteristics are the most fundamental to the generation of a creative product, and they directly affect the four stages of the creative process, namely, preparation, incubation, insight, and evaluation. Based on information processing theory, the main tasks in each of stages are defined as illustrated in Fig. 1. Notably, the four stages are interactive and can be a cycled process before a creative product is

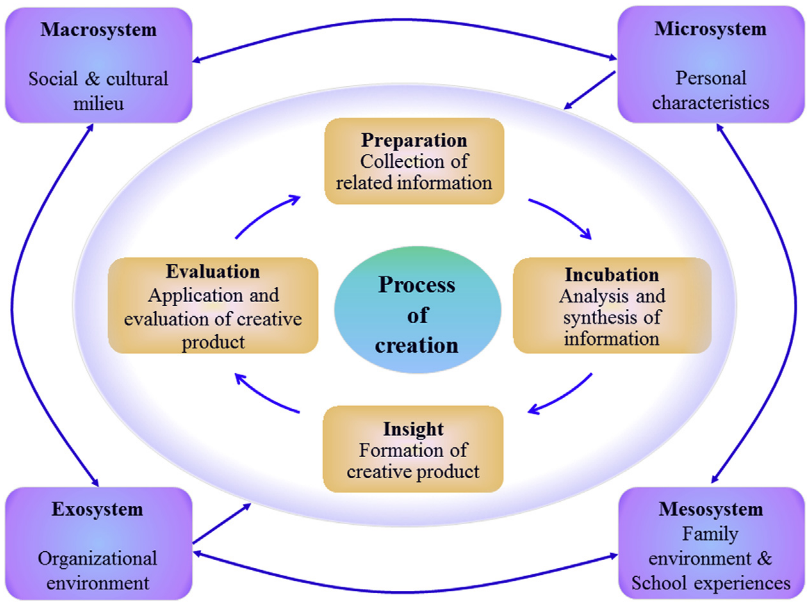

Figure 1 Ecological systems model of creativity development.

successfully produced. The mesosystem, meanwhile, consists of family and school experiences. These two subsystems interact with each other and greatly influence the creative potential of a person throughout his or her childhood and even into his or her teens. However, as the creative person grows up, these influences may become more indirect and perhaps less influential. The exosystem is comprised of organizational factors that relate to an individual's work, including the people, events, and things within an organization. This system mainly interacts with the creative person and influences the creative process both directly and indirectly. Finally, the macrosystem refers to a social culture and milieu, including the values, laws and customs within a culture. This system has a substantial impact on the evaluation of a creative product. From a mature adult perspective, the four layers of the system interact with one another to shape one's creativity. However, only the microsystem and exosystem directly influence the current creative process (see Fig. 1).

Approaches for Studying Creative Processes

Creative Processes

Some confluence theories have identified specific stages of creative processes. For example, the componential model of creativity indicates five stages of creativity (Amabile, 1996): (1) problem or task identification, in which task motivation determines whether the search for a solution will begin or continue; (2) preparation, in which domain-relevant skills determine which pathways will be available during the search for a response; (3) response generation, in which creativity-relevant procedures serve as an executive controller and influence how the search for a response will proceed; (4) response validation and communication, in which domain-relevant skills determine which criteria will be used to evaluate a response; and (5) the outcome, in which an appropriate decision is made; the result of the outcome will, in turn, influence task motivation and further determine whether the process will continue or end. Similarly, the *Ecological Systems Model of Creativity Development* (Yeh, 2004) identifies four stages of creativity: (1) preparation: collecting related information and organizing it into schematic patterns; (2) incubation: analyzing and synthesizing the information in the schema; (3) insight: finding connections between information in the schema and forming a creative product; and (4) evaluation: using the product and validating its originality and value. On the other hand, the creative cognition approach claims that five types processes commonly occur during creation: (1) the retrieval of existing structures from memory; (2) the formation of simple associations among the structures or combinations thereof; (3) the mental synthesis of new structures; (4) the mental transformation of existing structures into forms; and (5) the analogical transfer of information from one domain to another (Ward et al., 1999).

Accordingly, creative processes are largely comprised of the retrieval, integration, and retention of knowledge, the close connections between cues and the activation of knowledge, the crucial role of motivation, and the contribution of incubation to insight. Exploring how these factors or components may actually interact in the process of creation, undoubtedly, is central to any understanding of creativity. Before 1990s, most studies based on one of the 4Ps or the confluence theories have employed a psychometric approach; how a creative solution is produced remands a mystery. The more recently developed approach of creative cognition and cognitive neuroscience provide a new window into this mystery.

Creative Cognition Approach

What Is Creative Cognition?

Cognitive creation emphasizes that creative capacity is an essential property of normative human cognition and that the relevant processes are open for investigation. It also emphasizes that creative ideas and products emerge via the application of ordinary, fundamental cognitive processes to existing knowledge structures (Ward et al., 1999).

Creative cognition seeks to move beyond traditional psychometric approaches to an understanding of creative thoughts. It has three goals (Ward, 2007); The first goal is to advance the scientific understanding of creativity by adapting the concept, theories, methods, and frameworks of mainstream cognitive psychology to the study of fundamental cognitive operations that produce creative thoughts. The second goal is to extend the scientific understanding of cognition by conducting experimental observations of the cognitive processes that operate when people are engaged in creative tasks. Finally, the third goal is to specify the factors and processes that determine how existing knowledge will be applied to new situations and the precise way in which such information can either facilitate or inhibit creative functioning. Some studies that involve understanding the cognitive process of creativity have undertaken the creative cognition approach.

Creative Cognition Approach

The major concern of the cognitive approach to creativity is how differences at the level of information-processing operations can influence creative performance. Early models within the creative cognitive domain suggest that the ability to be creative is influenced by the manner in which semantic networks are organized. Specifically, less creative people have steep associative hierarchies in semantic networks, such that a stimulus activates many closely associated or stereotypical representations and therefore generates few unique representations. Highly creative people, in contrast, have flat associative hierarchies, such that they have comparable access to both closely and remotely associated concepts and therefore generate more unique representations (Abraham and Windmann, 2007).

In the 1990s, a creative cognition approach called the Geneplore model was proposed that has been employed to studies of insight, the extension of concepts, recently activated knowledge, conceptual combinations, and creative imagery. This model seeks to distinguish the differences between the cognitive processes that are used in creative cognition and the types of mental structures through which they operate. The central idea of this model is that many creative activities can be described as the initial generation of candidate ideas or solutions followed by the extensive exploration of those ideas. The initial ideas are sometimes pre-inventive in the sense that they are not complete plans for a product or tested solutions. Usually, one would alternate between generative and exploratory processes and refine the structures according to the demands or constraints of a particular task (Ward et al., 1999).

Cognitive Neuroscience Approach

The Goal of Cognitive Neuroscience

Despite six decades of experimental investigation, there are still many open questions concerning the essential nature of creativity. For example, what operations are involved in creative thinking? How is creativity brought about by and implemented in the brain? Such questions concerning creative processes are central to the cognitive neuroscience of creativity. Cognitive neuroscience involves relating cognitive functions to their underlying basis in the brain; it helps us to find the link between creative activities and their corresponding brain dimensions (Abraham and Windmann, 2007).

Cognitive Neuroscience and Creativity Research

Recently, neuroscience instruments such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), electroencephalography (EEG), magnetoencephalography (MEG), and event-related potential (ERP) have been employed in studies of creativity. Although studies of creativity conducted through these instruments are developing rapidly, especially in the recent decade, there is a long way to go before scientists interested in the neurological basis of creative behavior can reach a consensus of how creativity is produced (Hennessey and Amabile, 2010).

Early studies of cognitive neuroscience found the abilities required for creativity, such as working memory, sustained attention, and cognitive flexibility, are typically ascribed to the prefrontal cortex. Moreover, stored knowledge and novel combinations of that knowledge are implemented in two distinct neural structures—the TOP (the temporal, occipital, and parietal regions) and the prefrontal cortex. Such findings contribute to our understanding of the difference between creative and noncreative thinking (Dietrich, 2004; Fink et al., 2007).

However, a simple search for the brain regions involved in creativity would be fruitless. The involvement of the prefrontal cortex is presumably restricted to domain-general creative processes; when it comes to domain-specific aspects, other cerebral areas are more likely to be at work. It is also suggested that the creative insights that are produced after concerted deliberation and those that are generated spontaneously activate different regions of the brain (Dietrich, 2004). Therefore, when employing a comprehensive neuropsychological approach, it is essential to break down the underlying cognitive processes involved in creativity tasks and investigate the involvement of different regions of the brain in each of these processes (Kowatari et al., 2009). Moreover, as researchers proceed down this groundbreaking investigative path, they must make sure that it is sound theorizing and data that drive their use of new technologies to unfold the human brain (Hennessey and Amabile, 2010).

Studies of Insights

What Are Insight and Insight Problem?

Creativity is generally conceived of as the generation of insights or problem solutions that are both novel and useful. An insight is often defined as a sudden change in or the formation of a concept, which leads to the solution of a problem. Moreover, insights often involves breaking an impasse or mental block produced because a solver initially fixated on a solution which is ultimately not associated with the problem. The breaking of an impasse is accompanied by the reinterpretation or restructuring of a problem to reveal a new solution or solution strategy (Kounios and Beeman, 2014). In essence, insights are sporadic and unpredictable exceptional thinking where unwarranted assumptions must be discarded before solutions to problems can be obtained (De Dreu et al., 2008).

Unlike divergent thinking tests, insight problems are commonly used when the cognitive approach is emphasized. An insight problem is characterized as an open problem with a closed solution; it typically requires a mental restructuring of problem information that leads to a clear and sudden understanding of how to solve the problem. The Duncker Candle task is a classic insight problem (De Dreu et al., 2008). Moreover, the process of insight problem-solving requires both convergent thinking and divergent thinking. It is convergent in the sense that it aims for a single correct solution. On the other hand, when the problem needs to be restructured by means of flexible thought, it requires divergent thinking (Abraham and Windmann, 2007).

Cognitive Neuroscience Approach of Studying Insight

The paradigm of studying insight has been extended outside the realm of traditional experimental design to incorporate cognitive neuroscience since the latter was developed. However, related studies have just begun to be developed. Creative insights can be the result of two processing modes, deliberate and spontaneous, each of which can guide neural computation in structures that contribute emotional content and provide cognitive analysis (Dietrich, 2004). The cognitive neuroscience approach is able to provide concrete evidence of such assumptions. According to Luo and Knoblich (2007), an ideal experimental paradigm for studying the neural correlates of insight with cognitive neuroscience instruments should have at least the following features: (1) Be able to elicit restructuring of problem. (2) Elicit multiple insight events within a limited time period. Routine event-related fMRI or ERP studies require 10–50 trials in each condition to guarantee reliable analysis. (3) Allow one to test various kinds of research hypotheses, including general hypotheses derived from theories as well as hypotheses about the precise function of particular brain areas. (4) Enable researchers to define suitable reference states (i.e., the baseline). Brain imaging analysis relies heavily on the contrast between a target state and a reference state. (5) Allow one to study internally and externally triggered insights.

To elicit creative insight in a short time period, solution hints can be used. Such a design allows one to obtain multiple insight events and their accurate onset times, which are required for fMRI and EEG, and to reliably record the activity associated with the restructuring component of insight. Moreover, to relate the dynamic development of insight to neural activity, implicit learning tasks can be employed; such tasks enable researchers to pursue the development of an insight on a trial-by-trial basis (Luo and Knoblich, 2007).

Studies of Emotions and Creativity

Emotional Valence and Creativity

Emotional valence includes positive emotions and negative emotions. Over the last 30 years, systematic studies have examined the relationships between emotions and creative cognition. Some experimental studies have found that a positive emotional state facilitates creativity, whereas others have found that a negative emotional state enhance creativity. The approaches to explaining the relationships between emotional states and creativity include the following: (De Dreu et al., 2008; Zenasni and Lubart, 2008).

Cognitive Justifications

This perspective argues that positive emotional states influence an individual's attention, which enhances the possibility of combining different elements, facilitates access to positive material in one's memory, promotes the spread of knowledge activation, and increases the possibility of making remote associations conducive to creative thought, therefore facilitating creative problem-solving (Baas et al., 2008; Zenasni and Lubart, 2008).

Broaden-and-Build Theory

This theory proclaims that positive emotions momentarily broaden people's attention and thinking, enabling them to draw on higher-level connections and a wider range of percepts or ideas, and thereby leads to creative thought. In turn, these broadened outlooks help people to discover and build consequential personal resources that contribute to the development of creative abilities (Fredrickson et al., 2008; Jones and Kelly, 2009).

Hedonic Contingency Theory

This theory assumes that happy individuals scrutinize the hedonic consequences of a particular action more carefully than do individuals in other moods and that they will choose actions that either maintain or improve their positive mood. Therefore, individuals in happy moods might be more creative because they are motivated to maintain or enhance their positive affective state (Hirt et al., 2008).

Cognitive Tuning Theory

This theory suggests that negative moods indicate that the current situation is problematic and motivate actions designed to alleviate or eliminate the problem; creative solutions to the problem are thereby produced. In contrast, positive moods signal that the current situation is satisfactory and that no further action is necessary; creative thoughts are thereby inhibited (Hirt et al., 2008).

The Interaction of Valence and Activation

The dual-pathway model suggests that mood states can be conceptualized in terms of two underlying dimensions—hedonic tone (positive vs. negative) and activation (activating vs. deactivating). More specifically, cognitive activation is a necessary precondition for creativity, and hedonic tone determines the route (the flexibility route or the perseverance route) through which creative fluency and originality are achieved. In other words, activating moods with a positive tone is linked to cognitive flexibility and thereby promotes creative performance, whereas activating moods with a negative tone is linked to perseverance and thereby enhances creativity (De Dreu et al., 2008)

Research findings also suggest that the pleasanter one's emotional state and the greater the level of arousal, the more original ideas are produced. On the other hand, the more negative the emotional state is and the greater the level of arousal, the less likely it is that ideas will be produced (Zenasni and Lubart, 2008). Moreover, the interaction between negative reactivity and level of arousal has an inhibitory effect; that is, when people react actively to negative stimuli, their creative ideas are inhibited because of increased arousal. Accordingly, levels of activation may interact with valence of emotion and carry different effects on creativity performances.

The Interaction of Valence, Activation, and Regulatory Focus

A three-dimension theory (De Dreu et al., 2008) has been proposed to explain the relationship between one's emotional state and creativity; the three dimensions are hedonic tone (positive vs. negative), the level of activation involved (activating vs. deactivating), and its association with regulatory focus (promotion vs. prevention). Mood states that are associated with a promotion focus (e.g., anger, sadness, and happiness) should expanded attentional scope and thereby facilitate creative performance, whereas mood states that are associated with a prevention focus (i.e., fear, relax, and calm) should produce a more constricted scope of attention and thereby impede creativity.

Based on this three-dimensional theory, a meta-analysis of mood–creativity research conducted over 25 years suggests that positive moods produce more creativity than do mood-neutral controls but that there are significant differences between negative moods and mood-neutral controls or between positive and negative moods (Baas et al., 2008). Moreover, creativity may be enhanced most by positive emotional states that are activating and with a promotion focus. In a recent study of game-based learning, Yeh et al. (2015) integrated the three dimensions of emotions and investigated the relationships between different types of emotion and creativity. They found that the positive-high activation-promotion emotion facilitated creativity performance, whereas the negative-high activation-promotion emotion decreased creativity performance. Therefore, providing appropriate challenges to induce highly-activated and promotion-focused positive emotions are critical for the success of creativity learning.

Studies of Working Memory and Creativity

Theories of Working Memory

Multi-component Model of Working Memory

This model assumes that human thought processes are underpinned by an integrated system for temporarily storing and manipulating information. Four subcomponents are included in this model. The first is the central executive, responsible for directing attention to relevant information, suppressing irrelevant information and inappropriate actions, and coordinating the two slave systems: the phonological loop and the visuospatial sketchpad. The second is the phonological loop, which is comprised of a phonological store and an articulatory rehearsal process. The third is the visuospatial sketchpad, which manipulates visual images and spatial information. The fourth is the episodic buffer, which is a limited-capacity store that binds together information to form integrated episodes (Baddeley, 2003).

Embedded-Process Model

This model claims that the human memory system operates by way of rich interaction between attentional and memory mechanisms. Working memory is organized into two embedded levels. The first level is comprised of activated long-term memory (LTM) representations. The second level is the focus of attention. Attentional resources are used to stimulate information from LTM to meet current goals. Moreover, activated units can arise from sensory input as well as semantic and episodic information from LTM. Though one may or may not be consciously aware of these representations, they are readily accessible for use if necessary. A portion of these representations can be further promoted to a highly active state that comprises the focus of attention (Cowan, 1999).

Working memory is the executive and attentional aspect of short-term memory which involves in the integrating, processing, retrieval of information, maintenance, and manipulation of task-relevant information in mind for brief periods of time to guide subsequent behavior (Autin and Croizet, 2014; Gazzaley and Nobre, 2012). To date, most studies focused on working memory have employed the multicomponent model of working memory; in contrast, only a few studies have adopted the embedded process model.

Working Memory and Creativity

The multi-component model of working memory (Baddeley, 2003) suggests that a working memory buffer is critical for creative thinking. The dual pathway model (De Dreu et al., 2008) also claims that activating rather than deactivating moods increase working memory capacity, thereby facilitating cognitive flexibility. It is also suggested that positive emotions may serve as a retrieval cue for positive material in memory, which leads to multiple interpretations and ways of organizing material in memory and therefore contributes to creative thinking (Hirt et al., 2008).

Moreover, the cognitive network model of creativity (Santanen et al., 1999) indicates that a creative solution is a function of the degree to which frames that were previously distant from one another become saliently associated with one another through problem-solving. The frame is the basic unit of knowledge that is stored in memory. When the frames occupy short-term memory, they are salient; when two or more frames are simultaneously salient, they are associated. The association of remote frames is influenced by cognitive load and the sophistication of problem frames. When people use many salient frames simultaneously or use fragmentary frames to represent a problem, cognitive load may be high, and this may therefore decrease the probability of combining remote frames and thus generate less creative solutions. However, when people chunk the problem into a sophisticated frame, cognitive load may be reduced and lead to more efficient short-term memory processing, which will ultimately lead to more creative solutions.

Cognitive Neuroscience, Working Memory, and Creativity

In recent years, many studies based on theories of working memory have been conducted to connect working memory and brain structure. For example, studies based on lesion location in patients and neuroimaging in normal subjects indicate that the basic components of working memory are localized in different brain regions. The phonological loop clearly involves the left temporoparietal region; visuospatial working memory is primarily localized in the right inferior parietal cortex, right premotor cortex, and right inferior frontal cortex (as cited in Dietrich, 2004). The nature of working memory is a topic that is difficult to tackle using purely behavioral methods, but neuroimaging studies are beginning to shed light on this complex process (Dietrich, 2004). Moreover, neuroimaging studies have also suggested that verbal working memory and spatial working memory components are represented by different cortical networks. For example, Rothmayr et al. (2007) found that verbal rehearsal involved left language-associated temporal and parietal areas, whereas non-verbal rehearsal involved right dorsolateral prefrontal and medial prefrontal areas. Habeck et al. (2012) found that the neural substrates of verbal versus non-verbal rehearsal processes involved material-specific neural substrates. Using eye-tracking techniques, Yeh et al. (2014) found that attention, eye movements, and working memory capacity interactively influenced insight problem solving, and the influence patterns varied with working memory capacity and insight stages. They suggested that individuals with better working memory capacities may employ top-down processes and deliberately direct attention to pertinent information for solving insight problems, whereas individuals with poorer working memory capacities may be less capable of directing pertinent information and therefore employ bottom-up processes that take more time for solving insight problems. Yeh et al. also identified three stages for insight problem solving based on indices of eye movements (see Fig. 2). In addition, integrating neuroscience techniques, Yeh et al. (2015) found that increased cortisol concentration enhanced working memory and, further, facilitated creativity performance, suggesting stress measured by cortisol concentration enhances attention which is critical to the function of working memory related to the resolved tasks. According, combining different cognitive neuroscience instruments can help unveil the mechanisms of how working memory influences insight problem solving or creativity.

Conclusion

Creativity is commonly defined in terms of originality and valuation. Although there has been a long debate over whether creativity is domain-specific, most recent theories and research findings suggest that creativity is a domain-specific trait. However, compared to the domain-general realm, the domain-specific aspect of creativity is less well understood. If we are to develop a better grasp of domain-specific creativity, more studies are required that consider a single domain in depth and focus on examining the key components of creative processes and people who differ across domains.

Creativity may be affected by personal characteristics, family environment, formal education, and even one's social milieu; personal characteristics, however, play the essential role during the creative process. Cognitive tests, such as those of divergent thinking, remote association and word association, have been commonly used to examine the relationship between creativity and its influential factors as well as to validate major theories of creativity. Only a few standardized domain-specific tests and insight tasks have been developed, and few studies have been conducted to test the complete confluence theories of creativity. Accordingly,

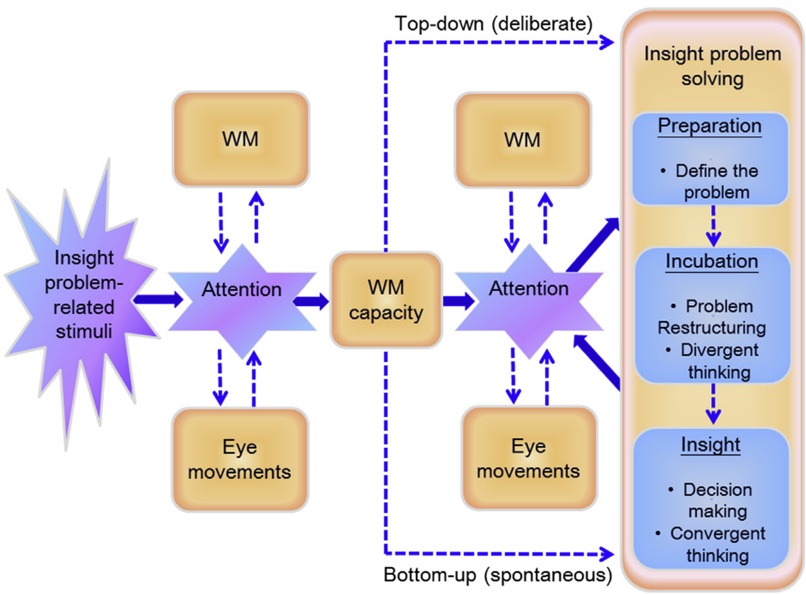

Figure 2 A model of how working memory capacity influences insight problem solving and stages of insight problem.

more domain-specific creativity tests (especially those other than divergent thinking tests) and path models of the confluence theories based on empirical data need to be developed.

Among the many variables that have been shown to predict creativity, emotion stands out as one of the most widely studied predictors. Studies that focus on the relationship between emotions and creativity have gradually evolved from one dimension (valence) to two dimensions (valence × activation) and, recently, to three dimensions (valence × activation × regulatory focus). More empirical studies that focus on interactions among varied dimensions of emotions are required to establish the interaction theory of emotion and creativity. Moreover, it has been suggested that highly positive emotions are closely related to the efficiency of working memory and working memory is critical if creative thoughts are to emerge. Employing cognitive neuroscience approaches to examine the neural mechanisms underlying the interrelationship among emotional states, working memory, attention, and creativity would shed light on the cognitive processes of creativity.

Due to the development of cognitive neuroscience, the paradigm of studying insight has recently been extended outside the realm of traditional experimental design to incorporate cognitive neuroscience. However, related studies are still scarce. Further studies of insight that employ cognitive neuroscience instruments should take into account the aforementioned ideal experimental paradigm in order to broaden our understanding of how insights are produced.

In conclusion, the development of the research paradigm of creativity is basically in line with that of psychological studies. The cognitive approach, creative cognition approach, and cognitive neuroscience approach have focused on uncovering the mystery of the creative process and related factors. Studies that employ the cognitive approach have defined many mental operations involved in creative thinking: for example, attention, working memory, and emotions. The way forward would be to assume a process-based approach, such as that of creative cognition, to define a process that reflects one aspect of creative thinking in a specific domain; then, one might use cognitive neuroscience methods to assess the features of this process in terms of cognitive and neural functions. Such studies should contribute to unraveling the fascinating complexity that is central to creativity.

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Footnote

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