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The Influence of Perception and Attention on Creativity

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Abstract

Creativity is primarily a cognitive process, yet to date, no comprehensive review of the influence on creativity of basic cognitive processes, like perception and attention, has been done. The purpose of this article was to investigate how these mechanisms affect novelty recognition and generation to apply this knowledge in understanding and fostering creativity. A sample of empirical research in the last ten years, relating perceptual and attentional processes to novelty, was chosen for its relevance. Three main points can be drawn from the present review: First, a possible underlying mechanism affecting association learning and creativity, habit-learning, is suggested. Second, effortless attention, a kind of attention dissimilar to focus or unfocused attention, should be considered in future research in creativity. Finally, production of novel ideas could be achieved by two different ways: logical association (activation and combination of ideas) or automatic emergence (combination of parts resulting in new properties that cannot be deduced from the parts)

Keywords: perception, attention, creativity, association, emergence, habit-learning, effortless attention

The Influence of Perception and Attention on Creativity

"The very essence of the creative is its novelty, and hence we have no standard by which to judge it." (Rogers, 1961)

Creativity has been defined as the capacity to generate novel and useful ideas (Horan, 2009). The benefits of creativity have been shown in the progress of society, health, innovation and business, learning and development and is now discussed in almost every field and human domain (Yoruk & Runco, 2014). However, except from the early experimental work undertaken by Gestalt psychologists like Wertheimer in 1945, creativity research was seriously neglected by psychology (Guilford, 1950). Joy Paul Guilford in his farewell speech as president of the American Psychological Association in 1950, is said to have begun creativity research in psychology. He proposed to study creativity via *divergent thinking.* A divergent thinking (DT) task is defined as a task where the goal is to generate multiple solutions to an open problem. The dependent variables in these tasks are ideational fluency, flexibility and novelty (Dietrich & Kanso, 2010). DT tests are reliable and have a good predictive validity (Yoruk & Runco, 2014). DT is not synonymous with creative thinking but it is useful because it tells us about the cognitive processes that can result in novel ideas and solutions (Runco, 2008). *Insight* is another concept used to measure creativity. It can be explained as a process of mental restructuring where new schemes of thought emerge (Ohlsson, 1984). Insight problem solving can be conceived like the unconscious association process that allows the "aha!" moment of a new discovery (Gupta, Jang, Mednick & Huber, 2012; Runco, 2014). Computational theory explain insight as a network where nodes and links change as result of remote connections and unexpected links of representations and concepts (Schilling, 2005). Insight is different to divergent thinking, insight leads to just one novel solution. It could be related to an experiential, perceptual or unconscious way of associating information (Epstein, 1998).

In the last two decades, research in the performance and enhancement of creativity in organizational settings have grown as consequence of being recognized a core competence for personal and organizational performance (Treben, Mulej & Zumi, 2005). Also, research in educational strategies (Peter-Szarka, 2012), experimental learning (Apiola, Lattu & Pasanen, 2012), design-based learning (Rodriguez- Bencosme,2014) and technology (Candy & Edmonds, 2000) has shown the interest and importance of creativity in these fields. The different domains where studies are performed influence the factors that hinder or foster creativity. However, novelty recognition and production, even if not sufficient, will be necessary in all types or creative domains. Novelty recognition is crucial for adaptation and innovation in non-human animals (Kaufman, Butt, Kaufman & Colbert-White, 2011) . Also, is implicit in creativity models like the Four C model (Kaufman & Beghetto, 2009) that includes the idea of Mini-c: creativity inherent in the learning process. Therefore, the present article will focus on creativity as production and recognition of original ideas.

The relationship that this article seeks to establish between basic cognitive mechanisms, such as perception and attention with creativity, will be explored through the review of research that focus on perceptual, attentional and cognitive styles. The aim is to find common underlying mechanisms explaining the diverse constructs that have been associated in the literature with creativity.

This article has three goals: First, to provide understanding of basic cognitive processes that relate to creativity in any domain or developmental stage. Second, to review empirical studies on perception and attention related to construction of novel ideas. Third, to interpret critically these studies to find meaningful relationships to offer to the artistic and scientific community a more clear knowledge about creativity sources and how to facilitate the creative process.

Background

Componential Theories of Creativity

Research in creativity has led to many theories attempting to explain the nature and components of the creative process. Componential theories of creativity see creativity as a process where extrinsic and intrinsic factors interact to influence the final product. The componential theory of individual (or small team) creativity (Amabile, 1997; Conti, Coon & Amabile, 1996) propose three components of creative performance: (1) domain relevant knowledge and skills, (2) creativity relevant processes, and (3) task motivation. The theory suggests creativity will be higher the higher the level of each component (Bjorkman, 2004). Other componential models (Sternberg & Lubart, 1997; Woodman, Sawyer & Griffin, 1993; Mumford et al., 1993) also posit personal, cognitive and environmental interactions intervening in the creative process.

Cognitive Theories and Creativity

The study of cognitive processes leading to creativity has the aim of increasing understanding of creativity using concepts and methods from cognitive science (Finke, 1996). It assumes that creativity occurs with the same components as other cognitive processes such as learning or thinking processes.

Finke (1992) unfold the roots of the creative cognition approach: (1) Associationism (Thorndike, 1911; Watson 1958), conceives creativity as a generalization of learned behaviors, (2) Gestalt psychology (Dunker, 1945; Maier, 1940; Wertheimer, 1954), in contrast to associationism, acknowledges the creative process as something special and specific, (3) Computational approaches, emphasizes defined operations that may lead to the same creative ideas (Colton, Badia, & Stock, 2009).

Research on creative cognition study associative processes and focus on how ideas are generated and strung together. Mednick (1962), defined creative thinking as the combination of different associations and found that original ideas tend to be remote. Common and typical ideas are produced earlier in the creative process with original ideas being produced later. Associations of not related or remote concepts like tree-whale, can lead to uncommon or original ideas. Eysenck (1995) suggested that creativity increases when normal mechanisms that limit the formation of associations are disrupted.

Studies in creative cognition have investigated diverse areas like dreams as a natural mechanism to generate novelty (Mandler, 1995), memory and problem solving theory to explain creative thinking (Smith, 1995) and concept formation and representation as constraints to creative idea´s generation (Ward, 2009).

Stage models of creative cognition suggest the creative process involves several stages.Wallas ´model (1926) proposes the following stages: (1) "Preparation", (2) "Incubation", (3) "Illumination" and (4) "Verification". The illumination stage in Wallas´ model is also known as insight. Extensive research on creativity has focus in the last three stages. The incubation stage involves unconscious processing of information allowing associations to form (Wallas, 1926). However, unconscious cognitive processes, like perception and attention, can be found in all stages of the thinking process, hence, the creative process (Finke, 1992; Bailey et al., 2007).

In summary, cognitive theories of creativity explain the creative process as a thinking process, with senso-perception, attention, memory and imagination processes involved. However, the basic cognitive processes have been marginally studied in relationship with creativity, possibly because they are seen as automatic and uncontrollable.

Basic Cognitive Processes: Perception and Attention

The associative view of creativity assumes that active unconscious processes are involved in creativity (Ritter & Dijksterhuis, 2014). However, unconscious processes related to creativity like perception and attention have been confined to research in sleep, incubation as distraction and mind-wandering. Basic cognitive processes are present in all stages of the thinking and creative process, not just in the incubation period (Finke, 1992; Bailey et al., 2007). Moreover, the incubation period might need a state of mind "allowing" unconscious perceptual and attentional processes to work and not just a resting or forgetting state. For example, contrary to other findings were incubation is related to enhanced creativity, Ritter, van Baaren and Dijksterhuis (2012) found the control group (no incubation time) performed equally good that the experimental group (with a period of incubation) in a divergent thinking task. This suggest the incubation period might be necessary but not sufficient and may require perceiving and attending information in a certain way, challenging the customized cognitive *schemas.* Schemas are a theoretical construct developed by

Frederic Bartlett (1932). They are knowledge structures that organize information stored in long-term memory, are quickly accessible, and are more or less flexible in their use and application. Schemas guide us in what to perceive and attend in the world. They serve as a basis for searching memory and reconstructing it (Neuschatz, Lampinen, Preston, Hawkins & Toglia, 2002; Barclay & Subramaniam, 1987). Several theorists have developed the schema construct in greater detail. Schank and Abelson (1977) developed the script construct, Rumelhart (1980) the story grammars, and Minsky (1975) the concept of frames. However, these scripts, mind frames or schemas, if too rigid, could be detrimental for creativity. Therefore, breaking the usual way of thinking or mind frames, might be critical to produce novel or original ideas (Gallate, Wong, Ellwood, Chy & Snyder, 2011)

The question is, can we learn to perceive and attend flexibly? Can we influence intentionally these basic cognitive processes? Langer (1989) believes it is possible to control perceptual processes. She suggests that creativity will flourish avoiding automatic behaviors and fix schemas. However, knowledge of the underlying mechanisms affecting perception and attention and hence, creativity, will be necessary.

Perception. Perception is the process allowing the organization, identification and interpretation of sensory information. The perceptual process involves sensory input, where extraction of physical characteristics of the object interact with features of the system, like knowledge and expectancies, to influence attentional and memory processes leading to recognition (Goldstein, 2009). According to Debner and Jacoby (1994) conscious and unconscious perception seem to be influenced differentially by factors like dividing attention. The authors suggest individuals are particularly susceptible to unconscious influences when in "flow", state of mind subsequently explained. Unconscious perception is a perceptual process largely automatic (Debner & Jacoby, 1994). Individual differences in basic perceptual processes result in distinctive perceptual-cognitive styles, the way an individual perceives the environment and processes the information (Messick, 1984; Konrath, Bushman & Grove, 2009).

A better ability in organizing, identifying and interpreting sensorial information is a characteristic of individuals with higher creativity. For instance, in an experiment with 130 adults, by Winston, Tarkas and Maher (2014) an association between creativity and different perceptual tasks measuring selection, organization, and interpretation (three levels of perceptual processing) was found. Higher scores in fluency, originality, flexibility, and elaboration in a divergent thinking task, correlated with better perceptual accuracy and set-forming capacity as well as better perceptual plasticity and set-shifting. More creative individuals switched cognitive styles depending on the aim and instructions of the task (cognitive flexibility). Creativity improves when basic perceptual skills such as the selection, organization and interpretation of information are accurate. Moreover, perceptual ability correlates positively with cognitive flexibility.

Cognitive flexibility. In personality research, one of the most important characteristics of creative people is cognitive flexibility (Proctor & Burnett, 2004). Cognitive flexibility can be defined as the ability to switch mental sets or schemas in response to changing relevant cues in the environment, and to maintain a mental set when changes are irrelevant (Chevalier & Blaye, 2008). According to the dual pathway to creativity model (Nijstad, De Dreu, Rietzschel & Baas, 2010), cognitive flexibility and persistence are the two critical mechanisms of creative cognition. Ionescu (2011), considers cognitive flexibility a property of the cognitive system rather than a cognitive skill.

Cognitive flexibility has been suggested as the underlying mechanism of *distrust* (Mayer & Mussweiler, 2011). Distrust can be conceptualized as a cognitive tendency to perceive inconsistencies that foster thinking about nonobvious alternatives. The process of considering alternatives is also called counterfactual thinking, which has been shown to foster creativity (Markman, Lindberg, Kray, & Galinsky, 2007). Mayer and Mussweiler empirical study in 2011 found a beneficial effect of distrust on creativity. The ability to perceive irregularities or inconsistencies in the information seems to improve with cognitive flexibility.

A human lesion study to investigate the neural basis for cognitive flexibility, revealed the superior temporal gyrus as a key area (Barbey, Colom & Grafman, 2013). This region supports insight and recognition of novel semantic relations (Tian, Tu, Qiu, Lv, Wei, Su & Zhang, 2011). Thus, cognitive flexibility is related to neural mechanisms involved in the integration and synthesis of conceptual knowledge. This integration enables people to see connections previously unseen.

Cognitive flexibility seems to reflect a later stage on the thinking process when perceived information is integrated and other variables are involved. For instance a study performed by Diaz-Santos et al. (2015) concluded cognitive flexibility was not associated with perceptual flexibility (ability to consider both perceptual interpretations while observing a bistable stimulus). Instead, perceptual flexibility was associated with high *novelty seeking,* the tendency to explore novel and unfamiliar stimuli and environments. Novelty seeking has been related to higher dopamine levels in the brain (Costa, Tran, Turchi & Averbeck ,2014) and creativity (Schweizer, 2006; Kaufman et al., 2011). The authors suggest that at least some of the same structures associated with novelty seeking (e.g., caudate, medial and lateral orbitofrontal cortex, amygdala, and substantia nigra/ventral tegmental area) are also important for perceptual flexibility (Diaz-Santos et al., 2015). Novelty seeking is a component of the novelty generation process, therefore essential for creativity (Schweizer, 2006), and can be related to another personal characteristic, *need for closure (NFC).*

Need for closure. NFC is defined as a need to reduce the feeling of discomfort when confronted with cognitive uncertainty. Individuals high in NFC have a rigid processing style, use more simplified, effortless and heuristic processing. They display a low level of novelty seeking (Davidson & Laroche, 2014). In contrast, individuals low in NFC use a systematic processing style, based in an elaboration of information (Webster & Kruglanski, 1994). NFC can be considered an individual difference in cognitive style and has been shown to correlate with age. Older people, in comparison with younger individuals, show higher scores in NFC and recall more congruent than incongruent or irrelevant information (Kossowska, Jaśko, Bar-Tal & Marta Szastok, 2012). High NFC correlate negatively with creativity. For instance, in an experiment designed by Chirumbolo, Livi, Mannetti, Pierro and Kruglanski (2004), the percentage of creative acts, in small group interactions, was reduced under time pressure and in high versus low NFC groups.

The previous studies suggest creativity processes can be facilitated by perceptual flexibility, which in turn, facilitates novelty seeking. However, which is the underlying mechanism of perceptual flexibility?

Field independent perception. Individual differences in perception are also examined in an experimental study by Tsakanikos (2005) where field independent perception is related to ability for associative learning. *Field independent perception (FI)* is a theoretical construct defined as the extent to which the person perceives part of a field as discrete from the surrounding field as a whole, rather than embedded in the field. The opposite is called field dependent. It has also been described as a moderator variable involved in separating noise from perceptual signals (Evans, Richardson & Waring, 2013). FI has been show to relate to better performance in, among others, problem-posing and problem-solving, searching and information seeking and organization, manipulation, and restructuring of visual images (Evans et al., 2013). The results of the experiment by Tsakanikos (2005), showed individuals with FI perceptual style perform better on an associative learning task than subjects with field dependent perception. The finding suggests associative learning (the capacity to meaningful integrate different stimulus) improves with a field independent perception. Associative learning seems to be crucial for creativity, therefore, if associative learning is enhanced with FI perception, creativity might also improve.

The above studies point to a common underlying perceptual mechanism affecting the ability to perceive irregularities. The perception of irregularities could be impaired if regularities cannot be perceived and learned in an efficient and automatic way (*habit-learning*).

*Habit-Learning***.** Habit-learning is the learning of associations between stimuli and response (Hull, 1946 cited by Gasbarri, Pompili, Packard & Tomaz, 2014). Recognition of patterns is essential to establish the familiarity and manifest habituation (Cooke, Komorowski, Kaplan, Gavornik & Bear, 2015). Habituation is performed almost automatically and non-consciously, allowing organisms to focus on novel information (Gasbarri et al., 2014).

Animal lesion studies and human research has reported that lesions in areas related to habit-learning prevents association learning (Thomas, 1996; Bailey et al., 2007). For instance, Mitchell and Hall (2014) investigated the underlying mechanisms by which exposure to similar stimuli can increase their discrimination (perceptual learning). They found that initial detection of unique features appears to depend on the process of habituation.

Extensive literature and research explain habit-learning as automatic or overlearned behavior entirely organized in subcortical structures (Fuster, 2001). Contrarily, Ashby, Ennis and Spiering (2007) argue that novel behaviors are mediated by subcortical structures like the basal ganglia, and passed to the cortex once automaticity is attained. In this model, the subcortical path learns slowly and has greater neural plasticity via a dopamine-mediated learning signal from the substantia nigra whereas the cortical-cortical path respond automatically (Ashby et al., 2007). The findings suggest that habit-learning is a flexible and adaptive subcortical system influencing novel behaviors and higher cognitive processes, like creativity.

A deficient ability to automatize the perception of regularities (habit-learning) could impact recognition of novelty. For example, de Manzano et al. (2013) investigated the relationship between *flow* and dopamine receptor levels in the mesolimbic system. Flow is a theoretical construct introduced by Csikszentmihalyi (1975) defined as a mental state of total involvement in which accurate actions develop unconsciously. Mac Donald, Byrne and Carlton (2006), in an empirical investigation with university students, reported that higher levels of flow are related to higher levels of creativity, in a musical composition task. The study by de Manzano et al. (2013) found that flow proneness is more dependent on the nigrostriatal than mesolimbic dopamine system. Thus, flow, was not specifically related to the reward and intrinsic motivation system, as they expected. However, the nigrostriata path is important in the acquisition of habit, as suggested in the study by Faure, Haberland, Conde and El Massioui (2005). The study report that a depletion of dopamine in the nigrostriatal system was associated with motor and cognitive deficits, more precisely, procedural learning deficits. This signifies automatic or procedural mechanisms like habit-learning, could be necessary for the experience of flow. Flow is not synonymous with creativity, but individuals that experiment flow, have been shown to produce more original pieces (Mac Donald et al., 2006).

*Individual differences***.** Reedijk, Bolders and Homme´s empirical study in 2013, showed that binaural beats, an auditory illusion considered to organize or synchronize brain activity, affect divergent thinking in people differently. Individuals with low dopamine levels in the striatum benefitted from alpha binaural beat stimulation while individuals with high dopamine levels were unaffected or even impaired. This suggests that binaural beats, and possibly other stimuli influencing perceptual processes, might affect individuals in a different way. Individual differences should be considered when applying cognitive enhancement methods.

Numerous studies have shown perception can be improved by training (Blanch-Hartigan, Andrzejewski & Hill ,2012). For example, aged drivers have been trained to perceive hazards (Horswill et al., 2015) and impaired listeners have improved with training in speech perception (Woods et al., 2015). Therefore, if perceptual processing skills are improved, creativity could be enhanced. However, care should be taken in training perception as individual differences in cognitive perceptual processes and styles have been shown to influence creativity.

Attention. Attention is defined as the crucial cognitive ability to attend relevant and ignore irrelevant information from the physical environment and mental representations (Störmer, Passow, Biesenack & Li, 2012). Three attentional networks have been described, alerting, orienting and executive, which handle incoming stimuli, make decisions, and produce outputs (Petersen & Posner, 2012). The integrative framework of attention and memory postulates that contents of working memory are representations from long-term memory (or perceptions) that are temporarily in the focus of attention (Cowan, 2011). Attention is generally related to conscious awareness. However, recent evidence suggest that "in addition to regulating what we perceive, attention seems to influence our behavior through sensorimotor processes that are not involved in conscious awareness" (Sumner, Tsai, Yu & Nachev, 2006, p. 2).

The literature about the role of attention on creativity is varied and sometimes contradictory. This might be because the definition of creativity as novel and appropriate at the same time entails the engagement of classically opposite attentional processes. The production of original ideas would be facilitated by defocused attention, disinhibition and looser associations, whereas the production of appropriate ideas would require focused attention and effective inhibition (Zabelina & Robinson, 2010). On the other hand, maybe the classical definition of attention as the allocation of focus and control applying mental effort, is too limited. The concept of *effortless attention* will be introduced as a fundamental element to unravel the contradictory results.

Effortless attention. Effortless attention describes a state of mind where the individual keeps a high level of attention on a task simultaneously perceiving it as effortless, allowing a high performance on the task (Bruya, 2014). Effortless attention can also be characterized by "being in the flow" (Csikszentmihalyi, 1990). It reflects the capacity to have a distributed or unfocused attention, recognize novel stimuli and integrate the new information if relevant. To do this effectively, will be necessary to perceive and attend irregularities without them interfering with the task.

Most research relates creativity to better attentional capacities. The study by Edl, Benedek, Papousek, Weiss and Fink (2014), in line with previous studies, conclude that more creative individuals show better inhibition of irrelevant stimulus in the Stroop task (interference effect) than less creative subjects. The capacity to inhibit irrelevant stimulus has been shown crucial for attention. It is possible that creative thinking needs a balance between focused and defocused attention and creative individuals are more able to adjust the attentional focus according to demands of the task (Martindale, 1999). Alternatively, more creative individuals might better inhibit irrelevant stimulus because they perceive and attend information with effortless attention, allowing them to recognize and adapt faster to incongruent information.

For instance, better attention scores in more creative children (7 to 13 years old) compared to less creative was found in the study by Memmert (2010). Here, an inattentional blindness task, where a stimulus out of the focus of attention is introduced, was used. The stimulus was perceived by subjects scoring higher on a DT task, however, the perception of the stimulus did not interfere with the task. The results suggest that irrelevant information can be perceived without interfering with the task on hand, on more creative individuals. The study revealed that the interference effect was stronger in younger children (7 years old), suggesting developmental differences in attentional skills can affect creativity. Thus, training in creativity should be adapted to the developmental stage of the individual. These findings are in line with the idea that focused and unfocused attention are not enough to explain attentional states fostering creativity. Other constructs, like effortless attention, might be necessary.

Conflicting use of concepts. A problem in creativity research is that same concepts are used with different meanings depending on the field of study. For instance, a study by de Dreu et al. (2012), report creativity is enhanced by working memory and link working memory with the "persistence pathway" where individuals engage in focused attention, control and persistence. In contrast, they link "the flexibility pathway" with distributed or unfocused attention. The study concludes "the flexibility pathway" hinders creativity. Obviously, the concept of effortless attention is not contemplated here. Also, focused or unfocused attentional strategies are independent of the motivation to persist, and as previously mentioned, cognitive flexibility might be related to effortless attention and not to the capacity to switch between focused or unfocused attention . The study define "flexibility pathway" as a strategy with lower cognitive control, automatic activation, mind wandering and distractibility and assume this pathway is not dependent on working memory. Cognitive flexibility cannot be confused with "flexibility pathway" and the automatic processes they mention, are mandatory and not optional in cognitive processes. Automated processes are precisely those that facilitate faster and more flexible processes allowing higher cognitive performance (Bruya, 2014). Finally, they conclude individuals with higher working memory capacity score higher in an insight task. However, they interpret working memory as associated with control, focus and persistence ("the persistence pathway"), therefore, they deduce more focus and control lead to more creativity.

In another study by de Manzano (2010), the concepts of focused and unfocused attention are also explored. In this study, the author found that a continuous focus in the task is required to enter and maintain a state of flow. De Manzano describe flow as a psychological state of high but effortless attention. Thus, attention can be high but effortless. However, in the study by de Dreu et al. (2012), attention is defined like effortful control. It could be concluded that the results of both studies are contradictory, however, the conflicting use of definitions and concepts makes it impossible to compare.

The preceding studies highlight the importance of consensual understanding of perceptual and attentional processes for the study of higher cognition like creativity.

Attentional flexibility and Habit-Learning. Overall, attentional flexibility seems to be the differential characteristic between more or less creative individuals. For example, defocused attention in contrast to focused attention, has been long linked with more creative individuals. However, Vartanian (2009) in a series of experiments, found that subjects scoring higher in a divergent thinking task showed neither focused nor unfocused attention but attentional flexibility. Hence, more creative people used defocused attention when the task was ill defined and high in ambiguity but they showed focused attention in well defined and low-ambiguity tasks. The author´s interpretation of the results is that creativity benefit switching between attentional strategies depending on the task. However, the results could be explained by effortless attention or attentional flexibility.

But, what is the underlying mechanism allowing or restricting attentional flexibility? Habit-learning, the capacity of the organism to learn regularities and recognize novelty, has potential to be the answer.

Sensory gating. Sensory gating, in the context of attentional processes, is a largely automatic neurological process related physiologically to the thalamus. Sensory gating play a major role in attention, filtering out redundant or irrelevant stimuli from the environment (Freedman et al., 1987). P50 is an attentional component related to sensory gating that shows individual differences. It is measured with an event related potential occurring 50 ms after presentation of a stimulus (P50 ERP). Thus, after repetition of same stimulus, healthy individuals show a reduced amplitude of P50, called selective sensory gating (Yadon, Kisley & Davalos, 2015), suggesting they have learned it (habit-learning) and recognize the stimulus. P50 suppression deficits, "leaky" sensory gating, has been related to pathologies like Alzheimers, schizophrenia, panic attacks, post traumatic stress disorder, and migraine among others (Yadon et al.,2015).

A study by Zabelina, O´Leary, Pornpattananangkul and Nusslock (2015) investigated correlations between two types of creativity, self - reported real world creative achievement and divergent thinking, with the P50 ERP. They found creativity, measured with a DT task, was associated with selective sensory gating. On the contrary, real world creative achievement, measured with a self - report questionnaire, was associated with "leaky" sensory gating. They conclude DT and real-world creativity might require selective against "leaky" attentional processes respectively. However, self - reported creativity, measured in participants with mean age 20, and low scores in a mean score of 10 scales (ranging from dance and visual arts to cooking and architecture) does not show to discriminate between more or less creative individuals. Individuals with higher scores in creativity had better academic records, which suggest that higher scores in real world creative achievement could be due to a compensation and reinforcement of extra-academic activities. The interesting finding is that higher scores in originality in the DT task was associated with selective gating (P50 amplitude reduction over time), suggesting creativity improves with better habit-learning capacity. Zabelina et al. (2015) study, further suggest leaky attention may enhance creativity by broadening the range of unfiltered stimuli available in consciousness. However, it is unlikely that the creative process is best developed under these circumstances, because working memory capacity is limited. If incoming information is not learned and stored in the procedural memory (habit-learning), recognition of new stimuli will be prevented due to cognitive overload, leading to worse attentional control and flexibility (Lin & Yeh, 2014).

Orienting sensitivity. Better recognition and integration of novel stimulus in more creative subjects is also reported in a study by Wei-Lun, Kung-Yu, Hsueh-Chih and Wan-yun Chang (2012). A significant positive correlation was found between insight problem solution and *orienting sensitivity* but not with effortful control, measured with a divergent thinking task.

Orienting sensitivity is an attentional construct related to cognitive flexibility (Wei-Lung et al., 2013). Cognitive flexibility has been shown important in solving insight problems (Mednick, 1962; Feist,1988). According to Evans and Rothbart (2007) orienting sensitivity comprises three constructs: (1) General-perceptual sensitivity, the capacity to attend to low intensity external and internal stimuli; (2) Affective-perceptual sensitivity, the awareness of personal emotions associated with low-intensity stimuli on the environment; and (3) Associative sensitivity, automatic cognitive activity resulting in frequent and remote associations between perceptions, emotions and the environment.

The finding suggests insight improve with the ability to attend to, and associate, close and remote sensorial and emotional information. Nevertheless, the integration of a large amount of complex information is difficult because the working memory is very limited (Cowan, 2011). The integration of complex information might be facilitated by the ability to learn the regularities and store the information in the procedural memory (habit-learning), thus helping the recognition of novelty.

Discussion

The theories on creative thinking are multiple and varied. The basic cognitive processes perception and attention are intimately connected with creativity. They are universal and operate independently of the domain or aim to which it applies. Extensive research on individual differences in cognitive processes has been performed, but the study of universal basic processes has been neglected since assumed that these processes are automated, unconscious and therefore out of intentional control. The present article reviewed recent empirical research on perception and attention to better understand the underlying mechanisms implied in the production of novel thought and behavior.

Limitations of research in creativity

Research in creativity is varied and contradictory, this might be due to the fact that the different domains where studies are performed, influence the factors that hinder or foster creativity. The conclusions in one domain cannot be directly transferred to another. Also, most used measures of creativity, divergent thinking and insight, seem to gauge different processes or ways of creation. In addition, multiple intrinsic and extrinsic components interact in the creative process making it difficult to trace the causes. The generation of novel ideas cannot be fully explained by cognitive linear association´s theory (Henle, 1975). Non-linear theories, like complex system´s theory, are not contemplated in current research on creativity. The conclusions drawn from experiments with linear cause-effect relationships should be taken with caution. Unconscious cognitive processes are seen as uncontrollable and therefore are often neglected in creativity research, however, the creative process cannot be explained without them.

Main Findings

Three main points can be drawn from the present review:
First, a possible underlying mechanism affecting associative learning and creativity, habit-learning, is suggested. Second, effortless attention, dissimilar to focused or unfocused attention, should be considered in future research on creativity. Finally, another important point drawn from the review is that production of novel ideas might be achieved by two different ways: logical association (activation and combination of ideas) or emergence (unpredictable properties arising from a system).

1. Habit-learning. Better perceptual capacity has been related to more creative individuals

(Winston et al., 2014). Different personality and cognitive styles like NFC (Davidson & Laroche, 2014), cognitive flexibility (Barbey et al., 2013), counter-factual thinking (Markman et al., 2007), flow (Manzano et al., 2012) and FI perception (Tsakanikos, 2005) have been shown to influence the creative process.

Cognitive flexibility has been linked to creativity and activity in the STG (superior temporal gyrus) area of the brain (Barbey et al., 2013). The STG is known to support insight processes, the recognition of relevant and/or novel ideas when integrating information (Tian et al., 2011). The recognition of novelty will require a prior perception of relevant material separated from its context, called FI perception (Evans et al., 2013). "FI perception is especially important in the management and interpretation of complex cognitive tasks" (Evans et al., 2013, p. 210). The ability to perceive irregularities in a pattern (FI) can be seen as the result of the three stages of the perceptual process: selection, organization and interpretation (Levine & Shefner, 2006).

The implicit and automatic associative learning mechanism of habit-learning, facilitate recognition of irregularities or novelty. Creativity processes rely in the ability to recognize novelty (Kaufman et al., 2011), so it appears, habit-learning might be important for the creative process.

The production of novel behavior and thoughts are part of the cognitive processes based on the system's ability to learn and adapt to changing external and internal circumstances (Bailey, McDaniel & Thomas, 2007). Therefore, learning ability will be crucial for the production of novel acts and objects. Thomas (1996) proposed a hierarchy of learning and cognitive abilities evident in animals, including humans: Level 1. Habituation, Level 2-3. Classical and instrumental conditioning, Level 4-5. Chaining and discrimination, and Level 5-8. Classifications. Generally, lower levels will be prerequisite for higher levels. The level 1, habituation, defined as a progressive reduction in the strength of the response due to the repeated presentation of a stimulus, is primary to the development of higher levels, thus creativity. Perceptual and attentional processes are directly linked to habituation (Bailey et al., 2007).

Animal models are useful to investigate cognitive underlying mechanisms. Creativity research in animals show processes of recognition and motivation to novelty, observational learning and innovation as basic mechanisms for creative behavior. In a recent study Kolodny, Edelman and Lotem (2015) found animal creativity can be understood as the production of context-appropriate novel behavioral sequences, facilitated by the ability to learn the regularities in the environment (Kolodny et al., 2015). Habit-learning has been shown essential for association learning also in humans (Thomas, 1996; Bailey et al., 2007). Habit-learning implies the capacity to learn regularities, leading to habituation. Habituation has been suggested as the underlying mechanism facilitating perceptual learning (Mitchell & Hall, 2014). Perceptual learning " refers to the changes that take place within sensory and perceptual systems as a result of practice performing a perceptual task" (Goldstein, 2009, p. 781). The information learned by habit-learning is encoded in the procedural memory system. This information does not interfere with new stimuli and elaboration of information in the working memory, allowing integration of complex information.

Habit-learning has been shown to be supported by the nigrostriata dopaminergic path in the brain (Faure et al., 2005). The nigrostriata area has been related to the experience of flow (de Manzano et al., 2013). Individual differences exist in this dopaminergic system. Stimulation of synchronization of brain activity trough binaural beats, has been reported to affect differentially individuals with higher or lower levels of dopamine in the nigrostriata system (Reedijk et al., 2013). Research shows dopamine signal in the nigrostriatum affect habit-learning (El Massioui, 2005). The findings suggest more care should be taking in the propagation of general enhancing creativity methods or "creativity kits" as bio-psychological individual differences can affect the results.

Automatic or procedural mechanisms are also involved in attentional processes like orienting sensitivity and sensory gating, that affect creative processes (Wei-Lung et al., 2013; Yadon et al.,2015). Individuals with better orienting sensitivity show an ability to integrate complex information that could be facilitated by habit-learning. Selective gating, the capacity to learn regularities and not to attend consciously to repetitive stimuli, has been reported to be associated with higher scores in originality (Zabelina et al., 2015). The findings are in line with the hypothesis that habit-learning mechanisms facilitate the learning of regularities, transferring information to the automatic procedural system (Gasbarri at al., 2014). The release of the limited conscious working memory allows for integration of information stored in the procedural memory system and recognition of novelty. Individual differences in the capacity to learn regularities or patterns (habit-learning) have been reported in experimental studies (Zabelina et al., 2015; Yadon et al.,2015). The forming of original ideas by connection of remote associations, will be more influenced by the capacity of the working memory than for habit-learning mechanisms.

2. Effortless attention. Research on attention and creativity, suggest higher level of creativity is associated with better attention and inhibition processes (Edl et al., 2014). But, the definition of attention in dichotomous terms, focused against defocused attention, can miss essential components and lead to misleading conclusions. Effortless attention embody a nor focused or unfocused attention, where the individual keeps a high level of focus simultaneously perceiving the task as effortless (Bruya, 2014).

Research shows creativity is related to the capacity to adapt to demands of the task and explain it as an ability to switch between focused or unfocused attention. However, it is possible to perceive irrelevant stimuli (unfocused attention) without interfering with the task (focused attention)

(Memmert, 2010; Vartanian, 2009; Manzano et al., 2012). Effortless attention explain the results as the possibility to perceive irrelevant or peripheral stimuli in the background without interfering with the task. This attentional state might be facilitated by habit-learning mechanisms transferring the information to the procedural system.

In summary, as important and adaptive for an organism is to detect sudden changes in the environment as to filter out task irrelevant stimuli for better performance. The cost of keeping a "balance" could be distraction (Parmentier, 2014). Behavioral deviance distraction is often seen as a burden for a good performance in a task, but distraction is an ability of the cognitive system to work with complex and extensive information. Evidence shows distraction decrease with memory load and complex instructions, suggesting that the cognitive system prioritizes maintaining the load over directing attention to unexpected stimuli (Parmentier, 2014). If the working memory is "clear" the system allows distraction. Here, distraction is a state of mind where information stored in procedural memory and new information entering the system have the potential to integrate, maybe through effortless attention.

3. Association - emergence. Associative cognitive theories on creativity state the creative process implies association of ideas that are remote and need to be activated (Mednick,1962; Eynseck, 1995), but activation of remote ideas is not sufficient for creativity (Henle, 1975). **T**he production of novel ideas could be achieved through different paths. For instance, the theory of dual information processing systems posit individuals process information in two ways, experiential and rational (Epstein, 1998). The rational-cognitive system process information in a conscious, logical and conceptual way whereas the experiential system process information in a faster, automatic and perceptual way (Pashko, 2014). The complex system theory concept of emergence (new patterns and ideas arise out of simple interactions, Lozi, 2011), explain the production of novel ideas according to the automatic processing of information, whereas the logical assosiation concept of associationism, explain novelty with the rational, conscious way.

Emergence is described by Mihata (1997) as "the process by which patterns or global-level structures arise from interactive local-level processes. This structure or pattern cannot be understood or predicted from the behaviour or properties of the component units alone" (p. 31) . Emergence is an unconscious, procedural mechanism of self-organizing systems that integrate information "allowing", whereas logical association is a conscious integrative process, "making". It is possible that novelty can be achieved in both ways, associating ideas (making) or by emergence (allowing). A "pure creation" would happen by emergence, without a clear image of the final product. Allowing the content stored in the unconscious procedural memory to interact and integrate with the conscious content. Flow, could be a state of mind enabling this non-conscious interaction.

The "incubation" period in Wallas´model and the insight measure of creativity, might be related to the emergence mechanism.

General Conclusion and Future recommendations

Individual differences in working memory capacity result in more or less complex associations and thus creativity. However, working memory is limited in all individuals (Lin & Yeh, 2014). Under high memory load and complexity, automatic procedural proprieties of the system like emergence, might facilitate the thinking and creative process. Perceptual flexibility and effortless attention are constructs related to a "state of allowing" automatic processes to work in the background, in contrast to a "state of making it happen" related to logical association. These automatic processes would enable the cognitive system to work with larger and more complex information that the conscious working memory can support, therefore, improving the thinking and creative process. Whether the mechanism responsible for ensuring perceptual flexibility and effortless attention is habit-learning, constitute an interesting question that will require a further investigation.

While we know about several cognitive factors that influence the occurrence of creative behaviors, more research is needed addressing the importance of automatic procedural processes. The possibility of a wider spectrum of perceptual and attentional states and the study of creativity as a non-linear process should be also assessed in the future. For instance, research on how habit-learning facilitates the recognition of novelty and how it can foster creative processes. Also, the investigation of positive correlations between perceptual flexibility, selective gating and effortless attention with creativity, should be further studied. Future work should investigate if habit-learning is related to dopamine in the nigrostriata brain area and recognition of novelty.
Additionally, future studies could investigate if individuals with different perceptual and cognitive styles need different stimulus to enhance creative processes. Finally, as unconscious perceptual and attentional processes can be influenced by training and/or priming of the conscious processes (Ritter at al., 2014), future experiments could investigate how training can affect results in creativity. Taken together, there remain many exciting possibilities in the area of creativity for future work.

References

Amabile, T. M. (1983). The social psychology of creativity: A componential conceptualization. *Journal of Personality & Social Psychology, 45*(2), 357-376.

Amabile, T. M. (1997). Motivating creativity in organizations: On doing what you love and loving what you do. *California Management Review, 40*(1), 39-58.

Apiola, M., Lattu, M., & Pasanen, T. A. (2012). Creativity-supporting learning environment--CSLE. *ACM Transactions on Computing Education, 12*(3)

Ashby, F. G., Ennis, J. M., & Spiering, B. J. (2007). A neurobiological theory of automaticity in perceptual categorization. *Psychological Review, 114*(3), 632-656. doi:10.1037/0033-295X.114.3.632

Baer, J., & Kaufman, J. C. (2005). Bridging generality and specificity: The amusement park theoretical (APT) model of creativity. *Roeper Review, 27*(3), 158-163.

Bailey, A. M., McDaniel, W. F., & Thomas, R. K. (2007). Approaches to the study of higher cognitive functions related to creativity in nonhuman animals. *Methods, 42*, 3-11. doi:10.1016/j.ymeth.2006.12.003

Barbey, A. K., Colom, R., & Grafman, J. (2013). Architecture of cognitive flexibility revealed by lesion mapping. *Neuroimage, 82*, 547-554. doi:10.1016/j.neuroimage.2013.05.087

Benedek, M., & Neubauer, A. C. (2013). Revisiting Mednick's model on creativity-related differences in associative hierarchies. evidence for a common path to uncommon thought. *Journal of Creative Behavior, 47*(4), 273.

Björkman, H. (2004). Design dialogue groups as a source of innovation: Factors behind group creativity. *Creativity & Innovation Management, 13*(2), 97-108. doi:10.1111/j.0963-1690.2004.00298.x

Blanch-Hartigan, D., Andrzejewski, S. A., & Hill, K. M. (2012). The effectiveness of training to improve person perception accuracy: A meta-analysis. *Basic & Applied Social Psychology, 34*(6), 483-498. doi:10.1080/01973533.2012.728122

Bruya, B. (. (2014). Effortless attention: A new perspective in the cognitive science of attention and action. *Journal of Consciousness Studies, 21*(1-2), 209-215.

Candy, L., & Edmonds, E. (2000). Creativity enhancement with emerging technologies. *Communications of the ACM, 43*(8), 62-65.

Chadi, G., & Gomide, V. C. (2004). FGF-2 and S100ß immunoreactivities increase in reactive astrocytes, but not in microglia, in ascending dopamine pathways following a striatal 6-OHDA-induced partial lesion of the nigrostriatal system. *Cell Biology International, 28*, 849-861. doi:10.1016/j.cellbi.2004.08.005

Chevalier, N., & Blaye, A. (2008). Cognitive flexibility in preschoolers: The role of representation activation and maintenance. *Developmental Science, 11*(3), 339-353. doi:10.1111/j.1467-7687.2008.00679.x

Chi, R. P., & Snyder, A. W. (2011). Facilitate insight by non-invasive brain stimulation. *Plos One, 6*(2), 1-7. doi:10.1371/journal.pone.0016655

Chirumbolo, A., Livi, S., Mannetti, L., Pierro, A., & Kruglanski, A. W. (2004). Effects of need for closure on creativity in small group interactions. *European Journal of Personality, 18*(4), 265-278. doi:10.1002/per.518

Chiu, F. (2015). Improving your creative potential without awareness: Overinclusive thinking training. *Thinking Skills and Creativity, 15*, 1-12. doi:10.1016/j.tsc.2014.11.001

Colton, S., Badia, R. L. d. M., & Stock, O. (2009). Computational creativity: Coming of age. *AI Magazine, 30*(3), 11-14.

Conti, R., Coon, H., & Amabile, T. M. (1996). Evidence to support the componential model of creativity: Secondary analyses of three studies. *Creativity Research Journal, 9*(4), 385-389.

Cooke, S. F., Komorowski, R. W., Kaplan, E. S., Gavornik, J. P., & Bear, M. F. (2015). Visual recognition memory, manifested as long-term habituation, requires synaptic plasticity in V1. *Nature Neuroscience, 18*(2), 262-271. doi:10.1038/nn.3920

Costa, V. D., Tran, V. L., Turchi, J., & Averbeck, B. B. (2014). Dopamine modulates novelty seeking behavior during decision making. *Behavioral Neuroscience,* doi:10.1037/a0037128

Cowan, N. (2011). The focus of attention as observed in visual working memory tasks: Making sense of competing claims. *Neuropsychologia, 49*(-), 1401-1406. doi:10.1016/j.neuropsychologia.2011.01.035

Davidson, A., & Laroche, M. (2014). Connecting the dots: How personal need for structure produces false consumer pattern perceptions. *Marketing Letters,* , 14p. doi:10.1007/s11002-014-9332-z

Debner, J. A., & Jacoby, L. L. (1994). Unconscious perception: Attention, awareness, and control. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(2), 304-317. doi:10.1037/0278-7393.20.2.304

De Dreu, Carsten K. W., Nijstad, B. A., Baas, M., Wolsink, I., & Roskes, M. (2012). Working memory benefits creative insight, musical improvisation, and original ideation through maintained task-focused attention. *Personality and Social Psychology Bulletin, 38*(5), 656-669. doi:10.1177/0146167211435795

de Manzano, Ö., Cervenka, S., Karabanov, A., Farde, L., & Ullén, F. (2010). Thinking outside a less intact box: Thalamic dopamine D2 receptor densities are negatively related to psychometric creativity in healthy individuals. *Plos One, 5*(5), 1-6. doi:10.1371/journal.pone.0010670

de Manzano, Ö., Cervenka, S., Jucaite, A., Hellenäs, O., Farde, L., & Ullén, F. (2013). Individual differences in the proneness to have flow experiences are linked to dopamine D2-receptor availability in the dorsal striatum. *Neuroimage, 67*(0), 1-6. doi:http://dx.doi.org.ludwig.lub.lu.se/10.1016/j.neuroimage.2012.10.072

Díaz-Santos, M., Cao, B., Yazdanbakhsh, A., Norton, D. J., Neargarder, S., & Cronin-Golomb, A. (2015). Perceptual, cognitive, and personality rigidity in parkinson's disease. *Neuropsychologia, 69*, 183-193. doi:10.1016/j.neuropsychologia.2015.01.044

Dietrich, A., & Kanso, R. (2010). A review of EEG, ERP, and neuroimaging studies of creativity and insight. *Psychological Bulletin, 136*(5), 822-848. doi:10.1037/a0019749

Duch, W. (2006). Computational creativity. *2006 IEEE International Joint Conference on Neural Network Proceedings,* , 435.

Edl, S., Benedek, M., Papousek, I., Weiss, E. M., & Fink, A. (2014). Creativity and the stroop interference effect. *Personality & Individual Differences, 69*, 38-42. doi:10.1016/j.paid.2014.05.009

Epstein, S. (1998). Cognitive-experiential self-theory: A dual-process personality theory with implications for diagnosis and psychotherapy. In R. F. Bornstein, J. M. Masling, R. F. (. Bornstein & J. M. (. Masling (Eds.), (pp. 99-140). Washington, DC, US: American Psychological Association. doi:10.1037/10256-004

Evans, C., Richardson, J. T. E., & Waring, M. (2013). Field independence: Reviewing the evidence. *British Journal of Educational Psychology, 83*(2), 210-224. doi:10.1111/bjep.12015

Evans, D. E., & Rothbart, M. K. (2007). Developing a model for adult temperament. *Journal of Research in Personality, 41*, 868-888. doi:10.1016/j.jrp.2006.11.002

Eysenck, H. J. (2003). Creativity, personality and the convergent-divergent continuum. In M. A. Runco, & M. A. (. Runco (Eds.), (pp. 95-114). Cresskill, NJ, US: Hampton Press.

Eysenck, H. J. (1993). Creativity and personality: Suggestions for a theory. *Psychological Inquiry, 4*(3), 147.

Faure, A. (. 1.)., Haberland, U. (. 1.)., El Massioui, N. (1), & Condé, F. (2). (2005). Lesion to the nigrostriatal dopamine system disrupts stimulus-response habit formation. *Journal of Neuroscience, 25*(11), 2771-2780. doi:10.1523/JNEUROSCI.3894-04.2005

Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality & Social Psychology Review (Sage Publications Inc.), 2*(4), 290.

Finke, R. A. (1996). Imagery, creativity, and emergent structure. *Consciousness and Cognition, 5*(3), 381-393.

Finke, R. A. (1996). Imagery, creativity, and emergent structure. *Consciousness and Cognition: An International Journal, 5*(3), 381-393. doi:10.1006/ccog.1996.0024

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition : Theory, research, and applications* Cambridge, Mass. : MIT Press, cop. 1992.

Freedman, R., Adler, L. E., Gerhardt, G. A., Waldo, M., Baker, N., Rose, G. M., Franks, R. (1987).

Neurobiological studies of sensory gating in schizophrenia. *Schizophrenia Bulletin, 13*(4), 669-

678.

Fuster, J. M. (2001). Review: The prefrontal Cortex—An update. time is of the essence. *Neuron, 30*, 319-333. doi:10.1016/S0896-6273(01)00285-9

Gallate, J., Wong, C., Ellwood, S., Chi, R., & Snyder, A. (2011). Noninvasive brain stimulation reduces prejudice scores on an implicit association test. *Neuropsychology, 25*(2), 185-192. doi:10.1037/a0021102

Gasbarri, A., Pompili, A., Packard, M. G., & Tomaz, C. (2014). Review: Habit learning and memory in mammals: Behavioral and neural characteristics. *Neurobiology of Learning and Memory, 114*, 198-208. doi:10.1016/j.nlm.2014.06.010

Goldstein, E. B. (2009). *Encyclopedia of perception. [elektronisk resurs]* Thousand Oaks, Calif. : Sage Publications, c2009.

Groborz, M., N&ecedil, & cka, E. (2003). Creativity and cognitive control: Explorations of generation and evaluation skills. *Creativity Research Journal, 15*(2), 183.

Guilford, J. P. (1950). Creativity. *American Psychologist, 5*(9), 444-454.

Gupta, N., Jang, Y., Mednick, S. C., & Huber, D. E. (2012). The road not taken: Creative solutions require avoidance of high-frequency responses. *Psychological Science, 23*(3), 288-294. doi:10.1177/0956797611429710

Hassabis, D., & Maguire, E. A. (2007). Opinion: Deconstructing episodic memory with construction. *Trends in Cognitive Sciences, 11*, 299-306. doi:10.1016/j.tics.2007.05.001

Henderson, J. M., & Luke, S. G. (2014). Stable individual differences in saccadic eye movements during reading, pseudoreading, scene viewing, and scene search. *Journal of Experimental Psychology: Human Perception and Performance, 40*(4), 1390-1400. doi:10.1037/a0036330

Horan, R. (2009). The neuropsychological connection between creativity and meditation. *Creativity Research Journal, 21*(2), 199-222. doi:10.1080/10400410902858691

Horswill, M. S., Falconer, E. K., Pachana, N. A., Wetton, M., & Hill, A. (2015). The longer-term effects of a brief hazard perception training intervention in older drivers. *Psychology and*

Aging, 30(1), 62-67. doi:10.1037/a0038671; 10.1037/a0038671.supp (Supplemental)

Ionescu, T. (2012). Exploring the nature of cognitive flexibility. *New Ideas in Psychology, 30*, 190-200. doi:10.1016/j.newideapsych.2011.11.001

Kaufman, A. B., Butt, A. E., Kaufman, J. C., & Colbert-White, E. (2011). *Towards a neurobiology of creativity in nonhuman animals*

Kaufman, J. C. (. 1.)., & Beghetto, R. A. (. 2.). (2009). Beyond big and little: The four C model of creativity. *Review of General Psychology, 13*(1), 1-12. doi:10.1037/a0013688

Kharkhurin, A. V. (2011). The role of selective attention in bilingual creativity. *Creativity Research Journal, 23*(3), 239-254. doi:10.1080/10400419.2011.595979

Kolodny, O., Edelman, S., & Lotem, A. (2015). Evolved to adapt: A computational approach to animal innovation and creativity. *Current Zoology, 61*(2), 350-368.

Konrath, S., Bushman, B. J., & Grove, T. (2009). Seeing my world in a million little pieces: Narcissism, self-construal, and Cognitive–Perceptual style. *Journal of Personality, 77*(4), 1197-1228. doi:10.1111/j.1467-6494.2009.00579.x

Kossowska, M. (. 1.)., Jasko, K. (. 1.)., Szastok, M. (. 1.)., & Bar-Tal, Y. (2012). The relationship between need for closure and memory for schema-related information among younger and older adults. *Aging, Neuropsychology, and Cognition, 19*(1-2), 283-300. doi:10.1080/13825585.2011.632617

Ladd, D. R., Turnbull, R., Browne, C., Caldwell-Harris, C., Ganushchak, L., Swoboda, K., . . . Dediu, D. (2013). Patterns of individual differences in the perception of missing-fundamental tones. *Journal of Experimental Psychology: Human Perception and Performance, 39*(5), 1386-1397. doi:10.1037/a0031261; 10.1037/a0031261.supp (Supplemental)

Langer, E. J. (2000). Mindful learning. *Current Directions in Psychological Science (Wiley-Blackwell), 9*(6), 220-223.

Leon, S. A. (. 1.)., Altmann, L. J. P. (. 2.)., Abrams, L. (. 2.)., Gonzalez Rothi, L.J. (2), & Heilman, K. M. (. 3.). (2014). Divergent task performance in older adults: Declarative memory or creative potential? *Creativity Research Journal, 26*(1), 21-29.

doi:10.1080/10400419.2014.873657

Lin, S., & Yeh, Y. (2014). Domain-specific control of selective attention. *Plos One, 9*(5), 1-12. doi:10.1371/journal.pone.0098260

Lin, W., Hsu, K., Chen, H., & Chang, W. (2013). Different attentional traits, different creativities. *Thinking Skills and Creativity, 9*, 96-106. doi:10.1016/j.tsc.2012.10.002

Lozi, R. (2012). Emergence of randomness from chaos. *International Journal of Bifurcation & Chaos in Applied Sciences & Engineering, 22*(2), 1250021-1250021; 1250021-15.

Mandler, G. (1995). Origins and consequences of novelty. Cambridge, MA, US: The MIT Press. 9-25

Markman, K. D., Lindberg, M. J., Kray, L. J., & Galinsky, A. D. (2007). Implications of counterfactual structure for creative generation and analytical problem solving. *Personality & Social Psychology Bulletin, 33*(3), 312.

Martindale, C. (1990). Innovation, illegitimacy, and individualism. *Creativity Research Journal, 3*(2), 118.

Mayer, J., & Mussweiler, T. (2011). Suspicious spirits, flexible minds: When distrust enhances creativity. *Journal of Personality & Social Psychology, 101*(6), 1262-1277. doi:10.1037/a0024407

Mayseless, N., Aharon-Peretz, J., & Shamay-Tsoory, S. (2014). Unleashing creativity: The role of left temporoparietal regions in evaluating and inhibiting the generation of creative ideas. *Neuropsychologia, 64*, 157-168. doi:10.1016/j.neuropsychologia.2014.09.022

Mednick, S. (1962). The associative basis of the creative process. *Psychological Review, 69*(3), 220-232. doi:10.1037/h0048850

Memmert, D. (2011). Creativity, expertise, and attention: Exploring their development and their relationships. *Journal of Sports Sciences, 29*(1), 93-102. doi:10.1080/02640414.2010.528014

Mihata, K. (1997) 'The persistence of emergence', in Chaos, Complexity and Sociology, eds R. A. Eve, S. Horsfall & M. E. Lee, Sage, Thousand Oaks, CA, pp. 30-38.

Mitchell, C., & Hall, G. (2014). Can theories of animal discrimination explain perceptual learning in humans? *Psychological Bulletin, 140*(1), 283-307. doi:10.1037/a0032765

Mullally, S. L., & Maguire, E. A. (2014). Memory, imagination, and predicting the future: A common brain mechanism? *Neuroscientist, 20*(3), 220-234. doi:10.1177/1073858413495091

Mumford, M. D., & Others, A. (1993). Developing creative capacities: Implications of cognitive processing models. *Roeper Review, 16*(1), 16-21.

Ness, R. B. (2015). Promoting innovative thinking. *American Journal of Public Health, 105*, S114-S118. doi:10.2105/AJPH.2014.302365

Neuschatz, Jeffrey S.Lampinen, James M.Preston, Elizabeth L.Hawkins, Emily R.Toglia,Michael P. (2002). The effect of memory schemata on memory and the phenomenological experience of naturalistic situations. *Applied Cognitive Psychology, 16*(6), 687-708. doi:10.1002/acp.824

Nijstad, B. A., De Dreu, Carsten K. W., Rietzschel, E. F., & Baas, M. (2010). The dual pathway to creativity model: Creative ideation as a function of flexibility and persistence. *European Review of Social Psychology, 21*(1), 34-77. doi:10.1080/10463281003765323

Ohlsson, S. (1984). Restructuring revisited: II. an information processing theory of restructuring and insight. *Scandinavian Journal of Psychology, 25*(2), 117-129. doi:10.1111/j.1467-9450.1984.tb01005.x

Parmentier, F. (2014). The cognitive determinants of behavioral distraction by deviant auditory stimuli: A review. *Psychological Research, 78*(3), 321-338. doi:10.1007/s00426-013-0534-4

Pashko, S. (2014). Conceptual versus perceptual information processing: Implications for subjective reporting. *Journal of Neuroscience, Psychology, and Economics, 7*(4), 219-226. doi:10.1037/npe0000027

Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience, 35*, 73-89. doi:10.1146/annurev-neuro-062111-150525

Peter-Szarka, S. (2012). Creative climate as a means to promote creativity in the classroom. *Electronic Journal of Research in Educational Psychology, 10*(3), 1011-1034.

Pica, GennaroPierro, AntonioBélanger, Jocelyn J.Kruglanski,Arie W. (2014). The role of need for cognitive closure in retrieval-induced forgetting and misinformation effects in eyewitness memory. *Social Cognition, 32*(4), 337-359.

Rasmussen, K., & Berntsen, D. (2014). 'I can see clearly now': The effect of cue imageability on mental time travel. *Memory & Cognition, 42*(7), 1063-1075. doi:10.3758/s13421-014-0414-1

Reedijk, S. A., Bolders, A., & Hommel, B. (2013). The impact of binaural beats on creativity. *Frontiers in Human Neuroscience, 7* doi:10.3389/fnhum.2013.00786

Ritter, S. M., & Dijksterhuis, A. (2014). Creativity—The unconscious foundations of the incubation period. *Frontiers in Human Neuroscience, 8*

Ritter, S. M., Kühn, S., Müller, B. C. N., van Baaren, R. B., Brass, M., & Dijksterhuis, A. (2014). The creative brain: Corepresenting schema violations enhances TPJ activity and boosts cognitive flexibility. *Creativity Research Journal, 26*(2), 144-150. doi:10.1080/10400419.2014.901061

Ritter, S. M., van Baaren, R. B., & Dijksterhuis, A. (2012). *Creativity: The role of unconscious processes in idea generation and idea selection* Elsevier Ltd. doi:10.1016/j.tsc.2011.12.002

Rodríguez Bencosme, A. M. (2014). El diseño como un instrumento pedagógico para incrementar la creatividad. (spanish). *Ciencia y Sociedad, 39*(2), 311.

Rogers, C.(1961). On becoming a person. Retrieved 05/22/2015 from http://psychology.about.com/od/psychologyquotes/a/rogersquotes.htm

Runco, M. A. (2004). *Creativity* doi:10.1146/annurev.psych.55.090902.141502

Runco, M. A. (2008). Commentary: Divergent thinking is not synonymous with creativity. *Psychology of Aesthetics, Creativity, and the Arts, 2*(2), 93-96. doi:10.1037/1931-3896.2.2.93

Runco, M. A. (2014). *Creativity: Theories and themes: Research, development, and practice (2nd ed.)*. San Diego, CA, US: Elsevier Academic Press.

Schilling, M. A. (2005). A"small-world" network model of cognitive insight. *Creativity Research Journal, 17*(2), 131-154. doi:10.1207/s15326934crj1702&3_2

Schmajuk, N., Aziz, D. R., & Bates, M. J. B. (2009). Attentional-associative interactions in creativity. *Creativity Research Journal, 21*(1), 92-103. doi:10.1080/10400410802633574

Schweizer, T. S. (2006). The psychology of novelty-seeking, creativity and innovation: Neurocognitive aspects within a work-psychological perspective. *Creativity & Innovation Management, 15*(2), 164-172. doi:10.1111/j.1467-8691.2006.00383.x

Sims-Knight, J., & Knight, R. A. (1978). Logical and nonlogical classification systems: A look at the underlying complexity of overinclusion in schizophrenics. *Journal of Clinical Psychology, 34*(4), 857-865.

Smith, S. M. (1995). Fixation, incubation, and insight in memory and creative thinking. In S. M. Smith, T. B. Ward, R. A. Finke, S. M. (. Smith, T. B. (. Ward & R. A. (. Finke (Eds.), (pp. 135-156). Cambridge, MA, US: The MIT Press.

Sternberg, R. J., O'Hara, L. A., & Lubart, T. I. (1997). Creativity as investment. *California Management Review, 40*(1), 8-21.

Storm, B. C., & Patel, T. N. (2014). Forgetting as a consequence and enabler of creative thinking. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*(6), 1594-1609. doi:10.1037/xlm0000006

Stormer, V. S., Passow, S., Biesenack, J., & Li, S. (2012). Dopaminergic and cholinergic modulations of visual-spatial attention and working memory: Insights from molecular genetic research and implications for adult cognitive development. *Developmental Psychology, 48*(3), 875-889.

Sumner, P., Tsai, P., Yu, K., & Nachev, P. (2006). *Attentional modulation of sensorimotor processes in the absence of perceptual awareness* National Academy of Sciences.

Thomas, R. K. (1996). Investigating cognitive abilities in animals: Unrealized potential. *Brain Research.Cognitive Brain Research, 3*(3-4), 157-166.

Tian, F., Tu, S., Qiu, J., Lv, J. Y., Wei, D. T., Su, Y. H., & Zhang, Q. L. (2011). Research report: Neural correlates of mental preparation for successful insight problem solving. *Behavioural Brain Research, 216*, 626-630. doi:10.1016/j.bbr.2010.09.005

Treven, S., & Mulej, M. (2005). *A requisitely holistic view of human resources management in innovative enterprises*

Tsakanikos, E. (2006). Associative learning and perceptual style: Are associated events perceived analytically or as a whole? *Personality and Individual Differences, 40* (3), 579-586. doi:http://dx.doi.org.ludwig.lub.lu.se/10.1016/j.paid.2005.07.014

Vartanian, O. (2009). Variable attention facilitates creative problem solving. *Psychology of Aesthetics, Creativity, and the Arts, 3*(1), 57-59. doi:10.1037/a0014781

Ward, T. B. (2009). ConceptNets for flexible access to knowledge. In A. B. Markman, K. L. Wood, A. B. (. Markman & K. L. (. Wood (Eds.), (pp. 153-170). New York, NY, US: Oxford University Press. doi:10.1093/acprof:oso/9780195381634.003.0008

Webster, D. M., & Kruglanski, A. W. (1994). Individual differences in need for cognitive closure. *Journal of Personality and Social Psychology, 67*(6), 1049-1062. doi:10.1037/0022-3514.67.6.1049

Winston, C. N., Tarkas, N. J., & Maher, H. (2014). Eccentric or egocentric? preoperational features in schizotypic and creative adults. *Psychology of Aesthetics, Creativity, and the Arts, 8*(4), 413-422. doi:10.1037/a0037442

Woodman, R. W., Sawyer, J. E., & Griffin, R. W. (1993). Toward a theory of organizational creativity. *Academy of Management Review, 18*(2), 293-321. doi:10.5465/AMR.1993.3997517

Woods, D. L., Doss, Z., Herron, T. J., Arbogast, T., Younus, M., Ettlinger, M., & Yund, E. W. (2015). *Speech perception in older hearing impaired listeners: Benefits of perceptual training* Public Library of Science. doi:10.1371/journal.pone.0113965

Yadon, C. A., Kisley, M. A., & Davalos, D. B. (2015). The effects of vigilance and visual distraction on the P50 mid-latency auditory evoked potential. *Journal of Psychophysiology, 29*(1), 33-44. doi:10.1027/0269-8803/a000132

Yoruk, S., & Runco, M. A. (2014). The neuroscience of divergent thinking. *Activitas Nervosa Superior, 56*(1), 1-16.

Zabelina, D. L., O'Leary, D., Pornpattananangkul, N., Nusslock, R., & Beeman, M. (2015). Creativity and sensory gating indexed by the P50: Selective versus leaky sensory gating in divergent thinkers and creative achievers. *Neuropsychologia, 69*, 77-84. doi:10.1016/j.neuropsychologia.2015.01.034

Zabelina, D. L., & Robinson, M. D. (2010). Creativity as flexible cognitive control. *Psychology of Aesthetics, Creativity, and the Arts, 4*(3), 136-143. doi:10.1037/a0017379

Zeman, A. Z. J., Beschin, N., Dewar, M., & Della Sala, S. (2013). Research report: Imagining the present: Amnesia may impair descriptions of the present as well as of the future and the past. *Cortex, 49*, 637-645. doi:10.1016/j.cortex.2012.03.008

Zheng, H., Luo, J., Yu, R., Osman, M., & Walter, S. (2014). From memory to prospection: What are the overlapping and the distinct components between remembering and imagining? *Frontiers in Psychology, 5*, 1-14. doi:10.3389/fpsyg.2014.00856