The neuroscience of creativity: a promising or perilous enterprise?

Dra. Anna Abraham

We live in a golden age of scientific opportunity with regard to the neuroscience of creativity. The field is very much in its nascent phase with an overabundance of questions waiting to be explored yet few research groups that focus on creative neurocognition as a primary field of study. We are therefore in a unique position to critically assess and unanimously determine the direction and standards that should be applied to investigations of the neuroscience of creativity. Indeed the endeavors that we pursue at this stage as neuroscientists and psychologists in order to understand the nature and function of human creativity in relation to the brain will form the very foundation of this incredible store of knowledge. The onus is therefore on us to deal head on with the thorny issues at hand, and to both operationalize and systematize the neuroscientific study of creativity. In the following chapter, three key issues which stand to hinder real progress being made in the neuroscience of creativity will be discussed.

a) Can creativity be optimally studied using current neuroscientific methods?

b) Should creative cognition be approached as a subject that is qualitatively distinct from other aspects of cognition?

c) Do we stand to gain significantly by explicitly circumscribing what is meant by creativity?

Creativity and the limitations of current neuroscientific methods

It is easy to understand the allure of applying neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and electrophysiological methods such as electroencephalography (EEG) to understand the brain response when carrying out different behavioral tasks (Senior, Russell, & Gazzaniga, 2006). Such techniques allow us to relate behavioral performance together with its corresponding brain activity, and the outcomes can be interpreted to gain insights about the underlying mental operations involved in one task over the other. This contributes to the understanding of the mechanisms underlying different psychological processes and can even aid in formulation of theories concerning the same. Given the great potential of these techniques in allowing us to gain substantial scientific knowledge, it is little wonder that almost every major topic in psychology has now been investigated using such means.

In order to successfully realize the immense potential of such techniques, existing behavioral paradigms have to be suitably adapted for use in neuroscientific settings. While such paradigm adaptation is not very problematic for most fields of study, the same cannot be said for creativity. There are unique problems that surface when seeking to adapt common creativity tasks for implementation using current neuroscientific methods (Abraham & Windmann, 2007; Arden, Chavez, Grazioplene & Jung, 2010; Dietrich, 2007b; Dietrich & Kanso, 2010). To illustrate this point the example of adapting the alternate uses task in an fMRI setting will be described, but the same setbacks would be applicable to almost all creativity tasks and neuroscientific methods.

The alternate uses task is perhaps the most widely employed creativity task and, in line with its original instructions (Wallach & Kogan, 1965), participants are asked to verbally generate as many novel uses as they can imagine for five common household objects (e.g., brick, shoe). The participants' responses are assessed in terms of the number of uses generated per object (fluency) and the degree of unusualness associated with each generated use (originality). The latter is assessed either in terms of how often the same use is generated by anyone else in the sample under study (e.g., Abraham, Windmann, McKenna & Gunturkun, 2007), or by having the uniqueness of the uses rated by judges (e.g., Fink, Grabner *et al.,* 2009). A high degree of originality is considered to be indicative of greater creative ability.

Directly adapting this task for an fMRI setting is challenging for several reasons. The total number of trials (five) is very low and is likely to compromise the quality of the average BOLD response. While an increase in the number of trials could potentially resolve this issue, how many trials can be added is limited by the trial duration. In the original alternate uses task, the trial duration is usually open-ended or very long (2-4 minutes). Such lengthy trial lengths are not optimal for either event-related or epoch-related analyses of the fMRI data. The alternate uses task has therefore commonly been adapted in fMRI setups with trial lengths of 20-30 seconds. But such trials lengths are still extremely long when compared to typical trial lengths in paradigms of normative cognition, such as attention and memory. fMRI testing durations are usually not more than 30-40 minutes. So, depending on the number of conditions within a paradigm, a lengthy trial length is like to result in a low total number of trials (e.g., 8 trials in Fink, Grabner *et al.,* 2009). And, just as in the case of behavioral measures like RT, low trial numbers can compromise the stability of the average BOLD signal.

In addition, the type of response, regardless of whether it is written or spoken, can lead to severe movement-related artefacts in the brain data. Most neuroimaging studies on creativity have not openly dealt with this issue in the publications (e.g., Chrysikou & Thompson-Schill, 2011) and only a handful appear to have taken this factor into consideration when devising trial events (e.g., Fink, Grabner *et al.,* 2009). An alternative approach to get around this issue would be to have participants generate the uses in the MRI scanner silently and verbally report the uses after the experiment in the feedback session (e.g., Abraham *et al.,* in review; Howard-Jones, Blakemore, Samuel, Summers & Claxton, 2005). However, this option also comes with its own set of problems. It is difficult to claim with any magnitude of certainty that participants are consistently following task instructions in the scanner when they do not have to make any behavioral responses in association with that task. It is also not possible to rule out that the post-experiment report of the responses is unaffected by elaboration or forgetting.

Another major shortcoming in neuroscientific studies on creativity is that the control task used for comparison to the creative task is usually far less cognitively demanding and qualitatively very different from the creative task. For instance, a control task where one is to generate a story using semantically related words is considerably easier than the creative task where a story is to be generated using semantically unrelated words (Howard-Jones *et al.,* 2005). A means to get around this issue is to instruct subjects to be creative on some trials and uncreative on other trials (Chrysikou & Thompson-Schill, 2011; Howard-Jones *et al.,* 2005). But this is a suboptimal solution as it is difficult to account for how well participants can follow task instructions. It is possible, for instance, that the participants generate uncreative responses when trying to be creative, and vice versa.

A related point is that block or epoch-related fMRI analyses of the brain activity related to generating creative responses usually involves contrasting creative trials with control trials by comparing the average brain activity that takes place for each condition over a 20-30 second trial period. The problem here is that when carrying out such analyses, the resulting brain activity is not only that which accompanies the generation of a creative response, but also that which results when trying to generate a creative response. The essential point to note is that trying to be creative is not the same as actually being creative. So unless a means is found by which these factors (trying to generate creative ideas versus actual generation of creative ideas) can be dissociated from one other, the results from such analyses are necessarily confounded and not clearly informative.

Other factors such as the phenomenon of the "path-of-least-resistance" could also play a significant role in complicating expectations related to subjects' behavior. This well-documented phenomenon in creativity research refers to the tendency to approach a situation from the least cognitively demanding standpoint as possible (Finke, Ward & Smith, 1992; Ward, 1994). For example, studies have shown that when instructed to make an object within a prescribed category (e.g., furniture) using 3 geometrical figures that were chosen from a collection of 15 figures (e.g., sphere, cube, rectangular solid, tube), participants generated more creative responses when the 3 figures were randomly assigned to them by the experimenter compared to when they had the option of selecting any 3 figures themselves (Finke, 1990). When given the category of "Transportation", for instance, participants who could select the figures were more likely to pick figures with round edges (such as a sphere or wheels) that they could readily use as tires or wheels in the generated object. The participants who were assigned figures, however, had no choice but to make do with the figures they had been provided with and were therefore compelled to think in more original ways when using their figures to construct an object. The path-of-least-resistance phenomenon has a considerable impact on our propensity to generate creative responses in any given situation. Evidence shows that we cannot assume that instructing people to be creative will guarantee that they can indeed be creative. Tasks have to be constructed such that participants are compelled to think in creative ways.

Perhaps the most critical problem though in being able to assess what happens in the brain during creative thinking is that unlike most aspects of cognition and behavior, creativity cannot be prompted upon cueing in a predictable or reliable manner (Dietrich, 2007b). Participants may certainly be trying their best to think creatively while carrying out a creativity task but these attempts at being creative may not necessarily translate to actual success in creative idea generation, especially in the time frame that is necessary for useful data to be derived for an fMRI analysis. Creativity cannot be prompted in a manner that is predictable, reliable or valid with any degree of certainty. This is the reason why it has proved to be extremely difficult to time-lock brain activity to the precise moment when the creative responses are generated.

All of the aforementioned issues are severe hindrances in our ability to investigate creativity from a neuroscientific perspective. What is obvious from this admittedly dreary picture is that if the neuroscience of creativity is to progress beyond making merely general statements about the link between creativity and different parts of the brain, it is imperative that a fundamental shakeup takes place in our minds about how we conceptualize creativity as well as how to optimally employ neuroscientific methods to inform us about creativity. Such a call to arms was made a few years ago in a rousing editorial piece by Arne Dietrich where he stated that "It is high time that researchers became more creative about creativity" (Dietrich, 2007a). A necessary first step in doing so would be to methodically operationalize creativity in terms of its component processes. Following this, it is imperative that we not only adapt established creativity tasks to neuroscientific settings but also devise entirely novel paradigms that either directly or indirectly target these processes.

Such directions have already been taken in the study of the process of "insight" in creative thinking which refers to the sudden dawning of a solution to the problem that occurs as a result of a perspective or set shift (Bowden & Jung-Beeman, 2007; Bowden, Jung-Beeman, Fleck & Kounios, 2005; Jung-Beeman *et al.,* 2004). To study the process of insight in creative thinking, new paradigms have been devised and existing paradigms have been systematically and effectively adapted for use in neuroscientific settings. This has led to the favorable situation where most of the methodological and conceptual limitations that plague most neuroscientific research on creativity have been overcome. And this in turn has rendered it possible for significant advances to be made in understanding the neurcognitive mechanisms underyling this select aspect of creative thinking.

Similar efforts are currently underway in exploration of the operation of creative "conceptual expansion" (Ward, 1994) or our ability to broaden our conceptual structures in the generation of new ideas (Abraham *et al.,* in review; Kroger *et al.,* 2012; Rutter *et al.,* 2012).

The uniqueness of creative cognition

At the crux of our conceptualizations and investigations of creativity is the assumption that the kind of mental operations that bring about creative thinking are somehow distinct from those that underlie normative cognition. It is no wonder that this supposition is customarily taken to be fact given that the end products of creative thinking (e.g., creating a poem) are often unusual or extraordinary compared to the end products of normative cognition (e.g., reciting a poem from memory). But are we correct in assuming that because the end products are so dissimilar, the cognitive processes involved in normative versus creative cognition are not comparable with one another? That would mean taking on the assumption that there is a separate toolbox in the brain that specializes in creative cognition that is distinct from or only partially overlaps with the normative cognition toolbox. What are the mental operations that are unique to creativity? How do they interact with those of normative cognition? Is such a modularity based premise of creative cognition viable from an evolutionary perspective? (Cosmides & Tooby, 1994; Uttal, 2003). And what evidence would be needed to empirically validate such ideas?

Such polemic questions have seldom been posed in the literature and the issues they expose are rarely, if ever, the subject of the focus in mainstream cognitive or neuroscientific research on creativity. An exception to this is "creative cognition approach" where this issue has been broached from an information processing perspective (Finke *et al.,* 1992; Smith, Ward & Finke, 1995; Ward, Finke & Smith, 1995). According to this theoretical framework, it is highly unlikely that there are mental operations that are exclusively in place for creative cognition. The information processing toolboxes would be expected to be one and the same for both creative and normative cognition. The essential difference between creative and normative cognition though lies in the kind of the situations in which our information processing toolboxes need to be applied. The situational factors during creative cognition are open-ended or unclear whereas the situational factors during normative cognition are concrete or predictable. A situation that is open-ended and involves the generation of novel responses to reach a solution to the problem would give rise to creative cognition. Although the creative cognition framework has received some attention in the domain of cognitive science, it has only been limitedly explored from a neuroscientific point of view (Abraham & Windmann, 2007; Abraham, Windmann, McKenna & Gunturkun, 2007; Abraham, Windmann, Siefen, Daum & Gunturkun, 2006; Kroger *et al.,* 2012; Rutter *et al.,* 2012).

In fact, most theoretical frameworks that have related the brain with mental operations relevant to creativity have largely adopted what can be referred to as an "individual differences approach" where the aim has been to uncover the information processing or brain biases that differentiate highly creative individuals from average or low creative individuals. Highly creative individuals have been primarily characterized as having flat associative hierarchies in the organization of semantic networks (Mednick, 1962), defocused or diffuse attentional processing (Mendelsohn, 1976), and cognitive disinhibition or the enhanced ability to overcome contextual constraints or mental sets that hinder creative thinking (Martindale, 1999). More recent findings have linked higher creativity with a host of individual factors such as reduced white matter integrity in inferior frontal brain regions (Jung, Grazioplene, Caprihan, Chavez & Haier, 2010), greater right hemisphere contributions (Kounios *et al.,* 2008), increased frontal activity (Carlsson, Wendt & Risberg, 2000; Chavez-Eakle, Graff-Guerrero, Garcia-Reyna, Vaugier & Cruz-Fuentes, 2007), and stronger alpha synchronization (Fink, Grabner *et al.,* 2009; Fink, Graif & Neubauer, 2009).

One of the more obvious issues that need to be addressed when adopting such an individual differences based approach in creative neurocognition is to determine how consistent the reported findings are both across creativity domains and within creativity domains. So, for instance, would the finding of a positive correlation between cortical connectivity and originality on verbal creativity measure X also be expected when using another verbal creativity measure Y? And how generalizable are these effects expected to be across domains (verbal versus non-verbal creativity)? Another issue of import is the choice of the control group to the highly creative group. In studies where high versus low creative groups are classified according to their performance on one or more creativity measures, it is important to determine what "low performance" actually means in the context of the creativity tasks in question. Does low performance on the alternate uses task, for instance, indicate below average or average creative ability? This is a difficult question to answer as most creativity tasks are not standardized and have no associated norm data available. But depending on how this question is answered, the choice of which control group (low performance group or average performance group) would be a better comparison group to the high creative performance group is a critical one that is likely to impact how one interprets the associated findings.

Another approach to investigating high versus low creative groups is to contrast individuals who are highly proficient in ostensibly creative pursuits (e.g., art, music) versus those who are not. Notwithstanding the significant impediments faced when ensuring homogeneity of the samples in such studies, the assumption that insights concerning creative thinking can more readily be gained by investigating people who pursue the fine arts compared to other professions is highly debatable. Original thinking is both highly valued and associated with greater success in several professions in the world including the domains of marketing, law, engineering, advertising, research, teaching and even accounting. It is also shortsighted to indiscriminately assume that anyone who pursues the fine arts is, per definition, highly creative. Such overgeneralizations not only significantly hamper our ability to uncover the neurocognitive mechanisms underlying creative thinking, but also contribute to a great deal of inconsistency and confusion in our basic conceptualizations of what creativity entails.

Delimiting creativity

In much empirical work, creativity is customarily investigated at the product level. A response or product is judged to be creative to the extent that it is both original (or unique or unusual or statistically rare) and relevant (or fitting or appropriate or functional) to a particular end (Abraham & Windmann, 2007; Boden, 2004; Hennessey & Amabile, 2010; Runco, 2004). This general definition of creativity is applicable in most situations that call for some kind of creative problem solving. Ironically, the usefulness of this standard definition of creativity is most debatable in the context of the fine arts where is considerably more difficult to obtain a consensus on both the presence and the degree of originality associated with a work of art as well as to ascertain to what extent the factor of relevance plays a role. The situation is further aggravated by the fact that it is unclear how creativity in one domain (e.g., mathematical creativity) relates to creativity in other domains (e.g., artistic creativity).

Despite these glaring problems, we continue to carry out neurocognitive investigations on creativity across domains and make generalizations about how this is indicative of creative thinking in general. But are we really justified in grouping the insights gained from assessing the brain response of high versus low performers on the alternate uses task with those of proficient versus novice dancers when we still lack a common comprehensive framework that brings all these different facets of creative thinking together? Imagine if the neurocognitive domain of memory research was in the same position as the field of creativity is in today. This would translate to, for instance, lumping together all the findings associated with learning procedural skills (such as learning to ride a unicycle) with those associated with spatial memory (such as the organization of the London Underground network) and episodic memory (such as one's memory of graduation day). Such an undertaking would at best enable only a vague understanding of memory function alongside a complete inability to develop any knowledge of the specific mechanisms underlying different types of memory. The field of memory research greatly profits from having systematic and detailed theoretical frameworks that guide interdisciplinary empirical investigations. The same is necessary for the domain of creativity research if truly significant advances are to be made. The first step in such an endeavor would be to delineate what creativity entails.

For instance, it may be necessary to dissociate the domain of creative thinking as it applies to problem solving from the domain of creative thinking as it applies to proficiency or skill. In the case of the former, the capacity for problem solving is assessed based on performance on one or more creativity tasks (Grabner, Fink & Neubauer, 2007; Jung, Segall *et al.,* 2010) whereas in the latter situation, the level of proficiency is determined either by the degree of existing skills (e.g., artistic) which are above average (Fink, Graif *et al.,*2009; Gibson, Folley & Park, 2009) or exceptional (Hou *et al.,* 2000; A. Snyder, 2009), or develop in a startling and unanticipated manner (Miller & Hou, 2004; Miller, Ponton, Benson, Cummings & Mena, 1996). Making dissociations between creative problem solving versus proficiency when understanding creativity would mean that insights obtained by, for instance, investigating the brain connectivity in absolute pitch musicians (Loui, Li, Hohmann & Schlaug, 2011) or patients with frontotemporal dementia who develop astounding artistic skills post-stroke (Seeley *et al.,* 2008), cannot be automatically generalized to, for instance, findings associated with studying brain activations that result while performing the alternate uses task (Chrysikou & Thompson-Schill, 2011).

This is not to say that selective findings are to be ignored. In fact the opposite needs to be the case. Any study that claims its insights are relevant to the domain of creativity needs to be assessed in terms of how it fits into the larger framework of creativity. Our problem is that such a framework is currently lacking, so it is the responsibility of the researchers to carry out their investigations with these larger objectives in mind. So, for instance, when drawing allusions between the proficiency and problem solving subdomains in creativity, it would be valuable to indicate how proficiency-based findings, such as purportedly enhanced proficiency in drawing skills following transcranial magnetic stimulation (TMS) (A. W. Snyder *et al.,* 2003), can be explicitly linked to problem-solving-based findings, such as enhanced originality and brain activity as a function of cognitive stimulation (Fink *et al.,* 2010). The link between the creative problem solving and proficiency subdomains needs to be tackled and research efforts which bring both these subdivisions together, such as evaluating the brain response during jazz improvisation in musicians (Limb & Braun, 2008), will aid us in reaching this aim.

Similar attempts at circumscribing creativity would help us broach further important issues such as formalizing the differences and similarities between different types of creativity as well as operationalizing the different creativity tasks in terms of what proportion of cognitive operations are shared between them. All of these are necessary initial steps to take if the overarching objective of neuroscientific studies of creativity is to glean the underlying neural and information processing mechanisms of this most extraordinary of human abilities.

References

Abraham A, Windmann S. Creative cognition: the diverse operations and the prospect of applying a cognitive neuroscience perspective. Methods 2007; 42(1):38-48.

Abraham A, Windmann S, McKenna P, Gunturkun O. Creative thinking in schizophrenia: the role of executive dysfunction and symptom severity. Cogn Neuropsychiatry 2007; 12(3):235-58.

Abraham A, Windmann S, Siefen R, Daum I, Gunturkun O. Creative thinking in adolescents with attention deficit hyperactivity disorder (ADHD). Child Neuropsychol 2006; 12(2):111-23.

Arden R, Chavez RS, Grazioplene R, Jung RE. Neuroimaging creativity: a psychometric view. Behav Brain Res 2010; 214(2):143-56.

Boden MA. The creative mind: Myths and mechanisms. London: Routledge, 2004.

Bowden EM, Jung-Beeman M. Methods for investigating the neural components of insight. Methods 2007; 42(1):87-99.

Bowden EM, Jung-Beeman M, Fleck J, Kounios J. New approaches to demystifying insight. Trends Cogn Sci 2005; 9(7):322-8.

Carlsson I, Wendt PE, Risberg J. On the neurobiology of creativity. Differences in frontal activity between high and low creative subjects. Neuropsychologia 2000; 38(6):873-85.

Chavez-Eakle RA, Graff-Guerrero A, García-Reyna JC, Vaugier V, Cruz-Fuentes C. Cerebral blood flow associated with creative performance: a comparative study. Neuroimage 2007; 38(3):519-28.

Chrysikou EG, Thompson-Schill SL. Dissociable brain states linked to common and creative object use. Hum Brain Mapp 2011; 32(4):665-75.

Cosmides L, Tooby J. Origins of domain-specificity: The evolution of functional organization.

In L. Hirschfeld & S. Gelman (Eds.). Mapping the Mind: Domain-specificity in cognition and culture. New York: Cambridge University Press, 1994; 85-116.

Dietrich A. The wavicle of creativity. Methods 2007a; 42:1-2.

Dietrich A. Who's afraid of a cognitive neuroscience of creativity? Methods 2007b; 42(1):22-7.

Dietrich A, Kanso R. A review of EEG, ERP, and neuroimaging studies of creativity and insight. Psychol Bull 2010; 136(5):822-48.

Fink A, Grabner RH, Benedek M, Reishofer G, Hauswirth V, Fally M, Neubauer AC. The creative brain: investigation of brain activity during creative problem solving by means of EEG and FMRI. Hum Brain Mapp 2009; 30(3):734-48.

Fink A, Grabner RH, Gebauer D, Reishofer G. Koschutnig K, Ebner F. Enhancing creativity by means of cognitive stimulation: evidence from an fMRI study. Neuroimage 201o; 52(4):1.687-95.

Fink A, Graif B, Neubauer AC. Brain correlates underlying creative thinking: EEG alpha activity in professional vs. novice dancers. Neuroimage 2009; 46(3):854-62.

Finke RA. Creative imagery: Discoveries and inventions in visualization. London: Routledge, 1990.

Finke RA, Ward TB, Smith SM. Creative cognition: Theory, research, and applications. Cambridge, MA: MIT Press, 1992.

Gibson C, Folley BS, Park S. Enhanced divergent thinking and creativity in musicians: a behavioral and near-infrared spectroscopy study. Brain Cogn 2009; 69(1):162-9.

Grabner RH, Fink A, Neubauer AC. Brain correlates of self-rated originality of ideas: evidence from event-related power and phase-locking changes in the EEG. Behav Neurosci 2007; 121(1):224-30.

Hennessey BA, Amabile TM. Creativity. Annu Rev Psychol 2010; 61:569-98.

Hou C, Miller BL, Cummings JL, Goldberg M, Mychack P, Bottino V, Benson DF. Autistic savants. [correction of artistic]. Neuropsychiatry Neuropsychol Behav Neurol 2000; 13(1):29-38.

Howard-Jones PA, Blakemore SJ, Samuel EA, Summers IR, Claxton G. Semantic divergence and creative story generation: an fMRI investigation. Brain Res Cogn Brain Res 2005; 25(1):240-50.

Jung-Beeman M, Bowden EM, Haberman J, Frymiare JL, Arambel-Liu S, Greenblatt R, Kounios J. Neural activity when people solve verbal problems with insight. PLoS Biol 2004; 2(4):E97.

Jung RE, Grazioplene R, Caprihan A, Chavez RS, Haier RJ. White matter integrity, creativity, and psychopathology: disentangling constructs with diffusion tensor imaging. PLoS One 2010; 5(3):e9818.

Jung RE, Segall JM, Jeremy Bockholt H, Flores RA, Smith SM, Chavez RS, Haier RJ. Neuroanatomy of creativity. Hum Brain Mapp 2010; 31(3):398-409.

Kounios J, Fleck JI, Green DL, Payne L, Stevenson JL, Bowden EM, Jung-Beeman M. The origins of insight in resting-state brain activity. Neuropsychologia 2008; 46(1):281-91.

Kröger S, Rutter B, Stark R, Windmann S, Hermann C, Abraham A. Using a shoe as a plant pot: neural correlates of passive conceptual expansión. Brain Res 2012; 1430:52-61.

Limb CJ, Braun AR. Neural substrates of spontaneous musical performance: an FMRI study of jazz improvisation. PLoS One 2008; 3(2):e1679.

Loui P, Li HC, Hohmann A, Schlaug G. Enhanced cortical connectivity in absolute pitch musicians: a model for local hyperconnectivity. J Cogn Neurosci 2011; 23(4):1.015-26.

Martindale C. Biological basis of creativity. In Sternberg RJ. (Ed.), Handbook of Creativity. New York: Cambridge University Press, 1999; 137-52.

Mednick SA. The associative basis of the creative process. Psychol Rev 1962; 69:220-32.

Mendelsohn GA. Associative and attentional processes in creative performance. Journal of Personality 1976; 44:341-69.

Miller BL, Hou CE. Portraits of artists: emergence of visual creativity in dementia. Arch Neurol 2004; 61(6):842-4.

Miller BL, Ponton M, Benson DF, Cummings JL, Mena I. Enhanced artistic creativity with temporal lobe degeneration. Lancet 1996; 348(9.043):1.744-5.

Runco MA. Creativity. Annu Rev Psychol 2004; 55:657-87.

Rutter B, Kröger S, Stark R, Schweckendiek J, Windmann S, Hermann C, Abraham A. Can clouds dance? Neural correlates of passive conceptual expansion using a metaphor processing task: Implications for creative cognition. Brain Cogn 2012; 78(2):114-22.

Seeley WW, Matthews BR, Crawford RK, Gorno-Tempini ML, Foti D, Mackenzie IR, Miller BL. Unravelling Bolero: progressive aphasia, transmodal creativity and the right posterior neocortex. Brain 2008; 131(Pt 1): 39-49.

Senior C, Russell T, Gazzaniga MS. Methods in Mind. Cambridge MA: MIT Press, 2006.

Smith SM, Ward TB, Finke RA. The creative cognition approach. Cambridge MA: MIT Press, 1995.

Snyder A. Explaining and inducing savant skills: privileged access to lower level, less-processed information. Philos Trans R Soc Lond B Biol Sci 2009; 364(1.522):1.399-405.

Snyder AW, Mulcahy E, Taylor JL, Mitchell DJ, Sachdev P, Gandevia SC. Savant-like skills exposed in normal people by suppressing the left fronto-temporal lobe. J Integr Neurosci 2003; 2(2):149-58.

Uttal WR. The new phrenology: The limits of localizing cognitive processes in the brain. Cambridge MA. MIT Press, 2003.

Wallach MA, Kogan N. Modes of thinking in young children: A study of the creativity-intelligence distinction. New York: Holt, Rinehart & Winston, 1965.

Ward TB. Structured imagination: The role of category structure in exemplar generation. Cognitive Psychology 1994; 27:1-40.

Ward TB, Finke RA, Smith SM. Creativity and the mind: Discovering the genius within. New York: Plenum Press, 1995.

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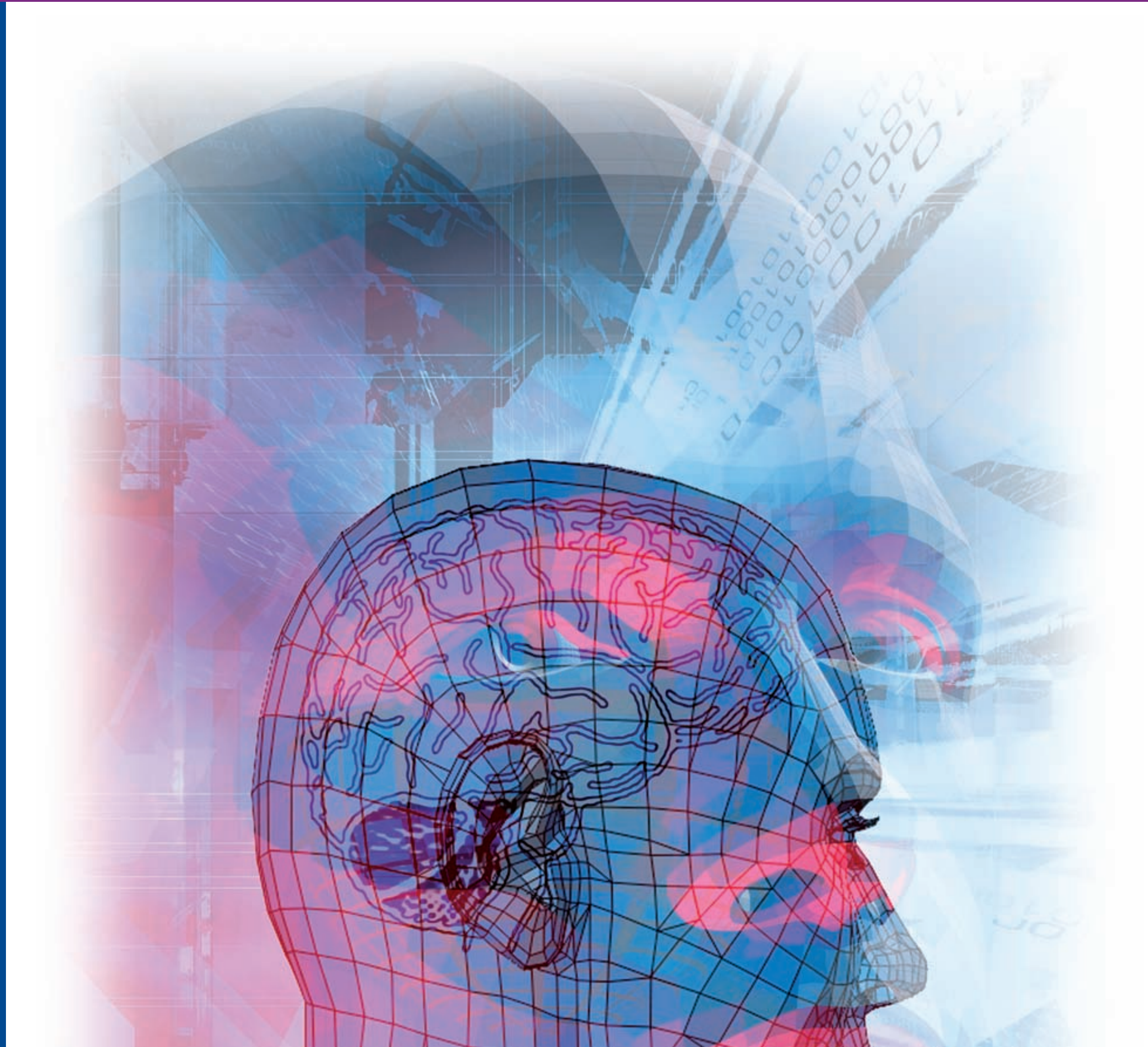

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