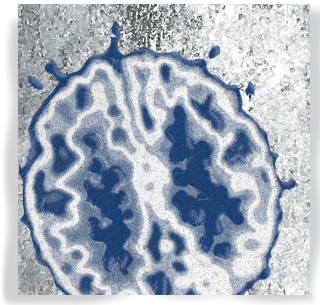
Creativity in art and science: are there two cultures?

Nancy C. Andreasen, MD, PhD, Kanchna Ramchandran, PhD



The study of creativity is characterized by a variety of key questions, such as the nature of the creative process, whether there are multiple types of creativity, the relationship between high levels of creativity ("Big C") and everyday creativity ("little c"), and the neural basis of creativity. Herein we examine the question of the relationship between creativity in the arts and the sciences, and use functional magnetic resonance imaging to explore the neural basis of creativity in a group of "Big C" individuals from both domains using a word association protocol. The findings give no support for the notion that the artists and scientists represent "two cultures." Rather, they suggest that very gifted artists and scientists have association cortices that respond in similar ways. Both groups display a preponderance of activation in brain circuits involved in higher-order socioaffective processing and Random Episodic Silent Thought /the default mode.

 Dialogues Clin Neurosci. 2012;14:49-54.

Keywords: *creativity; neuroimaging; fMR; REST; default network; association cortex*

Author affiliations: Psychiatric Iowa Neuroimaging Consortium; University of Iowa Carver College of Medicine; Iowa City, Iowa, USA

Introduction

The capacity to be creative is one of the most important characteristics that human beings possess. Long ago, some of our ancestors manifested the human capacity for creativity by seeing a grinding tool in a stone, a piercing projectile weapon in a thin cuneiform-shaped piece of flint, or a mechanism for moving things more easily in a round wheel-shaped object. They developed the capacity to pass information on to future generations by telling oral tales, and ultimately they developed ways to record these tales in writing. They identified principles of geometry and the physics of force and its mechanisms and built pyramids and temples. They painted in caves and later in temples using natural colors such as charcoal, ultimately moving on to fresco, oil, and acrylic. A "great chain of being" extends from them in the past to us in the present. Some of our great current creative people discover biological principles such as the role of telomerase, develop computers and digital imaging, design techniques for unmanned space research, imagine new worlds such as those of *Star Wars*, or pass on the experience of beauty or morality through novels and essays.

Creativity is a topic of enormous importance—and one that poses enormous challenges. Studying it from a scientific perspective, as opposed to an esthetic one, raises

Address for correspondence: Nancy C. Andreasen, MD, PhD, Psychiatric Iowa Neuroimaging Consortium; University of Iowa Carver College of Medicine, 200 Hawkins Drive, Room W278 GH, Iowa City, IA 52242, USA
(e-mail: luann-godlove@uiowa.edu)

a daunting series of questions. How should it be defined? Should we conceive of it as a unitary construct, or should we posit that there are "multiple creativities," much as Gardner has argued that there are "multiple intelligences."[1] What is the nature of the creative process? Does it involve flashes of insight, or slow preparatory processes, or both?[2,3] Is there a continuum between "big C" (genius-like creativity possessed by only a few) and "little c" (ordinary creativity that all human beings possess)?[4] What methods can be used to study it? How, during a golden age of neuroscience, can we develop ways to understand and measure its neural mechanisms? Some of these questions are addressed by Simonton in this issue. Here we focus on the topic of unitary creativity vs multiple creativities and the measurement of neural mechanisms.

Unitary vs multiple creativities: are there two cultures?

For many lay people, the word "creative" evokes images of novelists, poets, composers, and visual artists. If prompted, they would acknowledge the creativity of mathematician/physicists such as Einstein or inventors such as Thomas Edison, but there is a general tendency to assume that creativity is more associated with the arts than the sciences. This stereotyped view of creativity led C. P. Snow, who was both a physicist and a respected novelist, to deliver a provocative lecture, later published as a book, complaining about the perniciousness of the schism between the "two cultures"[5]:

> In our society (that is, advanced western society) we have lost even the pretense of a common culture. Persons educated with the greatest intensity we know can no longer communicate with each other on the plane of their major intellectual concern. This is serious for our creative, intellectual and, above all, our normal life. It is leading us to interpret the past wrongly, to misjudge the present, and to deny our hopes of the future. It is making it difficult or impossible for us to take good action…
>
> The literary intellectuals give a pitying chuckle at the news of scientists who have never read a major work of English literature. They dismiss them as ignorant specialists. Yet their own ignorance and their own specialisation is just as startling….
>
> Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is about the scientific equivalent of: *Have you read a work of Shakespeare's?*

The schism between the "two cultures" described by Snow would have been astounding to many great creative figures of earlier times, such as Plato, Aristotle, Michaelangelo, Leonardo da Vinci, or Francis Bacon. For them the study and observation of the world around them, often referred to as "nature" or "the natural world," was their source of inspiration, truth, and wisdom. In the absence of technology, "nature" was their laboratory. Using this laboratory, Plato and Aristotle laid the foundations for much of modern physics and mathematics, as well as more "artistic fields" such as esthetics, ethics, and political science. Leonardo, a devout "student of nature," was a painter and sculptor, but he was also an engineer, inventor, and anatomist. Michelangelo was also a painter and sculptor, as well as a poet, but he also was an engineer, anatomist, and architect. Francis Bacon is considered to be the founder of modern scientific methods, as articulated in the *Novum Organum*, but he also had a brilliant command of English prose writing, as demonstrated in his Essays. As he says in Aphorism 1 of the *Novum Organum*:

> Man can act and understand no further than he has observed, either in operation or in contemplation, of the method and order of nature.[6]

Any of these people would have been amazed if someone told him that clear boundaries exist between artistic and scientific thinking and creativity.

What has in fact occurred during recent times, particularly the past century, has been an increasing emphasis on specialization, with is frequently encouraged by educational systems and the structure of government agencies that fund education, the arts, and the sciences. Particularly in Great Britain and other European countries, students must choose an area of specialization prior to applying to university, where they are tracked into specific disciplines such as literature, social sciences, law, medicine, physics, and mathematics. The American system is more flexible, but specialization is still encouraged. There is very little time for doing studies that might "bridge the schism" described by Snow. Implicit in this specialized organizational structure is the notion that arts and sciences are driven by fundamentally different ways of thinking—and ultimately creating. Is this true?

The Iowa Study of Creative Genius

A variety of strategies can be used to study creativity. One that was widely used during the 1950s and 1960s was the Case Study Method. Using this method investigators identified individuals who were widely recognized as being creative, often using nominations from their peers, and invited them to participate in intensive assessments, applying the instruments that were available at the time. Barron, Drevdahl, and Roe are exemplars of this approach.[7-12] They are also exemplars in that they often chose to study both artists and scientists. Their work was influenced by psychodynamic thinking and the psychological tools of the time (eg, projective and personality tests) and is therefore less informative for the types of questions being asked today, rooted as they are in the principles of neuroscience. Ongoing research on creativity at the University of Iowa, although guided by neuroscientific principles, is also guided by their work using the case study method.

Iowa may seem like an unlikely place to base a major study of creativity. Initial appearances are, however, deceiving. Iowa City is one of five cities designated as a "City of Literature" by UNESCO and is the only American city that has received this designation. (Edinburgh, Melborne, Dublin, and Reykjavik are the other four.) The University of Iowa is home to the Writers' Workshop, the oldest and most famous creative writing program in the world, which recently celebrated its 75th anniversary in the spring of 2011. Most major American writers have been part of the Workshop at some time in their careers, either as students or teachers. Notable examples include Kurt Vonnegut, John Irving, Phillip Roth, and John Cheever, and recent Pulitizer Prize fiction winners Jane Smiley (1992), Marilynne Robinson (2005), and Paul Harding (2010). Access to this rich resource permitted studies of creativity conducted in the 1970s and 1980s, which examined the relationship between creativity and IQ, cognitive style, and mental illness.[13-16] Several findings emerged. The writers displayed a "cognitive style" on some of the neurocognitive tests that indicated a capacity to form original associative links. Their IQs were almost identical to an educationally matched group of noncreative controls—in the 120 range. They displayed a higher rate of mood disorder than the controls, as did their first-degree relatives. Their first-degree relatives also had a higher rate of creativity than did the relatives of the controls. A noteworthy observation concerning the familiality of creativity is that it did not breed true as to type. Relatives of writers sometimes had made noteworthy achievements in other apparently distant fields such as biochemistry or mathematics, as well as more "artistic" fields such as visual arts or dance. It has been an open question as to whether these findings are specific to writers (as a special and specific form of creativity), or whether they would generalize to a group of individuals who represent diverse forms of creativity in both arts and sciences. Implicitly, it raised the question as to whether creativity in the arts and the sciences are based on similar traits and mental processes, or on different ones, and if different, what the differences might be.

Therefore, we recently began a second study, conceived of as an important follow-up to the "Workshop Study": The Iowa Study of Creative Genius. This project, still in progress, is examining equal numbers of artists and scientists who represent what Simonton calls "big C" creativity. That is, they are selected because they have been recognized as highly creative through the receipt of major awards such as Nobel Prizes, Pulitzer or other literary prizes, Academy Awards, the National Medal of Science, or the award of multiple patents. Participants to date have included notable people such as George Lucas or Liz Blackburn.

Like its predecessor, the Workshop Study, the Iowa Study of Creative Genius uses the case study method to explore characteristics of an "extreme group" of highly creative people. It includes the multiple facets examined in the Workshop Study, but it adds the modern tools of neuroimaging to explore the neural basis of creativity.

The neural mechanisms of creativity

Although we have not previously conducted structural (sMR) or functional (fMR) magnetic resonance imaging studies in creative individuals, we have studied a closely related phenomenon: thoughts arising from unconscious processes.[17] Creative individuals frequently and quite consistently report that they get their best ideas intuitively and from unconscious reservoirs. For example, Neil Simon stated: "I don't write consciously. It is as if the muse sits on my shoulder."[16] Several years ago we conducted a positron emission tomography (PET) study of conscious vs unconscious episodic memory (ie, memories that draw on reservoirs of personal experience). We referred to the unconscious memory processes,

which were assessed during the resting state, as Random Episodic Silent Thought (REST), a title intended to be ironic, given that the brain is highly active during this state. We observed that during REST the association cortices were highly active, in comparison with conscious thought.[17] Since that study, a large literature has developed that explores REST, now renamed the Default Mode Network, and that has yielded surprisingly consistent findings that repeatedly implicate association cortex regions and create "the brain's dark energy." [18, 19] Therefore, we have formulated the hypothesis that the neural basis of creativity may be highly developed association cortices. This study examines that hypothesis in a diverse group of highly creative ("big C") people using fMR.

A major challenge to the exploration of the neural mechanisms of creativity in "big C" individuals is to choose specific tasks appropriate for assessing the creative process. Because the creative process is intuitive and spontaneous, we do not believe that it is feasible to attempt to design a functional imaging study that will model "big C" thought processes during the act of creation and that will capture brain function at the precise time that original or novel thoughts are occurring. Instead, we have based our design on the hypothesis that the creative brain possesses trait-like mental processes that are present even during more mundane thought. Thus we have chosen tasks that will assay the functions of association cortex: eg, word association. We hypothesize that during this relatively simple and menial task, creative individuals will have novel associations and more active association cortices.

Imaging study methods and results

The stimulus materials are new, locally developed, and programmed in Eprime using a block design. They were modified in a variety of ways during the debugging phase to ensure that instructions are clear, to produce good behavioral responses and activations that are replicable across individuals, and to maximize efficiency. In order to reduce head movement in the scanner, responses are made silently, with task completion signaled by a button press to measure reaction time and document that the subject is performing the task; behavioral data are collected using a digital recorder in a post-test after the scanning session. Button presses are performed on locally-developed MR-compatible ergonomic right and left handed four-digit response key pads. (These were built using acrylic hand/wrist splints from our Burn Unit and are much more comfortable than the average fMR keypad.) Prior to scanning, subjects are given a training session, to ensure that they understand the instructions, are familiar with the nature of the tasks, and are comfortable doing them. During the training they are also exposed to a sound background that duplicates scanner noise so that they are desensitized to it as a distractor. The actual content of training materials is different from those used during the fMR scan, but the design (ie, length of blocks, alternating experimental and control tasks, etc) is identical to what they will be doing in the scanner. Subjects repeat the tasks until they are familiar with the material and responses and feel that they can comfortably do the tasks in the scanner.

The words used for the word association task consist of nouns and verbs; they were selected from a list of the 5000 most commonly used words in English. Subjects look at the screen and silently say the first word that comes to mind; the control task consists of looking at a two-digit number on the screen and silently saying it. For both tasks subjects signal that they have responded with a button press. Within a run seven blocks of words (12 words each) alternate with eight blocks of numbers (10 numbers per block). Each word/number is on the screen for 1850 ms, followed by 150 ms of blank screen.

For image analysis, scans are corrected for motion using the AFNI algorithm to align each scan to the first image of the first functional scan. Motion is estimated for each subject as the average maximal displacement of subsequent images from the reference image across the six functional scans corresponding to the six runs of the task. Once aligned, the data are normalized by scaling the whole-brain signal intensity to a fixed value of 1000. Functional images are aligned to a 3D structural image. Following spatial normalization, individual functional images are averaged together for each of the two groups using a random effects model.

To date we have studied four artists and three scientists using this design. The artists included three writers and one writer/film-maker who also pioneered the use of digital imaging. The scientists included one neuroscientist and two molecular biologists. Their imaging data for the Word Association Task appears in *Figure 1*. Since this is a verbal task, one might expect to see different activity in the artists than in the scientists. However, the images indicate that the generation of word associations

recruits similar brain regions in both the artist and the scientist groups. At a basic level, it indicates that creative processing may involve the interactions of several regions between both hemispheres, laying to rest the notion that creativity resides primarily in the right hemisphere.[20] While the left hemisphere appears to have larger swathes of more intense activation, this may be attributed to the possibility that a verbal task is likely to recruit more of the left (language) hemisphere. It also appears that the association cortices are heavily recruited in this task in both groups, involving components that perform a variety of specialized associations. Thus, on the anterior portions of the brain, both groups show increased intensity in the left pre- and middle central gyri (Brodmann Area [BA] 6), a region that is central to the supplementary/association motor cortex. This region of activation extends down to the left inferior frontal gyrus. Both regions have been implicated in semantic and phonological processing and "theory of mind"/perspective.[21-23] Similarly, the left posterior association cortex is recruited in both groups with peak intensity in the left middle temporal gyrus (BA 21) a region that has also been implicated in complex semantic processing and theory of mind in attributing intention to others.[23] Another area of the brain associated with theory of mind and perspective taking that has been activated in both groups is the left anterior cingulate (BA 32).[23] Both groups also show intense activation in the right insula, a region associated with visceral processing, but specifically in the context of emotional self-awareness and non-language vocalizations such as laughing and crying.[24]

The bilateral visual cortices have also been invoked in imagery processing in this task in both groups, involving the cuneus and the lingual gyrus. While the involvement of this region is to be expected in visual imagery associated with verbal stimuli, there is increasing evidence that sensory cortices (such as the cuneus and lingual gyrus) are also involved in multimodal higher-order sensory processing (similar to the association cortices) as would be relevant to the creative generation of verbal responses.[25]

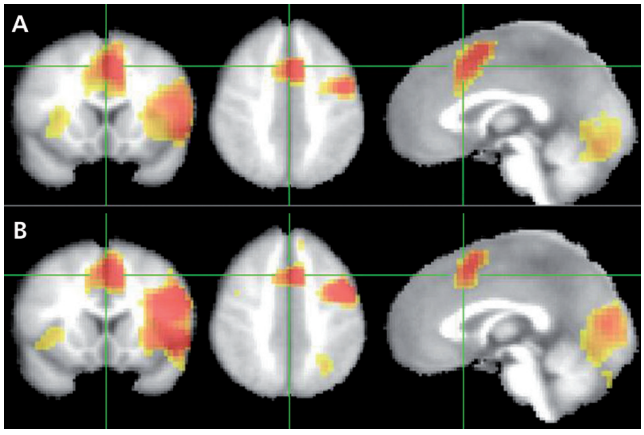


Figure 1. Patterns of activation during an fMR word association task performed by artists *(Figure 1a)* and scientists *(Figure 1b)* show strikingly similar patterns of activation in multiple regions of association cortex and areas involved in socioaffective processing. fMR, functional magnetic resonance

Discussion

This small group of "big C" individuals includes a diverse group of artists and scientists. When the activations in the two groups are compared, the findings give no support for the notion that the artists and scientists represent "two cultures." Rather, they suggest that very gifted artists and scientists have association cortices that respond in similar ways.

Both groups display a preponderance of activation in brain circuits involved in higher-order socioaffective processing and REST/the default mode network. This is to be expected, given that the artist group is comprised of storytellers working with various media. However, it is novel to report this similar pattern of activation in a group of scientists, stereotyped to be less verbal in their creative genius. One plausible explanation is that all highly creative geniuses, the "big C's," are unique and unified in their experience of high affectivity, vivid imagery, and ability to intuit feelings and thoughts that occur in the minds of others. Perhaps this intensity of feeling and rich imagination contributes to their passion, creativity, and discovery of new frontiers. ❑

Acknowledgements: This study was funded by a Senior Investigator Award to Dr Andreasen from NARSAD.

La creatividad en el arte y en la ciencia: ¿hay dos culturas?

El estudio de la creatividad se caracteriza por diversas preguntas clave, como la naturaleza del proceso creativo, si acaso hay múltiples tipos de creatividad, la relación entre altos niveles de creatividad ("Gran C") y la creatividad cotidiana ("poca c"), y las bases neurales de la creatividad. En este artículo se examina la pregunta acerca de la relación entre la creatividad en las artes y las ciencias y el empleo de imágenes de resonancia magnética funcional para explorar las bases de la creatividad en un grupo de individuos de ambas áreas con "Gran C" mediante un protocolo de asociación de palabras. Los hallazgos no apoyan la idea que se tiene que los artistas y los científicos representan "dos culturas". Sino que ellos sugieren que los artistas y científicos muy talentosos tienen cortezas de asociación que responden de formas similares. Ambos grupos presentan una activación preferente de los circuitos cerebrales involucrados en el procesamiento socioafectivo de orden superior y en el pensamiento silencioso episódico aleatorio/ modo por defecto.

Créativité dans l'art et créativité dans la science : deux cultures distinctes ?

Un certain nombre de questions clés caractérisent l'étude de la créativité, comme la nature du processus créatif, la multiplicité de la créativité, les relations entre les hauts niveaux de créativité (avec un grand « C ») et la créativité au quotidien (avec un petit « c ») et la base neuronale de la créativité. Nous examinons ici la question des relations entre la créativité dans les arts et la créativité dans les sciences en utilisant l'imagerie par résonance magnétique fonctionnelle pour explorer les bases neuronales de cette créativité dans un groupe d'individus « grands C » dans ces deux domaines en utilisant un protocole d'association de mots. Aucun résultat ne permet de soutenir l'idée selon laquelle art et science représentent « deux cultures ». Ils permettent plutôt de penser que les artistes et les scientifiques particulièrement doués présentent un cortex associatif qui répond de la même façon. Les deux groupes manifestent une prédominance de l'activation des circuits cérébraux impliqués dans un traitement des données socioaffectives d'ordre supérieur et dans la pensée silencieuse épisodique aléatoire/ le « mode par défaut ».

REFERENCES

1. Gardner H. *Intelligence Reframed: Multiple Intelligences for the Twenty-First Century*. New York, NY: Basic Books; 1999.
2. Kounios J, Fleck JI, Green DL, et al. The origins of insight in resting-state brain activity. *Neuropsychologia*. 2007;46:281-291.
3. Bowden EM, Jung-Beeman M. Aha! Insight experience correlates with solution activation in the right hemisphere. *Psychonom Bull Rev*. 2003;10:730-737.
4. Simonton DK. Quantifying creativity: can measures span the spectrum? *Dialogues Clin Neurosci*. 2012;14:100-104.
5. Snow CP. *The Two Cultures and the Scientific Revolution*. New York, NY: Cambridge University Press; 1959.
6. Bacon F. *The Works of Francis Bacon*. New York, NY: Hurd and Houghton, 1928.
7. Mackinnon, D.W. Personality and the realization of creative potential. *Am Psychol*. 1965;20:273-281.
8. Drevdahl JE, Cattell RB. Personality and creativity in artists and writers. *J Clin Psychol*, 1958;14:107-111.
9. Roe A. A psychological study of physical scientists. *Genet Psychol Monogr*. 1951;43:123-235.
10. Roe A. The personality of artists. *Ed Psychol Meas*. 1946;6:401-408.
11. Taylor CW, Barron FX. Scientific creativity, its recognition and development. *Utah Creativity Research Conference*. New York, NY: John Wiley & Sons; 1963.
12. Taylor CW, Barron F. *Scientific Creativity*. New York, NY: John Wiley & Sons; 1964.
13. Andreasen NJC, Canter A. The creative writer: psychiatric symptoms and family history. *Comp Psychiatry*, 1974;15:123-131.
14. Andreasen NJC, Powers PS. Creativity and psychosis: an examination of conceptual style. *Arch Gen Psychiatry*. 1975;32:70-73.
15. Andreasen NC. Creativity and mental illness: prevalence rates in writers and their first degree relatives. *Am J Psychiatry*. 1987;144:1288-1292.
16. Andreasen NC. *The Creating Brain: the Neuroscience of Genius*. New York, NY; Washington, DC: Dana Press, 2005.
17. Andreasen NC, O'Leary DS, Cizadlo T, et al Remembering the past: two facets of episodic memory explored with positron emission tomography. *Am J Psychiatry*. 1995;152:1576-1585.
18. Buckner RL, Andrews-Hanna JR, Schacter DL. The brain's default network:anatomy, function, and relevance to disease. *Ann N Y Acad Sci*. 2008;1124:1-38.
19. Raichle ME. The brain's dark energy. *Science*. 2006;314:1249-1250.
20. Lindell AK. Lateral thinkers are not so laterally minded: hemispheric asymmetry, interaction and creativity. *Laterality*. 2011;16:479-498.
21. Martin A, Wiggs CL, Ungerleider LG, Haxby JV. Neural correlates of category specific knowledge. *Nature*. 1996; 379:649-679.
22. Fiez JA. Phonology, semantics and the role of the inferior prefrontal cortex. *Hum Brain Map*. 1997;5:79-83.
23. Carrington SJ, Bailey AJ. Are there theory of mind regions in the brain? A review of the neuroimaging literature. *Hum Brain Map*. 2009;30:2313-2335.
24. Sander K, Scheich H. Left auditory cortex and amygdala, but right insula dominance for human laughing and crying. *J Cogn Neurosci*. 2005;17:1519-1531.
25. Laurienti PJ, Burdette GH, Wallace MT, Yen Y, Field AS, Stein BE. Deactivation of sensory cortices by cross-modal stimuli. *J Cogn Neurosci*. 2002;14:420-429.