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# Cortical morphology of visual creativity

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ABSTRACT

*Background and objective:* The volume of cortical tissue devoted to a function often influences the quality of a person's ability to perform that function. Up to now only white matter correlates of creativity have been reported, and we wanted to learn if the creative visuospatial performance on the figural Torrance Test of Creative Thinking (TTCT) is associated with measurements of cerebral gray matter volume in the regions of the brain that are thought to be important in divergent reasoning and visuospatial processing.
*Methods:* Eighteen healthy college educated men (mean age = 40.78; 15 right-handers) were recruited (via advertisement) as participants. High-resolution MRI scans were acquired on a 1.5 T MRI scanner. Voxel-based morphometry regression analyses of TTCT to cortical volume were restrained within the anatomic regions identified.
*Results:* One significant positive focus of association with TTCT emerged within the right parietal lobe gray matter (MNI coordinates: 44, −24, 63; 276 voxels).
*Conclusions:* Based on theories of parietal lobe function and the requirements of the TTCT, the area observed may be related due to its dominant role in global aspects of attention and visuospatial processing including the capacity for manipulating spatial representations.


## 1. Introduction

### 1.1. Definition of creativity and its relation to divergent thinking

There have been many definitions of creativity. Bronowski (1972) defined creativity as the ability to find unity in what appears to be diversity or finding the thread that unites. This definition does not mention novelty-originality and thus Heilman (2005) defined creativity as "the ability to understand, develop and express in a systematic fashion, novel orderly relationships".

Novelty-originality requires divergent thinking, which is often considered an important and measurable component of creativity (Guilford, 1967; Kim, 2008; Ryder, Pring, & Hermelin, 2002). Creativity is considered to be an adaptive mental trait.Whereas there are thresholds of intelligence required for specific forms of creativity, once that threshold is reached, creativity has little or no relationship to intelligence (Runco, 2007). Early considerations in measuring divergent thinking included Grant and Berg's (1948) development of the Wisconsin Card Sorting Test (WCST) for assessing the establishment of mental set as well as switching/disengaging from a strategy when it no longer was acceptable and finding an alternative sorting strategy (divergent thinking). Later, Guilford (1967) refined the notion of divergent thinking so as to be measured by the capacity to generate as many original and creative responses to a presented stimulus as possible. Though Guilford proposed both divergent thinking and convergent thinking were relevant to creativity, strong support has been found primarily for the association of divergent thinking and creativity (Kim, 2008; Ryder et al., 2002). Zangwill (1966) suggested that frontal lobe dysfunction could disrupt disengagement and divergent thinking. Subsequently Milner and Petrides (1984) demonstrated that patients who had frontal resections of epileptic foci for the treatment of medically intractable epilepsy were impaired on the WCST, providing empirical support for Zangwill's hypothesis that the frontal lobes are critical for disengagement with divergent thinking. Additional support for that hypothesis comes from functional imaging studies which demonstrate that when normal participants are

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performing the WCST they activate their frontal lobes (Weinberger, Berman, & Zec, 1986).

### 1.2. Cortical representations

Divergent reasoning is not the only step in the creative process. Creativity also requires the storage and manipulation of information and knowledge. Evidence for a modular organization of the human brain is hemispheric specialization, the left hemisphere being important for propositional language, including speech, reading, and writing and the right being important in spatial cognition (Benton, Hannay, & Varney, 1975) as well as spatial imagery (Butters, Barton, & Brody, 1970). The left hemisphere mediates categorical thinking and focused attention and the right mediates continuous-coordinate thinking and global attention (Barrett, Beversdorf, Crucian, & Heilman, 1998; Kosslyn, 1988; Robertson, Lamb, & Knight, 1988). Finding the thread that unites often requires a convergence of the knowledge stored in cortical modules. James (1890), one of the founders of modern psychology, suggested that creativity requires an “unheard of combination of elements and the subtlest associations”. Spearman (1931) also suggested that creativity results from the combination of ideas and these ideas are represented in modular networks distributed in different regions of the cerebral cortex.

Gall (1819) whom first put forth the concept of modularity also posited that bigger was better, a position that has been recently applied to the gray matter of normally developed adults as the ‘larger is more powerful’ doctrine (DeYoung et al., 2010). Whereas Broca (1861) demonstrated that the left hemisphere (versus right) of right handed people is dominant for mediating speech and language, it was not until about 100 years later that Geschwind and Levitsky (1968) demonstrated that there were left right asymmetries in the temporal lobe speech region, such that the planum temporale was on average one-third longer in the left than in the right hemisphere.

### 1.3. Creativity and inter-hemispheric connectivity

The human brain has both intra and interhemispheric connections. The major structure connecting the independent modular systems in the right and left hemisphere is the corpus callosum (CC). The importance of connectivity in creativity was illustrated by Lewis (1979) who used the Inkblot or Rorschach Psychodiagnostic test to assess creativity before and after 8 patients with intractable epilepsy underwent CC resection. Lewis found that following section of the CC, these patients demonstrated reduced creativity. To perform well on this test of creativity the participants must engage in a visuospatial analysis of the inkblots and then verbalize the results of this analysis. The reduced creativity seen in the participants may have been related to a visuospatial-verbal disconnection such that the callosal sectioning prevented the visuospatial analysis performed by the right hemisphere from reaching the verbal left hemisphere, and thus the verbal left hemisphere had to rely on the visuospatial analysis performed by the less adept left hemisphere. Bogen and Bogen (1988) posited the CC transfers specialized information between the hemispheres, and that this transfer was important for many tasks including creative innovation. They also thought that hemispheric specialization occurs, in part, because normally this callosal mediated interhemispheric communication is incomplete and this incomplete interhemispheric communication permits each hemisphere to develop independent networks. These networks store different forms of knowledge and use different forms of cognitive processes (hemispheric specialization). A recent study by Moore et al. (2009) assessed visuospatial creativity in healthy right handed men by using the Torrance Test of Creative Thinking (TTCT; Torrance, 1966) to learn if creativity was associated with the size of the CC as determined by anatomic magnetic resonance imaging (MRI). Visuospatial TTCT scores correlated negatively with the size of the splenium of the CC but not with overall left or right hemisphere white matter volume. This study, therefore, does appear to support Bogen and Bogen’s (1988) postulation that decreased callosal connectivity enhances hemispheric specialization. In regard to the splenium of the corpus callosum, Putnam, Steven, Doron, Riggall, and Gazzaniga (2010) used diffusion tensor imaging to delineate the complete cortical projection topography of the human splenium in normal participants. They found both homotopic and heterotopic connections between the splenium and the posterior visual areas, as well as the posterior parietal cortices. They also found more instances of connections with the right hemisphere, indicating a hemispheric asymmetry in interhemispheric connectivity within the splenium.

### 1.4. Cortical anatomy

If healthy participants who had greater visuospatial creativity had smaller spleniums, it follows more highly creative people may also demonstrate differences in the cortical regions connected by the CC. The frontal and parietal lobes are two possible cortical areas where these differences might be manifested. As the frontal lobes are implicated in divergent reasoning and Jones-Gotman and Milner (1977) demonstrated that patients with right frontal lesions are impaired at creating a variety of different drawings, it is possible that patients with smaller CC and greater visuospatial creativity will have more highly developed right frontal lobes. In addition, Grabner, Fink, and Neubauer (2007) hypothesized creative thinking was associated with anterior networks including the cingulate gyrus, lateral prefrontal, and supplemental motor area, and they demonstrated an association between creativity and electro-physiology of the frontal and central regions of the right hemisphere. A study of melodic and rhythmic improvisation in pianists concluded the invention and selection of novel motor sequences activates several overlapping bilateral frontal lateral and medial regions (Berkowitz & Ansari, 2008).

The drawing tests of the TTCT require both visuospatial imagination and skills. It has been repeatedly demonstrated by a variety of study techniques that visuospatial skills are mediated by the right parietal lobe (e.g., Fite, Conrad, Hom, Sarff, & Majovski,1992). In a recent study, parietal activation was inversely correlated with creativity ratings on a pen designing task, and length of design training predicted a decrease in parietal activation during the design task (Kowatari et al., 2009). These investigators posited that suspension of parietal activity, critical for visual imagery and mental rotation, promoted creative processes. Since the drawing test on the TTCT requires visuospatial imagination and skills, people who have a highly developed right parietal lobe might have superior creative performance on the drawing portion of the TTCT.

### 1.5. Study objectives

A variety of studies have provided evidence of an association between creativity and intra- and inter-hemispheric connectivity using methods such as cortical electrophysiological coherence (anteriorly and centrally; Grabner et al., 2007), and cerebral blood flow (anteriorly; Carlsson, Wendt, & Risberg, 2000). However, the anatomic morphology of the cortical gray matter has not been studied in relation to creative task performance despite the availability of quantification techniques. The role of cerebral cortex is critical given its necessity for higher level cognitive functions and recent evidence of the experience dependent nature of neural plasticity and gray matter (Aydin et al., 2007; Maguire et al., 2000). Therefore, we conducted an investigation of gray matter in subjects who