Diffusion Tensor Imaging of Creativity in Normal Human Subjects

R. E. Jung[1,2], A. Caprihan[1], R. S. Chavez[1], R. A. Flores[1], and R. J. Haier[1]
[1]Mind Research Network, Albuquerque, New Mexico, United States, [2]Neurosurgery, University of New Mexico, Albuquerque, New Mexico, United States

Introduction

The construct of creativity, defined here as the capacity to produce something both novel and useful within a given social setting (Flaherty, 2005) has garnered increased interest within the cognitive neurosciences in with the maturing of modern neuroimaging techniques. Indeed, relationships have been shown between creativity and frontotemporal dementia (Miller & Hou, 2004), and the frontal lobes have been implicated in creativity across numerous imaging paradigms (Fink et al., 2008; Bechtereva et al., 2004; Carlsson et al., 2000). However, there remains debate as to whether the frontal lobe plays a significant role in the creative process or whether more posterior brain regions (or subcortical regions) predominate (Dietrich, 2004; Heilman et al., 2003). We hypothesized that measures of diffusion tensor imaging would be *inversely* correlated with measures of divergent thinking (DT) and openness to experience, both centrally linked with the construct of creativity (Sternberg, 1999).

Methods

All images were acquired on a 3 T Siemens scanner system (Erlangen, Germany). A 72-slice, diffusion-weighted, spin-echo, echo-planar imaging (EPI) scan was acquired in 35 directions in the transverse plane: TR=9000,TE=84, FOV=256 mm, slice thickness = 2.0 mm, diffusion gradient strength mT/m (resulting in a b-value of 800s/mm2. Total scan time for each DTI sequence was 5:42. Two DTI runs were acquired and averaged. DTI and creativity measures were obtained from a cohort of 37 neurologically and psychiatrically healthy adults ranging age 18 to 29. Creativity was assessed with measures of divergent thinking described previously (Miller & Tal, 2007). Five independent judges ranked creative products of each subject, with high inter-rater reliability (α= 0.89), from which a "Creativity IQ" (CIQ) was calculated. Personality was measured with the NEO-FFI-PR, which assesses five main factors of normal personality functioning including neuroticism, extroversion, openness to experience, agreeableness, and conscientiousness. DTI data was processed using Tract-Based Spatial Statistics (Smith, et al. 2006) from which each subject's FA image was registered to a group "skeletonized" FA image. Applying a white matter atlas to obtain regions of interest, FA values were average across each voxel within each subject's particular fiber tract to calculate the mean FA of that tract (Figure 1).

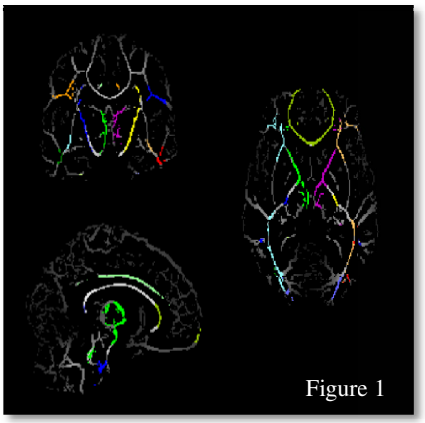
Figure 1

Results

In stepwise linear regression, we found that FA of the right inferior-frontal fasciculus *inversely* predicted the CIQ (F = 9.49, p = .004, r2 = .20)(Figure 2). Similarly, left anterior thalamic radiation FA *inversely* predicted Openness (F = 13.72, p = .001, r2 = 25)(Figure 3). Post hoc regressions were also obtained for other personality variables, with significant relationships found between the left cingulate gyrus – hippocampus extension FA for both extroversion (F = 9.6, p =.004, r2 = .18), and agreeableness (F =4.5, p = .04, r2 = .08). All relationships between FA and behavior were *inverse*.

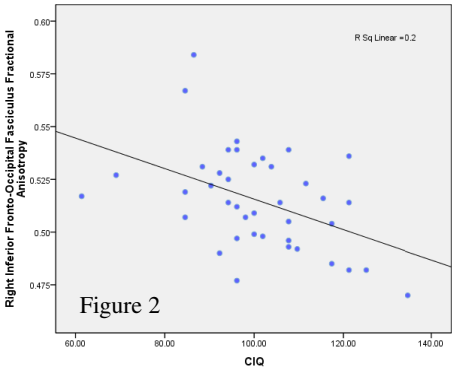

Figure 2

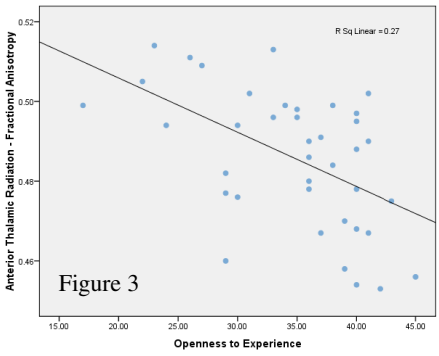

Figure 3

Discussion

The vast majority of imaging studies show positive relationships between neuroimaging findings (e.g., DTI, MRS, sMRI) and complex behavior (e.g., intelligence) in normal subjects (Jung & Haier, 2007). While the notion that "more is better" is overwhelmingly supported within the cognitive neurosciences, the brain is comprised of interdependent excitatory and inhibitory networks, which would tend to preclude such a universal design. Indeed, we make note of the recent "free energy principle" of brain functioning by which the brain works to minimize the entropy involved in performing a cognitive task (Friston, Kilner et al. 2006). Previous research has shown decreased tissue volume associated with increasing intelligence (Shaw, Greenstein et al. 2006), and intelligence measures related to both higher and lower N-acetylaspartate depending on location and sex (Jung et al., 2005). The construct of creativity appears to be a particular behavioral repertoire that requires careful consideration regarding how cortical regions are connected to one another to facilitate the optimum allocation of free energy. It is of note that the regions identified to *inversely* predict creative functioning in this normal cohort critically link subcortical structures (i.e. thalamus) and the occipital cortex to frontal lobe, suggesting possible *downregulation* of frontal functioning supporting creative capacity as hypothesized previously (Dietrich, 2007).