Cogn Affect Behav Neurosci
DOI 10.3758/s13415-013-0210-6

Creativity and schizotypy from the neuroscience perspective

Andreas Fink · Bernhard Weber · Karl Koschutnig · Mathias Benedek · Gernot Reishofer · Franz Ebner · Ilona Papousek · Elisabeth M. Weiss

Abstract Behavioral research has revealed that some cognitive features may be similar between creative and psychotic/schizophrenic-like thoughts. In this study, we addressed the potential link between creativity and schizotypy at the level of the brain by investigating functional patterns of brain activity (using functional magnetic resonance imaging) during creative cognition in preselected groups with low versus high psychometrically determined schizotypy. Our findings revealed an association between the originality component of creativity and reduced deactivation of right parietal brain regions and the precuneus during creative cognition, congruent with the idea that more-creative people may include many more events/stimuli in their mental processes than do less-creative people. Similarly, the high-schizotypy group showed weaker deactivation of the right precuneus during creative cognition. The fact that originality and schizotypy show similar functional brain activity patterns during creative ideation (i.e., reduced deactivation of the right precuneus) strongly supports the contention that similar mental processes may be implicated in creativity and in psychosis proneness.

Keywords FMRI · Creative ideation · Schizotypy · Originality

A. Fink (✉) · B. Weber · K. Koschutnig · M. Benedek · I. Papousek · E. M. Weiss
Institute of Psychology, Biological Psychology Division, University of Graz, Universitaetsplatz 2/III, 8010 Graz, Austria
e-mail: andreas.fink@uni-graz.at
URL: www.uni-graz.at/biologicalpsychology/

G. Reishofer
Department of Radiology, Medical University of Graz, Graz, Austria

F. Ebner
Department of Radiology, Division of Neuroradiology, Medical University of Graz, Graz, Austria

Research on the relationship between personality characteristics and creativity has a long tradition in psychology (Simonton, 2000). The profile of a creative individual is believed to include various “positive” traits—such as broad interests, attraction to complexity, or openness—but also less socially desirable traits—such as hostility or impulsivity (see, e.g., Eysenck, 1995; Feist, 1998; for a discussion on “the dark side of creativity,” see Cropley, 2010). The latter finding is certainly among the more “provocative” findings in this field, possibly unveiling a potential link between creativity and a certain degree of psychopathology (Simonton, 1999, p. 315). The idea that at least some facets of the dark side of personality may be associated with creativity has received some support from Eysenck’s psychoticism dimension (Eysenck, 1995), which has been observed to be substantially associated with various creativity-related demands, particularly with the originality facet of creativity (e.g., Abraham, Windmann, Daum, & Güntürkün, 2005; Acar & Runco, 2012; Fink, Slamar-Halbedl, Unterrainer, & Weiss, 2012). This finding has stimulated the idea that some cognitive styles may be similar between creative and psychotic- or schizophrenic-like thoughts (Eysenck, 1995). Such common cognitive processes can be assumed in reduced cognitive inhibition (Green & Williams, 1999) or reduced latent inhibition, which refers to the capacity of the brain to screen out from conscious awareness events that were previously experienced as irrelevant (Carson, 2011; Carson, Peterson, & Higgins, 2003). In fact, some evidence from the behavioral research tradition has suggested that a heightened level of creativity is associated with attenuated latent inhibition (Carson et al., 2003; Fink, Slamar-Halbedl, et al., 2012), which has been interpreted in a manner that “creative individuals appear to be characterized in part by the ability to perceive and describe what remains hidden from the view of others” (Carson et al., 2003, p. 499). Carson (2011) even argued that creativity and psychopathology may share some “vulnerabilities,” including

Published online: 11 September 2013

cognitive disinhibition (allowing more stimuli to enter conscious awareness), preference for novelty, and neural hyperconnectivity (allowing for associations among distantly related stimuli). These vulnerabilities are thought to interact with "protective factors," such as high intelligence, working memory capacity, and cognitive flexibility, facilitating an enlargement of "the range and depth of stimuli available in conscious awareness to be manipulated and combined to form novel and original ideas" (Carson, 2011, p. 144).

Motivated by the presumption that some cognitive styles may be similar between creative and psychotic- or schizophrenic-like thoughts, creativity has been related to different forms/symptoms of disorders on the schizotypy–schizophrenia continuum. Relevant studies in this field have consistently revealed evidence that schizophrenics perform worse than healthy controls in a broad range of different creativity-related tasks (Abraham, Windmann, McKenna, & Güntürkün, 2007; Rubinstein, 2008; Weiss, 2004; Weiss et al., 2006); however, the presence of some features of schizophrenia (e.g., positive symptoms such as unusual perceptual experiences or magical beliefs) is associated with higher levels of creativity (B. Nelson & Rawlings, 2010). Another important finding in this field is that creativity seems to be associated only with "mild forms" or less severe manifestations of schizophrenia (e.g., B. Nelson & Rawlings, 2010) such as schizotypy, "the less deviant bedfellow of 'schizophrenia'" (Claridge, 1997, p. 3). Schizotypy is commonly conceptualized as increased vulnerability to developing psychotic- or schizophrenia-like symptoms (e.g., Claridge, 1997; Fisher et al., 2004; B. Nelson & Rawlings, 2010; M. T. Nelson, Seal, Pantelis, & Phillips, 2013; Nettle, 2006). The same has been proposed for the personality dimension of psychoticism (Eysenck, 1995), but as was revealed by Chapman, Chapman, and Kwapil's (1994) longitudinal study, individuals scoring high on psychoticism were more prone to future antisocial behavior, while no prognostic validity was apparent for heightened risk of psychosis. The broader concept of schizotypy appears to have a stronger affinity to psychosis (see, e.g., Fisher et al., 2004; Nettle, 2006). M. T. Nelson et al. (2013) even argued, on the basis of recent neurobiological, neuropsychological, social, and environmental evidence, that schizotypy in healthy populations and disorders on the schizophrenia spectrum are fundamentally linked, supporting the idea of a fully dimensional model of schizotypy. Schizotypy involves different dimensions, such as unusual experiences, cognitive disorganization, introvertive anhedonia, and impulsive nonconformity (e.g., Claridge & Blakey, 2009), measured via psychometric self-report scales such as the Oxford–Liverpool Inventory of Feelings and Experiences (O-LIFE; Mason & Claridge, 2006). In the Schizotypal Personality Questionnaire (SPQ) of Raine (1991), schizotypy is assessed according to all nine criteria of schizotypal personality disorder of the DSM-III-R, involving aspects such as social anxiety, constricted affect, odd beliefs/magical thinking, unusual perceptual experiences, or eccentric/odd behavior and appearance (Raine, 1991). It appears to be worthy to note that these psychometric scales show convincing psychometric quality (i.e., reliability and validity), demonstrating their valuable role in the assessment of individual differences in schizotypal personality traits in clinical, psychometric, and experimental research (Mason & Claridge, 2006; Raine, 1991).

Behavioral research has accumulated some evidence that creativity and schizotypal personality traits may be linked. For instance, Nettle (2006) found that poets and artists exhibited comparatively high levels of unusual experiences (for similar evidence, see Nelson & Rawlings, 2010), at the same time that they scored low on the dimension of introvertive anhedonia. Batey and Furnham (2008) investigated the relationship between schizotypy and different psychometric measures of creativity and found that creativity was positively associated with unusual experiences and impulsive nonconformity, but negatively with cognitive disorganization. Similarly, Claridge and Blakey (2009) observed significant correlations between positive schizotypy (unusual experiences) and self-assessed creativity styles (participant's beliefs and strategies for being creative).

Studies that have addressed the potential link between creativity and schizoytpy (or psychopathology) from the neuroscience perspective are comparatively rare. Folley and Park (2005) used near-infrared spectroscopy and were able to demonstrate that psychometrically determined schizotypal individuals showed enhanced divergent thinking relative to both schizophrenics and controls, along with preferential recruitment of the right prefrontal cortex during divergent thinking. In another study, Jung, Grazioplene, Caprihan, Chavez, and Haier (2010) investigated white matter integrity (assessed by fractional anisotropy, FA) in a sample of young healthy volunteers in relation to divergent thinking and to the personality dimension "openness to experience," which has frequently been observed as being related to creativity (Feist, 1998). This study revealed evidence that lower levels of FA within left inferior white matter (especially the anterior thalamic radiation) were associated with higher divergent-thinking performance. Similarly, lower levels of FA within the right frontal white matter (e.g., anterior thalamic radiation) were associated with higher scores on the personality dimension of openness. In explaining their results, Jung et al. referred to studies that showed reduced FA in similar brain regions (such as the anterior thalamic radiation) in both schizophrenic and bipolar patients (Sussmann et al., 2009), demonstrating "an apparent overlap in specific white matter architecture underlying the normal variance of divergent thinking, openness, and psychotic-spectrum traits, consistent with the idea of a continuum" (Jung et al., 2010, p.1 (PLoS One)).

In this study, we investigated functional patterns of brain activity by means of functional magnetic resonance imaging (fMRI) in preselected groups of low versus high psychometrically determined schizotypy while the participants were engaged in creative idea generation. In focusing on the schizotypy concept—which is conceptualized as increased vulnerability to developing psychotic- or schizophrenia-like symptoms (Nelson & Rawlings, 2010)—we do not only consider the fact that only "mild forms" of schizophrenia might be related to creativity (see Nelson & Rawlings, 2010), but we also avoided the problems associated with hospitalization and drug therapy in schizophrenic patients, which might seriously complicate the interpretation of the results. Similar to our previous work on the fMRI correlates of creative cognition (Fink et al., 2009; Fink et al., 2010; Fink, Koschutnig, et al., 2012), blood oxygenation level dependent (BOLD) response was measured during the performance of the alternative-uses (AU) task, which is an established measure of creative thought (Runco & Acar, 2012). In this task, the names of conventional everyday objects (such as *tin* or *umbrella*) are presented on screen, and participants are instructed to generate original uses of these objects (requiring the retrieval of less obvious, more distantly related information). Former studies suggested that the generation of original (vs. typical) ideas is associated with activity patterns in a complex neural network responsible for processes such as attention, memory retrieval, and speech (Fink et al., 2009; Fink et al., 2010; Fink, Koschutnig, et al., 2012). If creativity and schizotypy indeed share some common traits (cf. Carson, 2011), we would expect that those brain mechanisms, which have been identified as being characteristic of creativity, should be sensitive to schizotypy as well.

Method

Participants

From a larger participant pool of university students (N = 516), which were screened with respect to a variety of psychometric variables (e.g., personality, trait creativity, schizotypal traits, etc.), the 24 participants scoring highest on a German, Likert-scaled version of Raine's (1991) Schizotypal Personality Questionnaire (SPQ-G; Klein, Andresen, & Jahn, 1997; Wuthrich & Bates, 2005) were drawn for the fMRI study, along with a sample of age- and sex-matched controls (n = 22), who scored lowest on the SPQ. Three participants had to be excluded from further analyses due to many artifacts during fMRI assessment, and two participants abandoned the fMRI scans. Only participants who moved less than 3 mm in any direction over the entire functional imaging session were included in the analysis. The final sample comprised 21 highly schizotypal individuals (12 females, nine males; mean age: 23.29 years, SD = 4.17; range of SPQ scores = 132–179) and 20 low-schizotypal individuals (12 females, eight males; mean age: 22.85 years, SD = 3.42; range of SPQ scores = 3–77). The high-schizotypy group scored higher on neuroticism [$F(1, 39) = 26.84$, $p = .00001$, $\eta_p^2 = .41$], as assessed by means of the Neuroticism Extraversion Openness Five Factor Inventory (NEO-FFI) by Costa and McCrae (1992; translated into German by Borkenau & Ostendorf, 1993), and was more introverted [$F(1, 39) = 10.60$, $p = .002$, $\eta_p^2 = .21$], less agreeable [$F(1, 39) = 6.67$, $p = .01$, $\eta_p^2 = .15$], and less conscientious [$F(1, 39) = 5.50$, $p = .02$, $\eta_p^2 = .12$] than the low-schizotypy group. No significant group differences emerged with respect to openness [$F(1, 39) = 0.55$, $p = .46$, $\eta_p^2 = .01$]. All of the participants were healthy, with no history of substance abuse or other medical, psychiatric, or neurological disorders (as determined via self-reports). Additionally, all participants were right-handed (as determined by self-report), had normal or corrected-to-normal vision, gave written informed consent, and received an expense allowance for their participation in the fMRI study. The study was approved by the local ethics committee of the Medical University of Graz, Austria.

Materials and procedure

BOLD response was measured during performance of the classic alternative-uses (AU) task, which had been successfully employed in our previous electroencephalography and fMRI studies on creative cognition (e.g., Fink & Benedek, 2012; Fink, Koschutnig, et al., 2012). In this task, participants were instructed to generate unusual, original uses of given conventional everyday objects (such as *tin* or *umbrella*). The task instructions stressed the quality (i.e., originality/creativity) of responses; that is, participants were informed that it was important to generate original ideas rather than merely a large number of ideas. The AU task was contrasted to a noncreative control task (common uses, or CU), which required participants to generate *typical* uses of the presented objects (requiring the retrieval of familiar, common information; see, e.g., Chrysikou & Thompson-Schill, 2011; Jauk, Benedek, & Neubauer, 2012). Thus, in both the AU and the CU tasks, conventional everyday objects were shown; the tasks differed only with respect to their creativity-related demands.

Participants were presented with 30 stimuli in each condition (CU, AU), resulting in a total of 60 trials. As is shown in Fig. 1, each trial started with the presentation of a fixation cross (12 s). Subsequently, the stimulus word was presented and remained on the screen for a time period of 12 s, which we refer to as the *idea generation* period. Conjointly with the stimulus word, a light bulb that either was or was not lighted appeared on screen, signaling to the participant to produce either original (lighted bulb) or typical (not lighted) uses of the presented objects. The order of presentation of the experimental conditions was randomized. During the idea generation

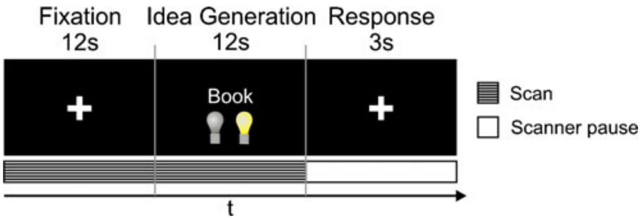

Fig. 1 Overview of experimental design and measurement intervals. Each trial started with the presentation of a fixation cross for a time period of 12 s. Subsequently, the stimulus word was presented and remained on the screen for 12 s, referred to as the *idea generation* period. Conjointly with the stimulus word, a light bulb appeared on screen that either was or was not lighted, signaling to the participant to produce either original (lighted bulb) or typical (not lighted) uses of the presented objects. Participants were presented with 30 items in each task condition (CU, AU), resulting in a total of 60 trials. The order of presentation of the experimental conditions was randomized. During the idea generation period, participants had to silently think of possible responses to the given stimulus word (either typical or original), and they were requested not to speak. After the idea generation period, the stimulus word disappeared from the screen (along with the presentation of a fixation cross), and the participant was now allowed to articulate his or her ideas (which were recorded by means of a microphone and transcribed for further analyses)

phase, participants had to silently think of possible responses to the given stimulus (either typical or original), and they were requested not to speak. After the idea generation period, the stimulus word disappeared from the screen (along with the presentation of a fixation cross), and the participant was now required to articulate his or her ideas. The oral responses were recorded and transcribed for further analyses. The total time of the task presentation (including short fixation periods of 25 s at the beginning and end of the task, as well as after 1/3 and 2/3 of the item presentations) was 28 min, and the entire MRI session (involving other imaging sequences) took about 42 min.

MRI data acquisition

Imaging was performed on a 3.0-T Tim Trio system (Siemens Medical Systems, Erlangen, Germany) using a 32-channel head coil. BOLD-sensitive T2*-weighted functional images were acquired using a single-shot gradient-echo EPI pulse sequence (TR = 1,980 ms, TE = 25 ms, flip angle = 90°, slice thickness = 3 mm, matrix size 64 × 64, FoV = 192 mm, 34 slices per volume). To record the verbal response of the participants, the scanner was interrupted for 3 s, reserved for the oral response that followed the idea generation interval of each trial. The first two volumes after each scanner pause were discarded so as to allow for T1 equilibration effects, resulting in a total of 747 volumes. Visual stimuli were presented using the Presentation software (Neurobehavioral Systems, Albany, CA).

Behavioral data analysis

The originality of creative idea generation during the fMRI experiment (AU task) was assessed by means of external ratings, similar to Amabile's (1982) Consensual Assessment Technique. For this reason, six experienced raters (three females) evaluated each single idea of the participants on a five-point rating scale, ranging from 1 (*highly original*) to 5 (*not original at all*). The raters received lists of all (nonredundant) responses of the participants in alphabetical order; hence, they were blind to the relationships of responses to the experimental groups. The raters were carefully instructed first to roughly scan the given list of responses in order to gain an overall impression of the originality range of the given responses. In addition, they were instructed to make use of the whole scale range as much as possible. The obtained ratings were averaged over all responses of a participant, so that one originality measure was available for each participant. Interrater agreement was satisfactory (intraclass correlation = .83). For greater clarity, the scale of the originality ratings was inverted for all further analyses, with higher scores (maximum of 5) now indicating higher originality.

FMRI data analysis

Functional MRI data analysis was performed using SPM8 software (Wellcome Department of Imaging Neuroscience, London, UK). Preprocessing steps included motion correction, slice time acquisition correction, and spatial normalization into the standard space (Montreal Neurological Institute). Finally, the functional data were smoothed using a Gaussian filter of 8 mm. A high-pass filter with a cutoff frequency of 1/128 Hz was employed in order to remove low-frequency drifts.

As in our previous research (e.g., Fink et al., 2009; Fink et al., 2010), each train of scans (for each trial; see Fig. 1) was treated as a single run. The onset of each stimulus presentation was convolved with the canonical form of the hemodynamic response function. Linear t-contrasts were computed. The analysis for the entire group was performed by computing linear t-contrasts between the two experimental conditions (AU > CU, CU > AU) for each participant individually; these contrasts were then entered into a random-effects one-sample t test. All reported activations were family-wise-error corrected for multiple comparisons at the cluster level ($p \leq .01$; initially uncorrected threshold values at the voxel level: $p < .0001$, $k > 30$ voxels); only activation clusters exceeding a spatial extent threshold of 30 voxels are presented.

In the next step, we extracted percentages of signal change (for both task conditions) for those brain regions that were significantly activated in the AU-versus-CU contrasts (using the SPM toolbox MarsBaR; Brett, Anton, Valabregue, & Poline, 2002). Thereby, we were able to examine whether the observed activation differences between the experimental conditions were due to differences in activation or deactivation relative to baseline. Signal changes in these regions of interest (ROIs) were then analyzed for differences between the low- and high-schizotypy groups.

Results

FMRI results

General activation patterns during the generation of alternative uses (AU) versus common uses (CU) The generation of original ideas (AU) was associated with stronger activation than was performance of the CU task in a left-lateralized neural network involving comparatively large activation clusters in inferior, middle, and superior frontal brain regions, along with activation clusters in the anterior cingulate bilaterally and in the left inferior parietal lobe (see Table 1 and Fig. 2). Additional activation clusters were observed in the right inferior frontal gyrus. The reverse contrast (CU > AU) yielded stronger activation in right parietal and temporal brain regions, involving the right angular and supramarginal gyri, and smaller portions within the superior parietal lobe and the superior and middle temporal gyri. Also, significantly stronger activation was observed in the right precuneus and in posterior portions of the cingulate gyrus, in the subcallosal gyrus, and in two comparatively small clusters in the left hemisphere (including inferior parietal and superior temporal brain regions; see Table 1). The extracted percentages of signal change indicated that the brain regions of the latter contrast were less strongly deactivated (except for the subcallosal gyrus, which was associated with increased activation relative to baseline) in the CU than in the AU task.

Effects of schizotypy and creativity on functional patterns of brain activity In a next step, we investigated potential differences between the low- and the high-schizotypy groups with respect to the percentages of signal change in functionally defined ROIs (i.e., significant activation clusters for the AU vs. CU contrasts; cf. Table 1). We performed a multivariate analysis of covariance (MANCOVA) on the functionally defined ROIs with Experimental Group (low vs. high schizotypy) as a between-subjects factor and originality during fMRI recording as the covariate.[1] In doing so, we were able to assess the specific effects of originality and schizotypy on functional patterns of brain activity during creative ideation. This appears to be particularly relevant in view of the fact that creativity and schizotypy are, at least to some extent, functionally related (cf. Nelson & Rawlings, 2010); the applied analysis approach would allow us to assess the specific contributions of creativity and schizotypy to brain activity, and hence to disentangle the two constructs on the level of the brain.

The MANCOVA yielded significant multivariate effects of group [$F(10, 27) = 3.46$, $p = .005$, $\eta_p^2 = .56$) and originality [$F(10, 27) = 3.33$, $p = .006$, $\eta_p^2 = .55$]. Subsequent univariate ANCOVAs revealed that low-schizotypal individuals exhibited significantly stronger activation than the high-schizotypy group in left superior/middle frontal [ROI 3, $F(1, 36) = 8.60$, $p = .006$, $\eta_p^2 = .19$], left inferior frontal [ROI 2, $F(1, 36) = 11.69$, $p = .002$, $\eta_p^2 = .25$], and left inferior parietal [ROI 5, $F(1, 36) = 15.47$, $p = .0004$, $\eta_p^2 = .30$] brain regions, along with stronger activation in the anterior cingulate [ROI 1, $F(1, 36) = 13.94$, $p = .001$, $\eta_p^2 = .28$; Fig. 2]. On the contrary, the high-schizotypy group showed stronger activation (or less deactivation, respectively) in the left superior temporal gyrus [ROI 9, $F(1, 36) = 19.25$, $p = .0001$, $\eta_p^2 = .35$] and in the right precuneus [ROI 8, $F(1, 36) = 4.56$, $p = .04$, $\eta_p^2 = .11$; Fig. 2].

The univariate ANCOVAs yielded two significant effects related to originality—namely, in right parietal brain regions [ROI 6, $F(1, 36) = 5.28$, $p = .03$, $\eta_p^2 = .13$] and in the right precuneus [ROI 8, $F(1, 36) = 5.51$, $p = .03$, $\eta_p^2 = .13$]. In both cases, originality was positively associated with brain activity, which means that the higher the originality level of an individual, the weaker was the deactivation in these brain regions (see Fig. 3).

As we described in the Method section, significant group differences emerged with respect to Big Five personality dimensions. In order to demonstrate that the observed findings were specific to schizotypy, we ran follow-up ANCOVAs to additionally consider the Big Five dimensions of neuroticism, extraversion, openness, agreeableness, and conscientiousness as covariates. The ANCOVA findings largely matched those observed in the original ANCOVAs, with respect both to originality [ROI 6, $F(1, 31) = 4.16$, $p = .05$, $\eta_p^2 = .12$; ROI 8, $F(1, 31) = 5.78$, $p = .02$, $\eta_p^2 = .16$] and to schizotypy [ROI 1, $F(1, 31) = 4.18$, $p = .049$, $\eta_p^2 = .12$; ROI 2, $F(1, 31) = 2.82$, $p = .10$, $\eta_p^2 = .08$; ROI 3, $F(1, 31) = 7.40$, $p = .01$, $\eta_p^2 = .19$; ROI 5, $F(1, 31) = 9.53$, $p = .004$, $\eta_p^2 = .24$; ROI 8, $F(1, 31) = 3.19$, $p = .08$, $\eta_p^2 = .09$; ROI 9, $F(1, 31) = 8.64$, $p = .006$, $\eta_p^2 = .22$], indicating that the Big Five personality dimensions had no substantial impact on the observed pattern of results.

Behavioral results

We found no significant differences between low- and high-schizotypal individuals with respect to the originality of

[1] The recordings of the oral responses of two participants were of extremely bad quality, and thus could not be used for further analyses. The (M)ANCOVAs that we performed were based on a sample size of 39 participants (19 SPQ low, 20 SPQ high).

Table 1 Overview of significantly activated clusters (family-wise-error [FWE] corrected at the cluster level, $p \leq .01$; initially uncorrected threshold values at the voxel level: $p < .0001$, $k > 30$) for the contrasts between the experimental conditions (AU vs. CU)

ROI	*k*	*p* (FWE-cor)	*T*	MNI Peak Coordinates			Brain Area
AU > CU							
1	1,567	.0000	8.8804	9	29	28	Ant Cingulate L R, sup Frontal med L, Med Frontal G, Corpus Callosum
			8.3005	–9	29	31	
			7.2591	18	2	25	
2	594	.0000	8.3039	–33	26	–5	Inf Frontal G L, Insula L, Precentral L
			8.2842	–48	29	13	
			8.2436	–45	5	28	
3	136	.0002	5.4915	–27	2	67	Sup Frontal L, Mid Frontal L
			5.2830	–21	–1	58	
4	111	.0007	6.8799	33	23	–8	Inf Frontal G R, Insula R
			6.8402	36	26	1	
5	55	.0095	5.5024	–36	–34	43	Inf Parietal L
			5.4775	–48	–31	37	
CU > AU							
6	407	.0000	6.1097	60	–58	25	Angular G R, Inf Parietal R, Supramarginal G R, Sup Parietal R, Sup Temporal G R
			6.1024	51	–61	46	
			5.9954	51	–67	37	
7	118	.0005	5.4399	12	5	–14	Subcallosal G
			5.3631	–15	8	–11	
			5.0436	–9	14	–14	
8	109	.0008	5.3855	6	–55	31	Precuneus R, Cingulate G
			5.2157	3	–49	25	
			5.0575	6	–64	34	
9	67	.0051	5.8612	–57	–1	4	Sup Temporal G L
			5.5001	–63	–13	10	
10	54	.0100	6.6026	–54	–61	40	Inf Parietal L

ROI, region of interest; MNI, Montreal Neurological Institute brain space; G, gyrus; L, left hemisphere; R, right hemisphere; Ant, anterior; Inf, inferior; Sup, superior; Med, medial; Mid, middle; CU, common uses; AU, alternative uses

generated ideas during fMRI recording (SPQ low, $M = 2.90$, $SD = 0.22$; SPQ high, $M = 2.74$, $SD = 0.44$), $F(1, 37) = 2.12$, $p = .15$. In analyzing the correlations between originality and schizotypy separately for both experimental groups, we consistently observed positive correlations between originality and total SPQ score (SPQ low, $r = .37$, $p = .12$; SPQ high, $r = .21$, $p = .37$), positive schizotypy (SPQ low, $r = .40$, $p = .09$; SPQ high, $r = .17$, $p = .47$), and negative schizotypy (SPQ low, $r = .18$, $p = .47$; SPQ high, $r = .02$, $p = .94$); these results, however, failed to reach statistical significance (possibly due to low sample size).

The originality of idea generation during fMRI recording was significantly associated with the creativity measures obtained in the preexperimental screening, including a self-report measure of ideational behavior (German version of Runco's Ideational Behavior Scale; Runco, Plucker, & Lim, 2001; an example item was *I am good at combining ideas in ways that others have not tried*), $r = .34$, $p = .04$, and the originality score (based on statistical infrequency) of Torrance's Picture Completion Test (a performance test for the assessment of figural creativity; Torrance, 1966), $r = .33$, $p = .04$. These findings indicate that the operationalization of task performance during fMRI assessment could be considered successful. However, no significant correlation emerged between originality and the personality dimension of openness ($r = .16$, $p = .34$).

Discussion

Perhaps the most important finding of this study was that schizoytpy and creativity are related to similar brain activity patterns during creative ideation (i.e., reduced deactivation of the right precuneus for both high schizotypy and high creativity). As is shown in Fig. 2, low-schizotypal individuals exhibited significantly stronger deactivation of the right precuneus. This brain region is thought to be part of the resting-state brain network (Cavanna, 2006). Raichle et al. (2001) specifically mention that "the posterior cingulate cortex and adjacent precuneus can be posited as a tonically active

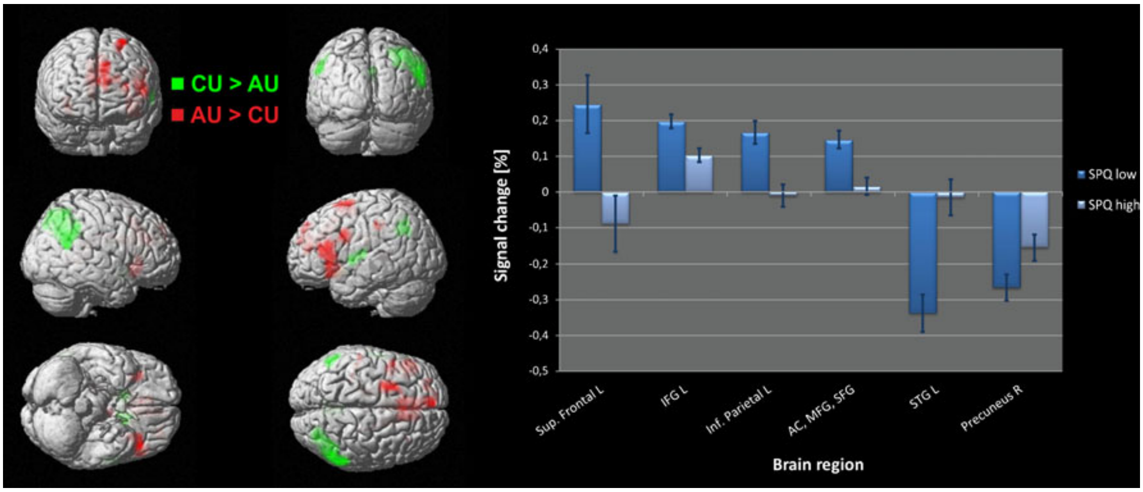

Fig. 2 Significant activation clusters (left-hand side) for the contrasts between CU > AU (green, in online version; light gray, in print version) and AU > CU (red online; dark gray, in print version). The plots (right-hand side) indicate significant differences in activation (percentage of signal change) between the low-schizotypy (SPQ low) and high-schizotypy (SPQ high) groups. CU, common uses; AU, alternative uses; L, left hemisphere; R, right hemisphere; Sup, superior; Inf, inferior; IFG, inferior frontal gyrus; AC, anterior cingulate; MFG, medial frontal gyrus; SFG, superior frontal gyrus; STG, superior temporal gyrus

region of the brain that may continuously gather information about the world around and possibly within us" (p. 681). Interestingly, this brain region consistently exhibits deactivations during goal-directed information processing (i.e., when successful task performance requires focused attention; cf. Raichle et al., 2001), thereby suppressing such broad and unsystematic information gathering activity. Related to our findings, a possible interpretation would be that the high-schizotypy group was more likely to continuously gather external information during creative cognition. Given the presumed role of the precuneus in episodic memory retrieval (Cavanna, 2006) and Raichle et al.'s interpretation, our findings could also suggest broad internal information gathering during the process of creative ideation. Further converging evidence for the significant role of the right precuneus in creativity was revealed by structural MRI findings, which reported evidence for a positive correlation between creativity and gray matter density (Fink et al., 2013; Takeuchi et al., 2010). Similarly, Takeuchi et al. (2011) found reduced task-related deactivation of the precuneus in more creative individuals during a working memory task and they referred to similar findings of Whitfield-Gabrieli et al. (Whitfield-Gabrieli et al., 2009) who found reduced task-related deactivation of the default network in schizophrenics and their relatives, whereas controls exhibited the typical task-related suppression of default network brain regions. In presuming that the extent of task-related deactivation in the default mode network could indicate the reallocation of attention or cognitive resources from task-irrelevant to task-relevant cognitive processes, Takeuchi et al. (2011) interpreted the "failing to deactivate" (p. 681) in more creative individuals as a sign of inefficient reallocation of attention, congruent with the idea of diffuse attention being crucial in creativity (Takeuchi et al., 2012). Such an interpretation would also be nicely in line with psychological concepts such as "overinclusive" or "allusive" modes of thinking, which have been postulated as being characteristic for both psychotic-prone and creative people as well (Eysenck, 1995). Carson (2011) specifically argued that creativity and psychopathology may share processes such as cognitive disinhibition or neural hyperconnectivity, along with an "attentional style driven by novelty salience" (p. 144), which allow more stimuli to enter conscious awareness and facilitate remote associations, an important prerequisite for the generation of novel ideas. The observed reduced task-related deactivation of the precuneus in the high-schizotypy group, which could be indicative of states of more broadly oriented attention involving continuously gathering information about the world around and within us (Raichle et al., 2001), thus may nicely support Eysenck's and Carson's assumptions at the level of the brain.

Similar to the schizotypy effect, originality was associated with reduced deactivation of right parietal brain regions and the precuneus during creative idea generation (Fig. 3). According to a framework of Corbetta, Patel, and Shulman (2008), right temporo-parietal brain regions are conceived as being part of an attentional network of the brain that is involved in attending to environmental stimuli. Suppressed or attenuated activity in this region has been observed to occur in order to prevent reorienting of attention to task-irrelevant stimuli, which could interfere with task performance. Similarly, deactivation of the precuneus is thought of as being indicative of a state of more task-focused attention, in which broad information-gathering activities are suppressed (Raichle et al., 2001). In this study, individuals with greater originality tended to display weaker deactivations in these brain regions during creative cognition, possibly indicating that they

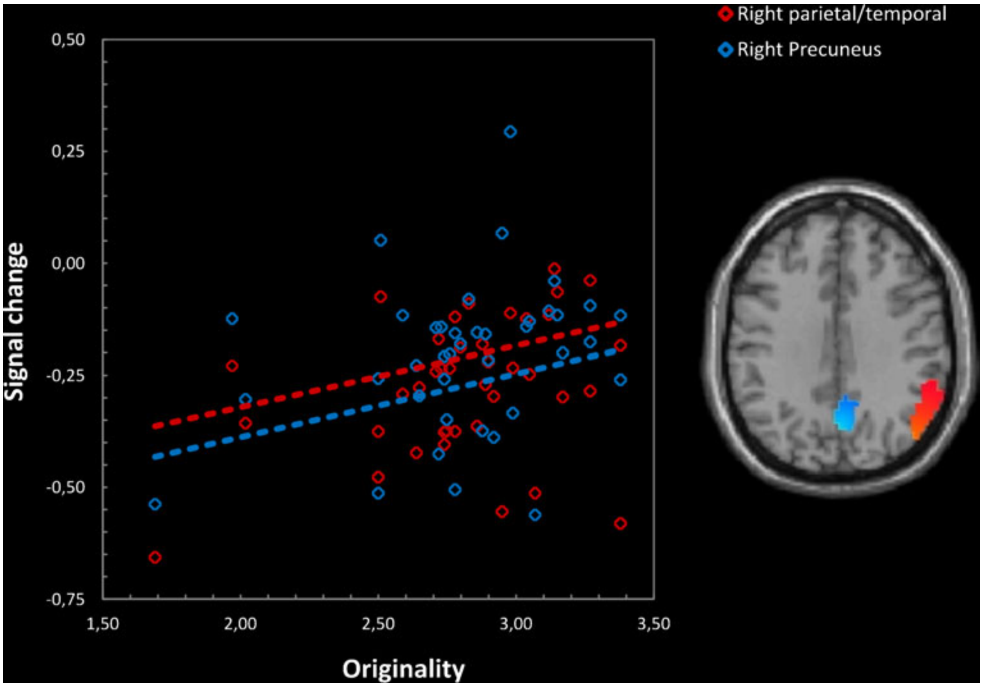

Fig. 3 Brain regions that exhibited significant associations with originality (as measured during fMRI recording). In both the right parietal/temporal brain regions (red online; dark gray, in print version) and the right precuneus (blue online; light gray, in print version), a heightened level of originality was associated with reduced task-related deactivation

performed the task—as highly schizotypal individuals did—in states of more broadly oriented attention.

Analyses of the functionally defined ROIs moreover revealed that low-schizotypal individuals exhibited significantly stronger activation than did the high-schizotypy group in left-lateralized language-related ROIs, and in frontal regions that are associated with processes such as attentional cognitive control, semantic selection, or (verbal) working memory processing (Fig. 2). This finding does not seem surprising, in light of the well-documented functional and structural brain abnormalities in patients with schizotypal traits. For instance, Koenigsberg et al. (2005) reported evidence that patients suffering from schizotypal personality disorder showed decreased activation during working memory processing (as compared to healthy controls) in key frontal regions such as the left ventral prefrontal cortex or the superior frontal gyrus. In a similar vein, Carter, Mintun, Nichols, and Cohen (1997) observed anterior cingulate gyrus dysfunction and selective-attention deficits in schizophrenic individuals. Smieskova et al. (2010) recently reviewed neurobiological correlates of vulnerability to schizophrenia, and they came to the conclusion that structural and neurochemical abnormalities in, among other areas, prefrontal brain regions and the anterior cingulate might be predictive for the development of psychosis. In a similar vein, schizophrenia patients, as well as healthy individuals with a genetic predisposition to schizophrenia, showed aberrant lateral prefrontal activation when preparing to overcome a prepotent response (MacDonald, Becker, & Carter, 2006; Snitz et al., 2005).

The high-schizotypy group also showed stronger activation (or less deactivation) in the left superior temporal gyrus. The superior temporal gyrus is assumed to play a key role in language-related processes such as activating and integrating semantic representations (Jung-Beeman, 2005). In light of this notion, the lower-schizotypy group in this study appeared to rely less strongly on these cognitive processes during creative idea generation (or to work more efficiently) than high-schizotypal individuals do. However, this finding needs replication, particularly in view of the comparatively low cluster size of this region ($k = 67$; see Table 1).

In summary, our findings suggest an association between originality and reduced deactivation of right parietal brain regions and the precuneus during creative idea generation, congruent with the idea that more-creative people may include many more events/stimuli in their mental processes than less-creative people do. Similarly, the high-schizotypy group showed (besides lower activation in language-related ROIs and in regions associated with attentional cognitive control) weaker deactivation of the right precuneus during creative ideation. The finding that creativity and schizotypy show similar effects at the level of the brain would thus support the idea that similar cognitive processes may be implicated in creativity as well as in psychosis proneness. However, this study also has some limitations that we should briefly pay attention to. We only assessed the specific effects of creativity and schizotypy on functional patterns of brain activity during creative ideation. Future research will be challenged to also investigate potential interactive effects between schizotypy and creativity in order to assess whether the two variables are systematically linked in some way. This would require considerably larger sample sizes, and such studies would also be required to overcome some potential confounds between creativity and schizotypy, due to the fact that these two constructs are functionally related to some extent (e.g., one would expect elevated levels of schizotypy in highly creative groups such as artists or dancers, but also in psychometrically determined high creative people; Nelson & Rawlings, 2010; Nettle, 2006). Future studies should also investigate functional patterns of brain activity in relation to different facets of schizotypy, such as positive or negative schizotypy. This topic appears to be especially exciting, inasmuch as the degrees of positive and negative schizotypy appear to vary among different creativity domains (Nelson & Rawlings, 2010; Nettle, 2006). In this study, positive and negative schizotypy were quite highly correlated in the total sample of participants (r = .77), so that only little discriminant validity can be assumed (note that the low- and the high-schizotypy groups showed contrary associations between positive and negative schizotypy in our sample; viz., r = .43, p = .057, vs. r = –.56, p = .009, for the low- vs. high-schizotypy groups). Also, both positive (r = .98) and negative (r = .88) schizotypy were quite highly correlated with total SPQ score. Our findings thus apply only to schizotypy in general, and not to specific facets of this construct, such as positive or negative schizotypal traits. This could be considered a potential limitation of this study. Finally, future studies in this field will be particularly challenged to demonstrate the specificity of effects. Our findings seem to be specific to schizotypy rather than to general personality characteristics such as the Big Five dimensions. However, other individual-difference variables could also have an impact on our results. For instance, recent neuroimaging studies have revealed a reliable and consistent picture of some brain correlates underlying intelligence, with respect to both structural and functional characteristics of the brain (Jung & Haier, 2007; Neubauer & Fink, 2009). Studies dealing with the potential link between creativity and psychopathology thus should control individual differences in intelligence, or even better, assess the roles of intelligence and working memory capacity as potential "protective factors" within the framework of a shared-vulnerability model of creativity and psychopathology (Carson, 2011).

References

Abraham, A., Windmann, S., Daum, I., & Güntürkün, O. (2005). Conceptual expansion and creative imagery as a function of psychoticism. *Consciousness and Cognition, 14,* 520–534. doi:10.1016/j.concog.2004.12.003

Abraham, A., Windmann, S., McKenna, P., & Güntürkün, O. (2007). Creative thinking in schizophrenia: The role of executive dysfunction and symptom severity. *Cognitive Neuropsychiatry, 12,* 235–258.

Acar, S., & Runco, M. A. (2012). Psychoticism and creativity: A meta-analytic review. *Psychology of Aesthetics, Creativity, and the Arts, 6,* 341–350.

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. *Journal of Personality and Social Psychology, 43,* 997–1013.

Batey, M., & Furnham, A. (2008). The relationship between measures of creativity and schizotypy. *Personality and Individual Differences, 45,* 816–821.

Borkenau, P., & Ostendorf, F. (1993). *NEO-Fünf-Faktoren Inventar (NEO-FFI) nach Costa und McCrae [Neo Five Factor Inventory of Costa and McCrae] (German version)*. Göttingen, Germany: Hogrefe.

Brett, M., Anton, J.-L., Valabregue, R., & Poline, J.-B. (2002, June). Region of interest analysis using an SPM toolbox [Abstract]. Article presented at the 8th International Conference on Functional Mapping of the Human Brain, Sendai, Japan. [Available on CD-ROM in *NeuroImage*, *16*(2)].

Carson, S. H. (2011). Creativity and psychopathology: A shared vulnerability model. *Canadian Journal of Psychiatry—Revue Canadienne de Psychiatrie, 56,* 144–153.

Carson, S. H., Peterson, J. B., & Higgins, D. M. (2003). Decreased latent inhibition is associated with increased creative achievement in high-functioning individuals. *Journal of Personality & Social Psychology, 85,* 499–506.

Carter, C. S., Mintun, M., Nichols, T., & Cohen, J. D. (1997). Anterior cingulate gyrus dysfunction and selective attention deficits in schizophrenia: [15O]H_2O PET study during single-trial Stroop task performance. *American Journal of Psychiatry, 154,* 1670–1675.

Cavanna, A. E. (2006). The precuneus: A review of its functional anatomy and behavioural correlates. *Brain, 129,* 564–583.

Chapman, J. P., Chapman, L. J., & Kwapil, T. R. (1994). Does the Eysenck Psychoticism Scale predict psychosis? A ten year longitudinal study. *Personality and Individual Differences, 17,* 369–375.

Chrysikou, E. G., & Thompson-Schill, S. L. (2011). Dissociable brain states linked to common and creative object use. *Human Brain Mapping, 32,* 665–675.

Claridge, G. (1997). *Schizotypy: Implications for illness and health*. Oxford, UK: Oxford University Press.

Claridge, G., & Blakey, S. (2009). Schizotypy and affective temperament: Relationships with divergent thinking and creativity styles. *Personality and Individual Differences, 46,* 820–826.

Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: From environment to theory of mind. *Neuron, 58,* 306–324.

Costa, P. T., & McCrae, R. R. (1992). *Revised NEO Personality Inventory (NEO PI-R) and NEO Five Factor Inventory. Professional Manual*. Odessa, FL: Psychological Assessment Resources.

Cropley, D. (2010). *The dark side of creativity*. New York, NY: Cambridge University Press.

Eysenck, H. J. (1995). Creativity as a product of intelligence and personality. In D. H. Saklofske & M. Zeidner (Eds.), *International handbook of personality and intelligence* (pp. 231–247). New York, NY: Plenum Press.

Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality and Social Psychology Review, 2,* 290–309.

Fink, A., & Benedek, M. (2012). EEG alpha power and creative ideation. *Neuroscience and Biobehavioral Reviews*. doi:10.1016/j.neubiorev.2012.12.002

Fink, A., Grabner, R. H., Benedek, M., Reishofer, G., Hauswirth, V., Fally, M., & Neubauer, A. C. (2009). The creative brain: Investigation of brain activity during creative problem solving by means of EEG and fMRI. *Human Brain Mapping, 30,* 734–748. doi:10.1002/hbm.20538

Fink, A., Grabner, R. H., Gebauer, D., Reishofer, G., Koschutnig, K., & Ebner, F. (2010). Enhancing creativity by means of cognitive stimulation: Evidence from an fMRI study. *NeuroImage, 52,* 1687–1695.

Fink, A., Koschutnig, K., Benedek, M., Reishofer, G., Ischebeck, A., Weiss, E. M., & Ebner, F. (2012). Stimulating creativity via the exposure to other people's ideas. *Human Brain Mapping, 33,* 2603–2610.

Fink, A., Koschutnig, K., Hutterer, L., Steiner, E., Benedek, M., Weber, B., . . . Weiss, E. M. (2013). Gray matter density in relation to different facets of verbal creativity. *Brain Structure and Function*. doi:10.1007/s00429-013-0564-0

Fink, A., Slamar-Halbedl, M., Unterrainer, H. F., & Weiss, E. M. (2012). Creativity: Genius, madness, or a combination of both? *Psychology of Aesthetics, Creativity, and the Arts, 6,* 11–18.

Fisher, J. E., Mohanty, A., Herrington, J. D., Koven, N. S., Miller, G. A., & Heller, W. (2004). Neuropsychological evidence for dimensional schizotypy: Implications for creativity and psychopathology. *Journal of Research in Personality, 38,* 24–31.

Folley, B. S., & Park, S. (2005). Verbal creativity and schizotypal personality in relation to prefrontal hemispheric laterality: A behavioral and near-infrared optical imaging study. *Schizophrenia Research, 80,* 271–282.

Green, M. J., & Williams, L. M. (1999). Schizotypy and creativity as effects of reduced cognitive inhibition. *Personality and Individual Differences, 27,* 263–276.

Jauk, E., Benedek, M., & Neubauer, A. C. (2012). Tackling creativity at its roots: Evidence for different patterns of EEG alpha activity related to convergent and divergent modes of task processing. *International Journal of Psychophysiology, 84,* 219–225.

Jung, R. E., Grazioplene, R., Caprihan, A., Chavez, R. S., & Haier, R. J. (2010). White matter integrity, creativity, and psychopathology: Disentangling constructs with diffusion tensor imaging. *PLoS ONE, 5,* e9818. doi:10.1371/journal.pone.0009818

Jung, R. E., & Haier, R. J. (2007). The parieto-frontal integration theory (P-FIT) of intelligence: Converging neuroimaging evidence. *Behavioral and Brain Sciences, 30,* 135–154.

Jung-Beeman, M. (2005). Bilateral brain processes for comprehending natural language. *Trends in Cognitive Sciences, 9,* 512–518.

Klein, C., Andresen, B., & Jahn, T. (1997). Psychometric assessment of the schizotypal personality according to DSM-III-R criteria: Psychometric properties of an authorized German translation of Raine's "Schizotypal Personality Questionnaire. *Diagnostica, 43,* 347–369.

Koenigsberg, H. W., Buchsbaum, M. S., Buchsbaum, B. R., Schneiderman, J. S., Tang, C. Y., New, A., & Siever, L. J. (2005). Functional MRI of visuospatial working memory in schizotypal personality disorder: A region-of-interest analysis. *Psychological Medicine, 35,* 1019–1030.

MacDonald, A. W., Becker, T. M., & Carter, C. S. (2006). Functional magnetic resonance imaging study of cognitive control in the healthy relatives of schizophrenia patients. *Biological Psychiatry, 60,* 1241–1249.

Mason, O., & Claridge, G. (2006). The Oxford–Liverpool Inventory of Feelings and Experiences (O-LIFE): Further description and extended norms. *Schizophrenia Research, 82,* 203–211.

Nelson, B., & Rawlings, D. (2010). Relating schizotypy and personality to the phenomenology of creativity. *Schizophrenia Bulletin, 36,* 388–399.

Nelson, M. T., Seal, M. L., Pantelis, C., & Phillips, L. J. (2013). Evidence of a dimensional relationship between schizotypy and schizophrenia: A systematic review. *Neuroscience & Biobehavioral Reviews, 37,* 317–327. doi:10.1016/j.neubiorev.2013.01.004

Nettle, D. (2006). Schizotypy and mental health amongst poets, visual artists, and mathematicians. *Journal of Research in Personality, 40,* 876–890.

Neubauer, A. C., & Fink, A. (2009). Intelligence and neural efficiency. *Neuroscience & Biobehavioral Reviews, 33,* 1004–1023. doi:10.1016/j.neubiorev.2009.04.001

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences, 98,* 676–682.

Raine, A. (1991). The SPQ: A scale for the assessment of schizotypal personality based on DSM-III-R criteria. *Schizophrenia Bulletin, 17,* 555–564.

Rubinstein, G. (2008). Are schizophrenic patients necessarily creative? A comparative study between three groups of psychiatric inpatients. *Personality and Individual Differences, 45,* 806–810.

Runco, M. A., & Acar, S. (2012). Divergent thinking as an indicator of creative potential. *Creativity Research Journal, 24,* 66–75.

Runco, M. A., Plucker, J. A., & Lim, W. (2001). Development and psychometric integrity of a measure of ideational behavior. *Creativity Research Journal, 13,* 393–400.

Simonton, D. K. (1999). Creativity as blind variation and selective retention: Is the creative process Darwinian? *Psychological Inquiry, 10,* 309–328.

Simonton, D. K. (2000). Creativity: Cognitive, personal, developmental, and social aspects. *American Psychologist, 55,* 151–158.

Smieskova, R., Fusar-Poli, P., Allen, P., Bendfeldt, K., Stieglitz, R. D., Drewe, J., & Borgwardt, S. J. (2010). Neuroimaging predictors of transition to psychosis—A systematic review and meta-analysis. *Neuroscience & Biobehavioral Reviews, 34,* 1207–1222. doi:10.1016/j.neubiorev.2010.01.016

Snitz, B. E., MacDonald, A. W., Cohen, J. D., Cho, R. Y., Becker, T., & Carter, C. S. (2005). Lateral and medial hypofrontality in first-episode schizophrenia: Functional activity in a medication-naive state and effects of short-term atypical antipsychotic treatment. *American Journal of Psychiatry, 162,* 2322–2329.

Sussmann, J. E., Lymer, G. K. S., McKirdy, J., Moorhead, T. W. J., Muñoz Maniega, S., Job, D., & McIntosh, A. M. (2009). White matter abnormalities in bipolar disorder and schizophrenia detected using diffusion tensor magnetic resonance imaging. *Bipolar Disorders, 11,* 11–18. doi:10.1111/j.1399-5618.2008.00646.x

Takeuchi, H., Taki, Y., Hashizume, H., Sassa, Y., Nagase, T., Nouchi, R., & Kawashima, R. (2011). Failing to deactivate: The association between brain activity during a working memory task and creativity. *NeuroImage, 55,* 681–687.

Takeuchi, H., Taki, Y., Hashizume, H., Sassa, Y., Nagase, T., Nouchi, R., & Kawashima, R. (2012). The association between resting functional connectivity and creativity. *Cerebral Cortex, 22,* 2921–2929.

Takeuchi, H., Taki, Y., Sassa, Y., Hashizume, H., Sekiguchi, A., Fukushima, A., & Kawashima, R. (2010). Regional gray matter volume of dopaminergic system associate with creativity: Evidence from voxel-based morphometry. *NeuroImage, 51,* 578–585.

Torrance, E. P. (1966). *Torrance tests of creative thinking*. Princeton, NJ: Personnel Press.

Weiss, E. M. (2004). Brain activation patterns during a verbal fluency test—A functional MRI study in healthy volunteers and patients with schizophrenia. *Schizophrenia Research, 70,* 287–291.

Weiss, E. M., Hofer, A., Golaszewski, S., Siedentopf, C., Felber, S., & Fleischhacker, W. W. (2006). Language lateralization in unmedicated patients during an acute episode of schizophrenia: A functional MRI study. *Psychiatry Research: Neuroimaging, 146,* 185–190.

Whitfield-Gabrieli, S., Thermenos, H. W., Milanovic, S., Tsuang, M. T., Faraone, S. V., McCarley, R. W., & Seidman, L. J. (2009). Hyperactivity and hyperconnectivity of the default network in schizophrenia and in first-degree relatives of persons with schizophrenia. *Proceedings of the National Academy of Sciences, 106,* 1279–1284. doi:10.1073/pnas.0809141106

Wuthrich, V., & Bates, T. C. (2005). Reliability and validity of two Likert versions of the Schizotypal Personality Questionnaire (SPQ). *Personality and Individual Differences, 38,* 1543–1548.