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The Neuropsychology of Creativity: A Profile of Indian Artists

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SUMMARY

Background: The present study aims at comparing the cognitive profile of creative artists and non-creative participants. We assessed creativity correlates by taking a sample of professionally creative artists unlike those previous studies conducted with college students or which employed biographical data from eminent creators who form a rare and extreme group on the continuum of creativity.

Material/Methods: A matched control design with cross sectional assessment was used for the study. The study sample comprised two groups – Creative group (CR) and matched Non-creative group (NC) with 30 participants each. All participants were in the age range of 20-40 years and had a minimum average intelligence (IQ score >90). Screening measures included the Edinburgh Handedness Inventory, Raven's Standard Progressive Matrices and the Creativity Achievement Questionnaire used to select pro C creative individuals for the creative group. NIMHANS Neuropsychological Battery (Rao et al, 2004) was used to assess the comprehensive cognitive profile (domains of speed and attention; executive functions; learning & memory) of the participants. The Battery comprises globally recognized neuropsychological tests which have been standardized for the Indian population.

Results: It was found that CR group had statistically significant higher scores on focused attention, category fluency, design fluency (both free and fixed), visuo-spatial working memory (medium effect size), set shifting ability, response inhibition and verbal memory. A significant positive correlation was found between intelligence, mental speed, focused attention, category fluency, design fluency (both free & fixed), set shifting, response inhibition, verbal memory and all components of creativity.

Conclusions: The present study elucidates the functions associated with creativity. It was possible to identify creative individuals, one to one matching across both the groups, thereby controlling the influence of age, gender and education; using a standardized and comprehensive battery to assess cognitive functions and statistical rigor in analyzing the data.

Key words: cognition, mental speed, focused attention, category fluency, design fluency, visuo-spatial working memory, verbal memory

INTRODUCTION

Reading a heart-warming poem, watching an inspiring movie, listening to a divine musical composition and viewing a painter's masterpiece are ethereal experiences that bring us a reverence of creative artists. When looking at these fascinating creative products, one wonders how their creators devise such "out of the box" ideas. Is it an unfiltered perceptual attention that exposes artists to a far wider range of information when compared to others? (Mendelsohn, 1976; Muhlenen, Rempel, & Enns, 2005; White & Shah, 2006) Or is it a heightened capacity to manipulate the information mentally and come up with unique remote associations between two far-fetched ideas? (Takeuchi et al, 2011; Vartanian et al., 2013 & Lee & Therriault, 2013). While scientific research has attempted to provide answers to these questions, the cognitive profile of creative artists remains obscure. The impediments inherent in the field of creativity research, such as difficulties with the identification of creative people, variability in the assessment measure and type of creative sample, make it challenging for an abstract construct such as creativity to be previewed through the objective, concrete lens of cognitive research (Dietrich & Kanso, 2010).

Definition, Types & Measures

Creativity is a versatile and abstract human ability which has been defined in numerous ways; its most consensual definition conceptualizes it as an ability to yield products (e.g., ideas, stories, objects) that are both novel (i.e., original) and useful (Stein, 1953; Barron, 1955; Sternberg, Lubart, Kaufman, & Pretz, 2005). Cognitively, creativity has been conceptualized as a higher order thinking ability involving analysis, evaluation and synthesis i.e., the creation of new knowledge (Anderson & Krathwohl, 2001). Another discerning factor in creativity research has been its classification (Amabile, 1996; Lubart & Guignard, 2004; Plucker & Beghetto, 2004) into a domain general (creative processes in general) and specific (creative processes specific to a domain). While domain specific creativity has been studied in some artistic populations such as music, dance and theatre etc. (Fink & Woschnjak, 2011; Benedek et al., 2014); creativity relevant processes have largely been restricted to college students (Martindale, 2007; Batey et al., 2009; Hughes, Furnham & Batey, 2013). However, in order to understand the inherent nature of creativity, it is vital to explore domain general creative processes in professional artists rather than college students as the former may strengthen the ecological validity of results. A developmental perspective on creativity (Beghetto & Kaufman 2007) considers it as a continuous variable increasing from intrapersonal creativity (mini c), to everyday problem solving (little c), to professional or vocational creativity (pro-c) and the epitome breakthrough contributions (Big C). Creativity has generally been assessed using two broad types of tasks - divergent thinking (DT) and convergent thinking (Guilford, 1967). DT involves open-ended, imaginative responses to items while convergent thinking explores a single correct answer technique to solve insightful problems. The predominant approach to the psychometric assessment of creative thinking is by means of DT tasks as they provide structured, valid and objective responses (Kaufman et al., 2008; Arden et al., 2010; Runco & Jaeger, 2012; Takeuchi et al., 2012).

Creativity & Intelligence

Is intelligence an intricate component necessary for creativity? Yes, a positive association between intelligence and creativity is well documented (Batey & Furnham, 2006; Silvia, 2008; Batey et al., 2009; Kim, Cramond, & VanTassel-Baska, 2010 & Jauk et al., 2014). However, this association may not be entirely linear; while some researchers assert that intelligence is a necessary but not sufficient condition for creativity with a threshold around 120 (Runco, 2007; Jung et al, 2009 & Jauk et al., 2013), others have found no empirical evidence for this threshold effect (Preckel, Holling, & Wiese, 2006). Threshold theory apparently applies itself to some tests of intelligence better than others (Runco & Albert 1986b; Sligh, Connors, & Roskos-Ewoldsen, 2005), but it is logical as well as consistent with the empirical research, and also corroborates with the very general principle of creative performances as optimal. This theory is supported by evidence from both lesion (Kolb and Whishaw, 2009) and neuroimaging studies (Jung et al, 2009).

Creativity – Attention & Speed of Information Processing

Attention enables a sustained performance on any task and a higher speed of information processing contributes efficiency to the performance. Research has posited that broad externally induced perceptual attention temporarily widens the scope of conceptual attention, enhancing access to remote associates, and thereby transiently bolstering the generation of creative ideas (Martindale et al, 1995; Friedman et al, 2003). Another line of evidence comes from psychopathology where individuals with Attention Deficit Hyperactivity Disorder (ADHD) demonstrate higher creativity due to defocused attention that facilitates divergent thinking (Fiore et al, 2001; Carson et al, 2003; White & Shah, 2006). While this defocused attention widens the array of associations available, it would slower the speed of processing information. But if this is true then we should find creative individuals struggling with routine daily problems and unable to complete a creative endeavour as it would require persistent and efficient processing (Dorfman et al, 2008). It has been argued that defocused attention is not a stable personality trait of creative individuals who are rather skilled at adjusting the focus of their attention depending upon task demands (Martindale, 1975, 1999, 2007; Ansburg & Hill, 2003). Studies have further corroborated that the idea generation phase of creativity may have a lower processing speed but creative individuals are must faster in the elaboration and verification phase of creativity (Martindale, 1999; Vartanian, Martindale, and Kwiatkowski, 2007 & Dorfman et al, 2008).

Creativity & Executive Functions

Executive functions are essential for performance in complex cognitive tasks and are closely associated with neural substrates in the prefrontal cortex. Mounting evidence is now pointing towards the executive nature of creativity and these executive processes largely include fluency, working memory, set shifting and response inhibition (Beaty & Silvia, 2012; Benedek et al., 2012; Abraham, 2014 & Benedek et al., 2014). Since divergent thinking tasks involve a generation of multiple ideas, creativity assessed using these has been strongly associated with verbal fluency (Silvia et al, 2013). Working Memory (WM) defined as a "cognitive system, which allows for the transient (up to a few seconds) storage and utilization of information" is associated with focused task relevant attention (Haberlandt, 1997, Baddeley, 1992, 2000, 2001; Kuntsi et al, 2001; Postle, 2006). Studies have indicated that working memory and creativity have opposing characteristics in terms of diffused attention (Takeuchi et al, 2011). ADHD children with poor attention and impaired working memory have been found to be more creative than their peers (Kuntsi et al., 2001; Healey & Rucklidge, 2006) and when Ritalin (methylphenidate) significantly decreased the symptoms of ADHD, it was found to reduce creativity (Swartwood et al., 2003) while improving WM (Mehta et al., 2004). However, counter evidence exists reporting positive correlations of working memory with creativity assessed by divergent thinking tasks (Oberauer et al., 2008; de Dreu et al., 2012). Also, improvisation (an important aspect and marker of creativity) would require a good mental manipulation of existing information and thus a higher working memory capacity (Mars & Grol, 2007; Jerde et al, 2011). Thus, though focused attention might be needed to persevere on the task, uninhibited attention and good working memory capacity may facilitate the generation of novel thought.

Set Shifting is the ability to change a mental set/framework from one semantic category to another in response to environmental contingencies and is widely assessed using the Wisconsin Card Sorting Test. The flexibility aspect of creativity assessed by divergent thinking tests relates closely to this ability and it is used as a scoring criterion in creativity (Wallach & Kogan, 1965; Torrance, 1974; Chi, 1997). Further support for an association between creativity and flexibility of thought comes from studies suggesting an association between positive mood/bipolar disorder and cognitive flexibility thereby facilitating creative problem solving (Rowe, Hirsh, & Anderson, 2007; Baas, De Dreu, & Nijstad, 2008; Soeiro-de-Souzaa, Dias, Bioa, Post, & Morenoa, 2011).

Inhibition plays a key role in cognitive processing by limiting the content of consciousness to goal-appropriate information (Radel et al., 2015). Inhibition would promote selective attention thereby narrowing the focus of attention around one limited source of information (Hasher, Lustig, & Zacks, 2007) and thus reducing the performance during divergent thinking tests of creativity (Carson, Peterson, & Higgins, 2003. Studies have also indicated that the release of inhibitory control facilitates creative idea generation by expanding the semantic array of information (Radel et al., 2015). However not all the evidence indicates a negative correlation between creativity and response inhibition (Benedek et al., 2012). Groborz and Necka (2003) provided corroborating evidence by their findings that creativity assessed by divergent figural production was related to higher cognitive control as assessed by the Stroop and the Navon task.

Creativity & Memory

Are creative ideas a unique amalgamation of simple concepts stored and retrieved from semantic memory? Having reviewed the association of creativity with executive functions, it can be postulated that creativity relies on the integrity of the prefrontal cortex (PFC), as the latter plays a critical role in all the above functions (Dietrich, 2004) and also PFC activations are seen in subjects performing divergent thinking tasks (Carlsson et al., 2000; Seger, Desmond,Glover, & Gabrieli, 2000; Bechtereva et al., 2004; Howard-Jones, Blakemore, Samuel, Summers, & Claxton, 2005; Fink et al., 2009; Kowatari et al., 2009). However, some studies have reported higher artistic creativity in diseases involving degeneration of the frontal lobe (Miller, Boone, Cummings, Read, & Mishkin, 2000; Liu et al., 2009; Serrano, Allegri, Martelli, Taragano, & Rinalli, 2005). Further, other imaging studies have also indicated the involvement of the temporal lobe along with the frontal lobe in creative thought generation (Mashal et al., 2007; Liu et al., 2012 & Donnay et al., 2014) as these regions are involved in the semantic retrieval and integration of information. While Miller et al. (1998) reported enhanced creativity in patients with dementia (associated with memory loss), de Souza et al., (2010) found negative associations between dementia and creativity.

Thus the existing literature on cognitive functions and creativity appears to be conflicting, either associating creativity with better cognitive functions or impaired cognitive ability, or suggests an adaptive cognitive control that can be regulated by creative artists as per task demands.

The Present Research

The present study aims at comparing the cognitive profile of creative artists and non-creative participants. The professional creative artists were recruited to assess the cognitive correlates of creativity rather than college students who are generally divided into high and low creative groups based on their scores on DT tests. This was done to circumvent two confounding effects- (a) considerable evidence indicates a strong correlation between DT and cognitive functions (Batey et al., 2009; Batey, Furnham, & Saffiulina, 2010; Karwowski & Gralewski, 2013 & Jauk et al., 2014), thus suggesting that the groups discerned in existing studies had a cognitively biased predisposition; (b) to enhance the ecological validity of the results.

MATERIAL AND METHOD

We assessed creativity correlates by taking a sample of professionally creative artists unlike those previous studies conducted with college students or which employed biographical data from eminent creators who form a rare and extreme group on the continuum of creativity.

A matched control design with cross sectional assessment was used for the study. The study sample comprised two groups – Creative group (CR) and matched Non-creative group (NC) with 30 participants each. All participants were in the age range of 20-40 years and had a minimum average intelligence (IQ score >90). All participants belonged to middle socio – economic status backgrounds and were recruited from the urban metropolis of Bangalore, India. The artists in the CR group were contacted after recommendations from national art and design organizations, music centres, dance schools and theatre societies engaged in the area of the creative arts in the metropolitan city of Bangalore, India and were recruited if they met the criteria for professional creativity (score >5) on the Creativity Achievement Questionnaire (CAQ; Carson et al., 2005). In the present study creative cognition tests were administered on artists from various domains to unravel the generic creative cognition substrates. The NC group comprised of healthy adults from the urban community of Bangalore with no demonstrated artistic creativity. Individuals with any medical, psychiatric or neurological disorders whatsoever were excluded from the study. Written informed consent and socio-demographic details were obtained from all the participants and the study was approved by the National Institute of Mental Health & Neurosciences (NIMHANS) Ethics Committee.

Screening measures included – the Edinburgh Handedness Inventory (EHI; Oldfield, 1971) – used to determine the handedness; Raven's Standard Progressive Matrices (RPM; Raven, 1938) – used to assess intelligence; and the Creativity Achievement Questionnaire (CAQ; Carson et al, 2005) – used to select pro C creative individuals for the creative group. CAQ is a self-report measure of creative achievement comprising 96 items that assesses achievement across 10 domains of creativity (the visual arts, music, dance, creative writing, architectural design, humour, theatre and film, culinary arts, inventions, and scientific inquiry).

NIMHANS Neuropsychological Battery (Rao et al, 2004) was used to assess the comprehensive cognitive profile of the participants. The Battery comprises globally recognized neuropsychological tests which have been standardized for the Indian population. Three major cognitive domains were assessed, namely:

1) Domain of Speed and Attention
   a) The Digit Symbol Substitution Test (Wechsler, 1981) was used to assess the speed of information processing. The time taken to complete the task forms the score and the longer the time taken, the poorer is the mental speed.
   b) Colour Trails Test (CT; D'Elia et al, 1996) was used to assess focused attention. The time taken to complete the task forms the score and the longer the time taken, the poorer is the ability for focused attention.
2) Executive Functions Domain
   a) The Animal Names Test (ANT; Lezak, 1995) was used to assess Category fluency. It requires the subject to generate the names of animals excluding the names of fishes, birds and snakes for one minute. The number of animals reported forms the score.
   b) The Design Fluency Test (Jones- Gotman & Milner, 1977) was used to assess Visual Fluency. It measures the ability to produce novel designs.
   c) N back tests (Smith & Jonides, 1999) were used to assess verbal working memory.

   d) The Spatial Span Test (Milner, 1971) was used to assess Visuo-spatial Working Memory. It is a visual analogue of the Digits forward and backward test.
   e) The Wisconsin Card Sorting Test (WCST; Heaton et al, 1993) was used to assess Set Shifting Ability.
   f) The Stroop Test (Rao et al., 2004) was used to assess Response Inhibition.
3) Memory functions
   a) The Auditory Verbal Learning Test (AVLT; Schmidt, 1996) was used to assess Verbal Learning and Memory.
   b) The Complex Figure Test (CFT; Meyers & Meyers, 1995) was used to assess Visual learning and memory.

The assessment took approximately 3-3.5 hours for administration and adequate rest breaks were provided to the participants during the administration to reduce fatigue and monotony.

Creativity was assessed using the Wallach & Kogan Creativity Test (WKC). The test has been standardized on the Indian population (Paramesh, 1972) and its four subtests namely Instances (e.g., “think of all things that are round in shape”), Alternatives (e.g., “think of different ways in which you can use a newspaper”), Line Meaning and Pattern Drawing (e.g., “what does all this image look like”) were used. The first two subtests assessed the verbal component of creativity while the Line Meaning & Pattern Drawing subtests assessed the visual component of creativity. Responses were recorded on a response sheet and the test took approximately one hour and was completed in a single session. The responses on all these subtests are scored on three dimensions – Fluency (the number of responses given to each item in each subtest); Originality (the number of unique responses given to each item in each subtest) and Flexibility (the number of categories represented by the responses given to each item in each subtest). The responses from all participants were counted with the use of database (Microsoft SQL) and were manually stratified into different categories by mutual consensus between two subject experts. The total number of responses comprised the fluency score, while the number of categories generated constituted the flexibility score. For the originality aspect of creativity, a computer algorithm was written that identified any unique responses given to each item in the test. The fluency, flexibility and originality scores were calculated for each participant by adding their respective scores across all the test items.

RESULTS

Data was analyzed using SPSS 15.0 for Windows. The association between categorical variables was assessed using the Chi-square test. As revealed by Shapiro-Wilk’s test, the cognitive variables did not follow a normal distribution. Since each participant in the first group was matched with another in the second group (30 independent pairs), the Wilcoxon Signed Rank test was used to compare performances between the two groups. In view of the large number of test variables here of interest, the Bonferroni correction was employed and any P value of less than 0.01 was considered to be statistically significant. Spearman's rank correlations were calculated to study the correlation between the different cognitive variables and creativity. Corrections for multiple tests were not made because of the exploratory nature of the study but a conservative p value of < 0.01 was used to minimize false positives. Effect sizes were calculated using Cohen's d to assess the magnitude of the difference between the groups.

Comparison of Groups

Groups were matched on age (mean ages of CR was 29.37 ± 5.52 years and NC was 29.13 ± 5.37 years respectively); gender (23 males and 7 females in each group) and years of education (16.37 ± 0.67 years in the CR and 16.17 ± 0.79 years in the NC group). Hence, no statistically significant difference was found between the two groups on these variables. There was a statistically significant difference between the two groups on CAQ which was used as a screening measure to discern the two groups.

The CR group comprised 60.0% graduates and 40.0% post-graduates as compared to 46.7% graduates and 53.3% post-graduates in the NC group. The differences in degree could be explained by heterogeneity in the duration of courses. For example, a graduation degree in the Humanities had a duration of 3 years; in Engineering courses, the duration was 4 years and in certain Fine Arts courses, the duration required for the completion of a graduate degree was 5 years. The CR group included a heterogeneous mix of professional creative painters (4%), designers (14%), musicians (20%), dancers (14%), writers (25%) and theatre artists (23%). The mean duration of involvement in a creative profession was 11.37 ± 4.11 years. A large proportion of the NC group was comprised of students (44%) followed by managers (27%), engineers (20%) and a small percentage of businessmen, bankers and teachers (3% each). The average income of the CR group was INR 57,294 as compared to INR 51,875 for the NC group.

Table 1. Comparison of socio-demographic details between the Creative group (CR) and Non-creative group (NC)

Variables		**CR (N=30)**		**NC (N=30)**		**P value**
		Mean ±S.D		Mean ±S.D		
Age (Years)		29.37±5.52		29.13±5.37		0.34
Education (Years)		16.37±0.67		16.17±0.79		0.27
CAQ		16.93± 9.299		1.93 ±2.664		<0.001*
		N	**%**	**N**	**%**	**Chi square value**
Gender	Male	23	76.67	23	76.67	1.00
	Female	7	23.34	7	23.34	
Years of Education	Graduates	18	60.0	14	46.7	0.279
	Post-Graduates	12	40.0	16	53.3	
SES	Middle	30	100	30	100	
Marital Status	Single	23	76.7	18	60.0	0.134
	Married	6	20.0	12	40.0	
	Divorced/separated	1	3.3	0	0.0	

* significant at 0.01 level

Results indicate a significant difference across both the groups in all three dimensions of Creativity-Fluency, Originality & Flexibility (p=<0.001). The CR group scored significantly higher than the NC group in all domains of creativity. This finding provides evidence for the construct validity of the creativity test used and is in line with the existing literature indicating that creative individuals score highest on creativity tests (Srivastava et al, 2010; Vellante et al, 2011).

The main objective of the present study was to explore the cognitive profile of creative artists. The mean raw score of the CR group for intelligence was higher than the NC group. However, no significant difference was found between the NC & CR group on intelligence. Since tests for mental speed (DSST) and focused attention (CT) are both timed tests, the longer the time taken on these tests, the poorer will be the performance. Thus the CR group performed better on these two tests when compared to the uncreative control group though a significant difference was only found on focused attention between the two groups with a large effect size of 0.77. Both set shifting ability and response inhibition are also scored negatively indicating the lower the score, the poorer the performance on these two tests. The CR group scored higher on all executive functions and differences were significant with large effect sizes on Category Fluency, design Fluency (both free and fixed), visuo-spatial working memory (medium effect size), set shifting ability and response inhibition. While the CR group scored higher on both verbal and visual memory, a significant difference was only found for verbal memory.

Table 2. Comparison of Creativity scores between the CR & NC groups

	CR		NC		p Value
	Mean	**S.D**	**Mean**	**S.D**	
FLUENCY	84.23	25.412	47.17	20.16	<0.001*
ORIGINALITY	52.57	21.308	24.17	14.608	<0.001*
FLEXIBILITY	53.07	13.638	30.40	10.795	<0.001*

* significant at 0.01 level

Table 3. Comparison of Cognitive functions between the CR & NC groups

Cognitive Functions	CR (N=30)	NC (N=30)	P Value	Effect Size Cohen's d
Intelligence (RPM)	52.80 ± 4.06	50.43± 8.12	0.330	-
Mental Speed (DSST)	143.50±23.80	161.63±46.04	0.131	-
Focused Attention (CT)	99.67±28.04	121.43±28.76	0.010*	0.77
Category Fluency (ANT)	16.83±3.72	13.70±4.16	<0.004*	0.79
Design Fluency Free (DFFR)	19.67±7.64	10.27±3.84	<0.001*	1.56
Design Fluency Fixed (DFFX)	16.93±7.33	10.00±3.35	0.001*	1.21
Verbal Working Memory (N Back)	7.57±1.01	7.00±1.08	0.086	-
Visuo-spatial Working Memory (SPSS)	15.80±2.83	14.07±2.84	0.011*	0.61
Set Shifting Ability (WCST)	8.55±3.04	13.37±7.63	0.002*	0.82
Response Inhibition	101.93±26.66	140.87±54.50	0.003*	0.91
Verbal Memory (AVLT)	14.10±1.61	11.24±2.37	<0.001*	1.41
Visual Memory (CFT)	26.30±3.47	23.83±4.83	0.055	-

* significant at 0.01 level

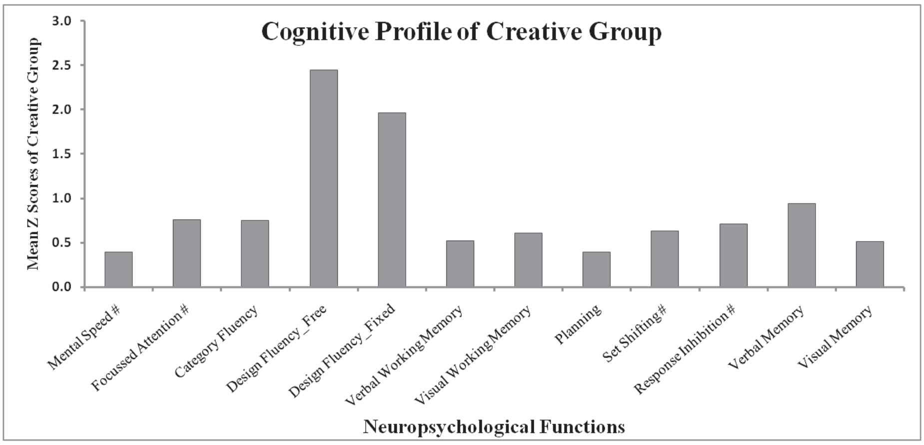

Fig. 1. Profiles of neuropsychological performance by CR group (# since the tests scoring these abilities are scored negatively, the scores were converted into positive for an accurate visual representation)

With regard to attention, our findings are incongruent with existing studies postulating defocused attention as an enhancer of the perceptual repertoire of creative individuals thereby facilitating creativity (Carson et al, 2003; White & Shah, 2006). While the present study did not find a significant difference between the two groups on verbal working memory; visuo-spatial working memory was found to be significantly higher in the CR as compared to NC. Higher fluency, WM, set shifting and response inhibition in the CR corroborates the existing evidence on the executive nature of creativity (Carson, Peterson, & Higgins, 2003; Bühner et al., 2005; Oberauer et al.,2008; Nijstad, De Dreu, Rietzschel & Baas, 2010; Zabelina and Robinson, 2010; Benedek, et al., 2012; de Dreu et al., 2012). These executive functions are known to be mediated by the frontal lobe especially the dorsolateral prefrontal cortex (Miller & Cohen, 2001; Alvarez & Emory, 2006 & Stuss, 2011) and functional neuroimaging studies have found PFC involvement in originality aspects of creativity (Folley & Park, 2005; Hori et al, 2008; Kowatari et al, 2009; Shamay-Tsoory et al, 2011). The cognitive profile of the CR group are depicted by calculating their standardized scores against healthy controls (taken as a baseline with a mean=0 and SD=1). Fig 1 below represents these results.

Correlates of Creativity

A significant positive correlation was found between intelligence, mental speed, category fluency, design fluency (both free & fixed), verbal memory and all components of creativity. A significant negative correlation was found between focused attention, set shifting, response inhibition, verbal memory and all components of creativity. Since these cognitive functions are negatively scored, it can be understood that there was a positive association between these variables and creativity. Also, visuo-spatial working memory was found to be significantly positively correlated with the flexibility component of creativity.

Table 4. Correlation between cognitive variables and the three principal components of creativity.

Cognitive Variables	Fluency	Originality	Flexibility
Intelligence	0.420*	0.408*	0.409*
Mental Speed	0.422*	-0.306*	-0.413*
Focused Attention	-0.508*	-0.515*	-0.487*
Category Fluency	0.407*	0.404*	0.377*
Design Fluency (Free)	0.474*	0.405*	0.430*
Design Fluency (Fixed)	0.520*	0.445*	0.472*
Verbal Working Memory	0.270	0.251	0.309
Visuo -spatial Working Memory	0.328*	0.276*	0.339*
Set Shifting	-0.465*	-0.449*	-0.492*
Response Inhibition	-0.357*	-0.371*	-0.383*
Verbal Memory	0.410*	0.364*	0.395*
Visual Memory	0.227	0.247	0.234

*significant at 0.01 level

Fluid intelligence has been consistently associated with performance on divergent thinking tests (Batey & Furnham, 2006; Silvia, 2008; Batey et al., 2009; Kim, Cramond, & VanTassel-Baska, 2010; Benedek et al., 2012; Jauk et al., 2014). An efficient neural basis of intelligence (e.g., Eysenck & Barrett, 1985; Jensen, 1993) explains some of the variance in the DT tests scores. Because of the timed nature of these tests, neural efficiency contributes to an increase in DT performance. A better focused attention might be needed to concentrate on the task at hand and would also lead to a higher speed of processing thus enabling an efficient process resulting in a creative product (Dorfman, Martindale, Gassimova, & Vartanian, 2008; Martindale, 1999; Vartanian, Martindale, & Kwiatkowski, 2007). With regard to category and design fluency our findings lend support to existing subject literature documenting a higher association between creativity (when assessed using divergent thinking) and fluency (Silvia et al., 2013); and with response inhibition (cognitive control) as assessed by the Stroop task (Groborz & Necka, 2003; Benedek, Franz, Heene, & Neubauer, 2012 & Zabelina, Robinson, Council, & Bresin, 2012). Set shifting refers to the process of switching between different mental sets (Monsell, 1996). As assessed by WCST, it involves the disengagement of a mental set that has become irrelevant in favour of a new and relevant mental set. An ability to switch across various categories would be highly useful in generating varied creative responses which resonates with the flexibility component of creativity assessed by divergent thinking. A divergent thinking task requires the generation of creative novel responses to common items (e.g., a car tire).The search and semantic retrieval of possible alternatives would require a higher memory capacity (Storm & Angello, 2010).

DISCUSSION

The “Geneplore” model of creativity bifurcates it into two phases – a generative phase and an exploratory phase (Finke et al., 1995). Research has consistently argued that the idea generation phase of creativity is more unconscious than conscious (Dijksterhuis & Meurs, 2006; Gao & Zhang, 2014). The neural substrates of these two contrasting processes have been identified as the Cognitive Control Network (CCN) and the Default Mode Network (DMN; Jung et al., 2013; Półrola P., Kaczmarek B., Góral-Półrola 2016). Integrating this model with the present findings, it can be hypothesized that functions such as fluency, the ability to shift mental states rapidly and associative sematic retrieval of information would be the cognitive aspects of DMN aiding in the imaginative idea generation. Further, focused attention, the ability to reason abstractly, the efficient processing of information and a good working memory could be the cognitive counterparts of CCN enabling task perseverance and completion (Pąchalska, Buliński, Kaczmarek et al. 2013). However, these inferences at best can be speculative as the two phases of idea generation and elaboration were not assessed exclusively and the correlation of specific cognitive functions with anatomical substrates is beyond the scope of the present study.

However, there are certain limitations to the study such as the small sample size, the small female representation thereby preventing an analysis of gender differences in the cognitive profile of creativity. Regression analysis indicating predictors of creativity could not be done due to the small sample size. Also multivariate analysis controlling for confounding variables such as IQ (known to affect executive functions) could not be done due to the small sample sizes and should be attempted in future studies. Despite these limitations, the study provides evidence for neuropsychological functions that could be considered as the cognitive substrates of creativity. Novice artists could work towards enhancing these functions through structured cognitive retraining tasks thereby expecting improvements in their creative pursuits. Additionally, the findings of the present study could be used to design educational programs based on divergent thinking that could result in cognitive enhancement.

CONCLUSIONS

Against a backdrop of paucity in the cognitive profile of creativity, the present study elucidates the functions associated with creativity. The strengths of the present study include methodological rigor such as using a robust and valid tool to identify creative individuals, one to one matching across both the groups, thereby controlling the influence of age, gender and education; using a standardized and comprehensive battery to assess cognitive functions and statistical rigor in analyzing the data.

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