Original Article

Gain of Function Presenting as Creative Skills in Patients with Progressive Cognitive Dysfunction and their fMRI Correlates: A Descriptive Study

Safwan Ahmed, Chandra Ratnaswami Sadanandavalli[1], Ganesan Venkatasubramanian[2], Subasree Ramakrishnan[3], Jamuna Rajeswaran[4], Mariamma Philip[5], Rajnish Kumar Gupta[6], Indupriya Babu[7]

Department of Neurology, Hazm Mebaireek General Hospital, Hamad Medical Corporation, Doha, Qatar, [1]Department of Neurology, S.K. Hospital, Edapazhanji, Thiruvananthapuram, Kerala, Departments of [2]Psychiatry, [4]Neuropsychology, [5]Biostatistics and [3]Neurology, National Institute of Mental Health and Neurosciences, Bengaluru, Karnataka, [6]Department of Psychology, Manipal University Jaipur, Rajasthan, [7]Department of Behavioural Sciences, Jindal Institute of Behavioural Sciences, O.P Jindal Global University, Haryana, India

Abstract

Background and Objectives: Patients with neurodegenerative disorders generally lose their acquired cognitive skills. However, a few of our patients showed creative skills in new areas, and we tried to evaluate a possible neural substrate for this phenomenon. **Methods:** Patients who attended the memory clinic of National Institute of Mental Health and Neuro Sciences between December 2016 and September 2018 were screened as per the inclusion and exclusion criteria. All mandatory investigations including complete neuropsychology workup were done. The Creativity Styles Questionnaire and Temperament and character inventory-Revised (TCI-R) were used to assess creativity. Magnetic resonance imaging, voxel-based morphometry, and resting-state fMRI were done and the results analyzed. **Results:** A group of previously non-creative patients showed creative skills in the face of neurodegenerative disorder. Out of 110 patients, 10 patients could be called creative. As the disease worsened, creativity was lost. These persons showed enhanced volume in the non-dominant angular gyrus, and its faciliatory connectivity to dorsolateral prefrontal cortex and inferior parietal lobe was seen. Paradoxically, creativity seems to emerge in some patients with major cognitive disorders and it disappears as the disease progresses. Creative domain varies from person to person, and the longest preserved domain is music. The fMRI findings suggest that the enhanced areas may play a role in sustaining creativity even in patients with degenerative diseases. **Conclusion:** Although case reports of creative skills in patients with major cognitive disorders exist, a complete workup of the neural basis has not been conducted so far. Higher volume in the non-dominant regions with relatively preserved language domain could be dysfunctional plasticity causing disinhibition of the innate creative skills when frontal lobe functions decline.

Keywords: Neurodegeneration, creativity, disinhibited versus neofunctional plasticity

Introduction

Progressive cognitive dysfunction happens when neural tissues deteriorate to lose function and become converted or replaced by gliosis, resulting in an altered state of function. Patients generally lose efficiency in single or multiple cognitive domains, but rarely creative skills are seen to emerge temporarily. Generally, therapeutic options are very few and the results are not very satisfactory; therefore, there is significant caregiver burden. Rehabilitation of the neuropsychiatric symptoms is based on exploiting the available functional domains, engaging in activities which interest the patients, distracting during difficult behavioral situations, engaging in reality-oriented therapies and group therapies, and including yoga in the early stage of the disease as pharmaco-sparing techniques. As the disease advances, cautious use of antipsychotics is needed, which can have detrimental effect on the course of disease, though temporary behavior control can be achieved. Creativity is the ability to do work that is novel, useful, adaptive, unexpected, and appropriate, according to Sternberg et al.[1] In certain people, creative activities are noticed in the beginning of degenerative processes in which they become fully engaged. These features are reported in literature as isolated case reports. In such situations, promoting the patient to get engaged in their area of creativity showed great efficacy in behavior control without the need for antipsychotics.

"Creativity is the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e. useful, adaptive concerning task constraints)".[1] However, enhanced creativity in dementia is a novel phenomenon as it reflects gain of function due to either disinhibition of specific areas or neofunctional plasticity. This is often seen to be of therapeutic

Address for correspondence: Dr. Chandra Ratnaswami Sadanandavalli, S.K. Hospital Edappazhanji, Thiruvananthapuram-06, Kerala, India.
E-mail: drchandrasasi@yahoo.com

Submitted: 03-Sep-2024 **Revised:** 04-Feb-2025 **Accepted:** 11-Feb-2025
Published: 11-Apr-2025

DOI: 10.4103/aian.aian_727_24

use in handling some of the symptoms like agitation and aggression by keeping them engaged in the newfound interest. In addition, looking into novel neurotransmitters which may be involved in this phenomenon may serve as a resource for future neurotransmitter research. Literature has variable reference to this phenomenon and has hypothesized it to be disinhibition of non-dominant hemisphere functions involving the prefrontal and parietal cortices.[2]

In this study, we tried to look for the prevalence of creative potential in patients with progressive cognitive decline, the type of creativity, and its efficacy in the management of neuropsychiatric symptoms of the patients, and attempted to identify its neural substrate by functional Magnetic Resonance Imaging (fMRI) default mode network analysis.

Methods

The present study is an original research study conducted at the Department of Neurology and Neuropsychology of the National Institute of Mental Health and Neuro Sciences (NIMHANS) at Bengaluru, India. The study period was from December 2016 to September 2018 with a total duration of 21 months. The study was approved by the Institutional Ethics Board (EC no: NIMH/DO/ETHICSSUB-COMMITTEE (BS and NS) 4THMEETING/2017). Informed written consent was obtained from all the participants and caregivers in some cases.

During the study period, 110 patients with progressive cognitive dysfunction fulfilled the inclusion criteria. These criteria included evidence of major cognitive dysfunction, an age range of 18–90 years, and willingness to participate in the study by both the patient and their relatives. Patients who were unwilling to participate or had a history of central nervous system disorders, previous neurosurgical or psychiatric illness, or premorbid creativity were excluded from the study.

Screening and assessment

Creativity in patients was screened using the Creativity Achievement Questionnaire.[3] It is a questionnaire with A–K set of parameters (A- Visual arts and painting, B- Music, C- Dance, D- Architectural design, E- Creative writing, F- Humor, G- Inventions, H- Scientific discovery, I- Theater and films, J- culinary arts, K- List other creative achievements). Ten patients in this group were found to have creative skills. These patients underwent detailed clinical and neuropsychological assessments by a trained clinical neuropsychologist. The Hindi Mental Status Examination (HMSE) and Adenbrook's cognitive examination-Revised (ACE-R)[4-6] were conducted to screen for cognitive deficits. Creativity was further assessed using the Creativity Styles Questionnaire (CSQ).[7] The Temperament and character inventory-Revised (TCI-R) and Zarit Caregiver Burden scores were recorded from primary caregivers.[8,9] The Zarit Caregiver Burden Score is a 22-item questionnaire with responses in the range of 0–4 and a maximum score of 88. Burden is categorized as severe for a score of 61–88, moderate for a score of 41–60, mild for a score of 21–40, and absent for a score below 21.

Correlation with cognitive dysfunction and educational status

Whenever possible, the area of creativity and its correlation with the type of cognitive dysfunction and educational status were analyzed. The neural substrate of creativity in patients who exhibited progressive cognitive dysfunction was examined using imaging.

Magnetic resonance imaging data acquisition

Five of the 10 patients who exhibited creativity underwent magnetic resonance imaging (MRI) scans on a Siemens Skyra 3.0 T MRI scanner (Siemens, Erlangen, Germany) at NIMHANS. T1-weighted images were obtained in a sagittal orientation using the Magnetization Prepared by Rapid Gradient Echo sequence.

Voxel-based morphometry analysis

The acquired images for each participant were reoriented to have the same point of origin (the anterior commissure [AC]) and spatial orientation. The structural data were then processed and analyzed using Statistical Parametric Mapping 12 (SPM12; http://www.fil.ion.ucl.ac.uk/spm/software/spm12/) with the Computational Anatomy Toolbox 12 (CAT12) (http://dbm.neuro.uni-jena.de/cat/) running in Matrix laboratory (MATLAB) R2016a (www.mathworks.com).

Resting-state fMRI data

A functional connectivity toolbox, Functional connectivity Toolbox (CONN) (https://web.conn-toolbox.org/), was used to process resting-state fMRI images for all subjects.[10] First, the anatomical and functional images were reoriented to the AC and posterior commissure (PC) line (AC–PC). The initial 10 volumes of each subject's resting-state data were removed to account for signal stabilization. All volumes in each functional scan were realigned with the first volume. Slice timing correction was performed to account for time differences across all slices. Motion correction was applied to detect and correct motion artifacts in each scan volume. Anatomical and functional scans were then normalized with the Montreal Neurological Institute (MNI) template and segmented into GM, white matter, and cerebrospinal fluid.[11] The resulting images were smoothed with a Gaussian kernel of 8 mm Full width at Half Maximum (FWHM) to ensure a good signal-to-noise ratio.[12-14]

After preprocessing, all subjects' images underwent first-level and second-level analyses. The first-level analysis provided connectivity between regions of interest (ROIs) in the form of Fisher-transformed correlation coefficients for each subject.[15] In the second-level analysis, group analysis was performed, which provided statistical significance of connectivity within ROIs.

Statistical analysis

All statistical analyses were performed using CAT12. To identify gray matter (GM) volume differences between patients and healthy controls, a two-sample *t*-test was conducted. The effects of age and gender were excluded as nuisance variables to remove variance related to these factors.

Results

Demographic characteristics

This study revealed that while major cognitive disorders of degenerative nature are more common in older age groups, they can be seen across all age groups (mean age of onset in creative vs. non-creative cases: 60.10 vs. 64.2 years). In the creative group, there was a slight female preponderance (M: 40%, F: 60%), whereas in the non-creative group, there was a male preponderance (M: 66%, F: 34%). Educational status varied from less than 10 years of schooling to individuals with high academic achievements (range: 5–17 years).

In our study, the creative group had significantly higher years of education and lower illness duration compared to the non-creative group (*P* value 0.023 and 0.023, respectively) [shown in Table 1a].

The disease spectrum varied from degeneration (e.g., Alzheimer's Dementia (AD), Frontotemporal Dementia (FTD)) to untreated inflammation progressing to degeneration, such as neurosarcoidosis. Patients in the creative group held high-profile jobs, including information technology professionals, schoolteachers, police constables, businessmen, and homemakers. This suggests that higher education and cognitive reserve may not necessarily influence creative skills. The mean years of education of creative patients was higher than that of non-creative dementia patients (mean: 13.7 vs. 10.3 years). The various domains of creative skills in the creative patient group included drawing skill in three patients, which was followed by two patients each in singing and interior designing/construction. Other skills noted were storytelling, innovative idea, and achieving a set goal in one patient each [Table 1b]. Singing skill lasted for the longest duration (range: 3–5 years).

Frontal lobe involvement

This study identified that major creative patients had significant impairment of frontal lobe functions, irrespective of the nature of the disease. Tables 2a and 2b show the mental status examination findings and various tests performed as a part of neuropsychological examination of the creative cases. Mental status examination (MSE) was amenable only in eight patients. Predominant involvement was noted in frontal lobe functions like fluency (n = 8, 100%) and digit span test (n = 7, 87%). Recent memory was involved in 7 (87%) of the patients. Neuropsychological testing revealed predominant impairment in verbal and category fluency (n = 7, 87%), suggestive of frontal lobe involvement, as well as deficits in visual and learning memory (n = 7, 87%), indicative of temporal lobe involvement. These findings were consistent with the results of the mental status examination. This shows the predominant involvement of frontal lobe, irrespective of the diagnosis, and also involvement of medial temporal lobe. Executive function, verbal fluency, and working memory were the most commonly affected domains, indicating that frontal lobe function impairment may play a key role in creativity.

Illustrative cases

Patient 1:

A police constable with 12 years of education developed frontotemporal dementia. During the later part of the first year of illness, his son observed that the patient started copying pictures and drawing line diagrams spontaneously when given a paper and pencil [Figure 1]. He was extremely quiet when engaged with this. This creative activity lasted for nearly 3 years before disappearing. At recruitment, the HMSE score was 17, which dropped to 12 after 6 months. The ACE-R score was 50. CSQ showed a high global measure of creative capacity, and TCI-R indicated traits such as persistence, self-directiveness, cooperativeness, and self-transcendence. The Zarit Caregiver Burden score was 42, indicating moderate to severe burden. Neuropsychological assessment revealed bitemporal and left frontal involvement [Table 2c].

Patient 2:

A young Birla Institute of Technology and Science Pilani graduate began drawing beautiful pictures, surprising

Figure 1: Pictures drawn by a police constable with FTD. FTD: Frontotemporal Dementia

Table 1a: Comparison of years of education, HMSE scores, illness duration, and burden score between creative and 40 age- and sex-matched non-creative cases

	Creative cases (n=10)	Non creative cases (n=40)	*p*-value
Years of education	13.7±3.7	9.75±5.5	0.023
HMSE	19.2±11.03	1493±8.3	0.151
Illness duration	2.18±1.4	3.34±1.5	0.023
Care giver burden score	32.2±13.87	39.68±12.83	0.205

All values are presented as mean±SD. HMSE: Hindi Mental Status Examination, SD: standard deviation

everyone [Figure 2]. This occurred while he was in a sedentary job, away from his family, and believed to be withdrawn due to depression. However, he was suffering from loss of secondary sexual characters for several years, visual disturbances, chorea, and most of his cognitive skills had declined. His evaluation revealed him to be suffering from advanced neurosarcoidosis.

Table 1b: Types of creativity seen

Creative domain	No. of patients (n=10)	Duration of creative skill (in years)
Drawing	3	3, 2, 2.5
Singing	2	5, 3
Achieving set goal	1	3
Interior designing/construction	2	1, 1
Storytelling	1	2
Innovative idea	1	0.5

Table 2a: MSE of creative cases

Frontal lobe tests	Interpretation	
	Adequate n (%)	Impaired n (%)
1) Fist edge palm	4 (50)	4 (50)
2) Digit span test	1 (13)	7 (87)
3) Fluency	0 (0)	8 (100)
4) Tap A test	3 (38)	5 (62)
Parietal lobe		
1) Right left orientation	7 (87)	1 (13)
2) Finger gnosis	6 (75)	2 (25)
3) Calculation	6 (75)	2 (25)
4) Praxis	6 (75)	2 (25)
5) Stereognosis	7 (87)	1 (13)
Temporal lobe		
1) Recent memory	1 (13)	7 (87)
2) Remote memory	6 (75)	2 (25)
Occipital lobe		
1) Color recognition, naming	7 (87)	1 (13)
2) Object and face recognition	7 (87)	1 (13)

MSE: Mental status examination

During the first assessment, creative skills were observed in patients with HMSE scores ranging from 10 to 29, indicating that HMSE may not significantly influence creativity. Neuropsychological tests suggested predominant involvement of left frontal and bitemporal lobes. The TCI-R questionnaire revealed traits such as novelty seeking, persistence, self-transcendence, cooperativeness, and self-directiveness, which may indicate a tendency to explore new avenues without feeling inhibited by social norms. CSQ showed high scores in creative capacity, consistent with styles of creativity in healthy populations [Table 3].

Follow-up

At six months follow-up, caregivers reported that engaging patients in their creative activities helped sustain attention and prevent behavioral problems. On average, creativity lasted for about 3 years (0.5–5 years). Follow-up HMSE scores were significantly lower in the creative cases compared to the initial evaluation, suggesting a decline in other cognitive functions (P value = 0.043) [Table 4].

Among the creative skills, music lasted the longest (up to 5 years) in two patients, potentially indicating the role of preserved non-dominant hemisphere functions and the cerebellum.

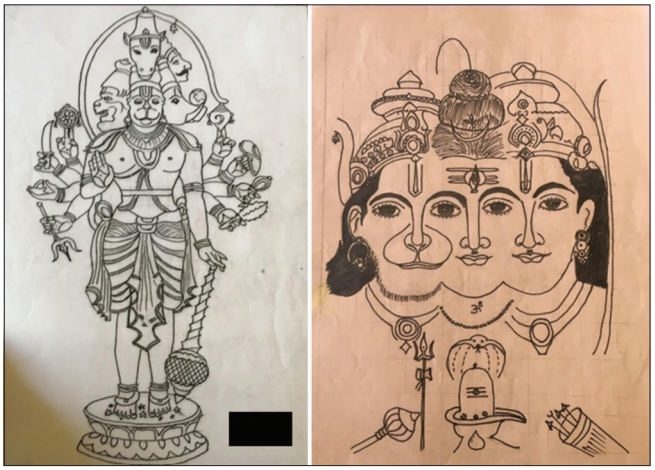

Figure 2: Pictures drawn by 37 year old neurosarcoid patient

Table 2b: Neuropsychological assessment of creative cases

Test	Cognitive domain	No. of amenable patients	Results	
			Adequate (n), mean score	Impaired (n), mean score
Controlled oral word association test	Verbal and category fluency	8	(n=1), 12	(n=7), 4.4
Verbal N-back test (hits)	Verbal working memory	8	(n=3), 7	(n=5), 3
Spatial span test	Visuospatial working memory	8	(n=4), 14	(n=4), 6
Bender Gestalt test/complex figure test—copy trials	Visuospatial constructional ability	8	(n=1), 35	(n=7), 12
Complex figure test—immediate and delayed recall trials	Visual memory	8	(n=1), 23	(n=7), 10
Tower of London	Planning	7	(n=3), 9	(n=4), 4
Rey's AVLT	Verbal learning and memory	7	(n=3), 48	(n=4), 21
Stroop test	Response inhibition	6	(n=2), 162	(n=4), 240
Wisconsin card sorting test	Set shifting	6	(n=2), 70	(n=4), 33
Color trail 1 and 2 test	Sustained attention	4	(n=3), 126	(n=1), 220

AVLT: Auditory Verbal Learning Test

Neuroimaging

Structural MRI brain scans in the creative group showed predominant involvement of frontal and temporal lobes (40% and 70%, respectively). Parietal lobe involvement was noted in three patients (30%). Voxel-based morphometry (VBM) analysis revealed GM volume enhancement in the right angular gyrus compared to healthy controls [Figure 3]. Resting-state fMRI data analysis showed significant functional activation in connectivity between the right angular gyrus [Figure 4], inferior parietal lobule, dorsolateral prefrontal cortex, and other related areas.

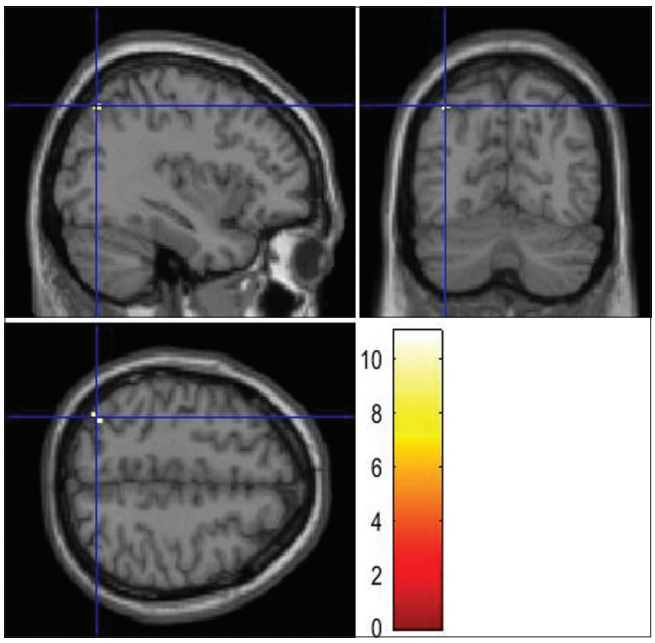

Figure 3: Patient group showed GM enhancement with healthy control in areas such as right angular gyrus. GM: Gray matter

There was no statistically significant difference in caregiver burden scores between creative and non-creative dementia patients. In the non-creative group, no burden was reported in 10%, mild burden in 37.5%, moderate burden in 47.5%, and severe burden in 5%. In the creative group, no burden was noted in 30%, mild burden in 30%, and moderate burden in 40%. Test of significance could not be applied as the number in creative group was low. However, frequency analysis showed the non-creative group had more persons in moderate to severe category, whereas in the creative group there was equal distribution of patients in various severity. In the non-creative group, caregiver burden scores inversely correlated with years of education and illness duration.

Discussion

The present study is, to the best of our knowledge, the first of its kind to include a comprehensive workup, encompassing clinical and neuropsychological assessments, as well as a detailed evaluation of creativity. It identified special creativity

Table 2c: Neuropsychological assessment

Test	Cognitive domain	ResultsScore, z-score
Controlled oral word association test	Verbal and category fluency	4, -0.133
Verbal N-back test (hits)	Verbal working memory	4, 0.33
Bender Gestalt test/complex figure test—copy trials	Visuospatial constructional ability	9, -0.5
Complex figure test—immediate and delayed recall trials	Visual memory	8, -0.28
Spatial span test	Visual working memory	5, -0.33
Tower of London	Planning	CNBT
Rey's AVLT	Verbal learning and memory	18, -0.5
Stroop test	Response inhibition	CNBT
Wisconsin card sorting test	Set shifting	CNBT
Color trail test	Sustained attention	CNBT

AVLT: Auditory Verbal Learning Test, CNBT: Could Not Be tested

Table 3: Creative style questionnaire

CSQ-R (subscales)	Mean±SD (n=7)	Category	
		High, n (%)	Low, n (%)
Global measure of creative capacity	7.85±1.06	7 (100)	0 (0)
Belief in unconscious process	2.89±0.45	2 (29)	5 (71)
Use of techniques	3.18±0.43	4 (57)	3 (43)
Use of people	3.34±0.40	5 (71)	2 (29)
Final product orientation	2.95±0.25	1 (14)	6 (86)
Environmental control/behavioral self-regulation	2.41±0.27	3 (43)	4 (57)
Superstition	2.14±0.47	2 (29)	5 (71)
Use of the senses	2.89±0.50	2 (29)	5 (71)

SD: standard deviation, CSQ-R: Creativity Styles Questionnaire-Revised

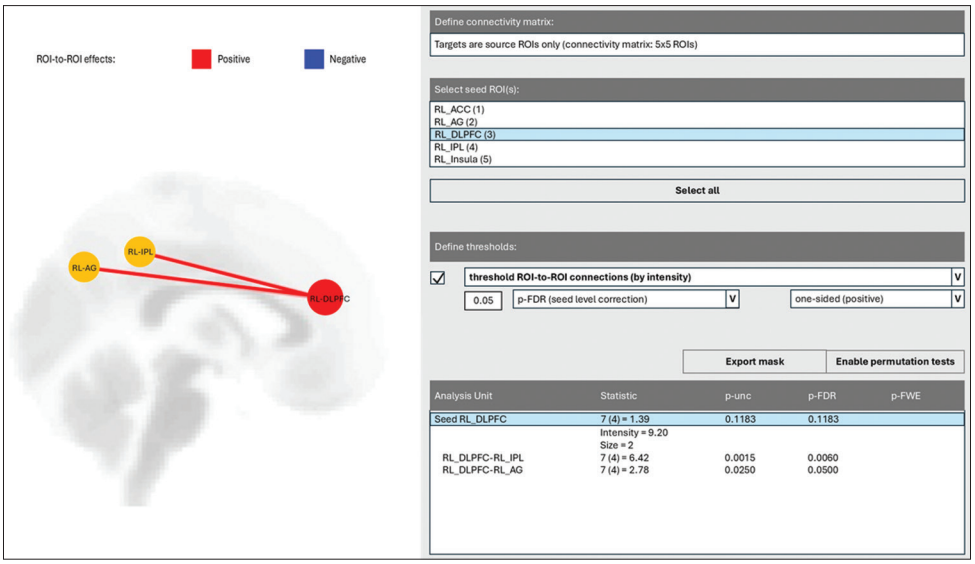

Figure 4: fMRI shows connectivity between right drosolateral prefrontal cortex and right inferior parietal lobule and right angular gyrus. fMRI: Functional magnetic resonance imaging

Table 4: Follow-up data

Parameter	Creativity cases (at the initial evaluation) (n=10)	Cases at follow-up (after 6 months) (n=10)	*P*-value
HMSE, Mean ± SD	19.2±11.03	16.5±11.237	0.043

HMSE: Hindi Mental Status Examination, SD: standard deviation

traits such as novelty seeking and self-transcendence using the TCI-R questionnaire. In addition, the study incorporated MRI brain imaging, VBM, and resting-state fMRI.

The mean age of onset in creative versus non-creative cases was 60.10 versus 64.2 years. The study by Ratnavalli et al.[16] in 2002 included 108 patients, with a mean age of onset of 56.1 ± 8.6 years for FTD and 60.7 ± 5.6 years for AD. In an Indian study by Alladi et al.[17] involving 347 patients, where all subtypes of dementia were studied, the average age of onset was 57 ± 8.9 years for FTD and 67.1 ± 9.0 years for AD.

This creativity appears to be independent of the specific disease and indicates that creativity can be upregulated in a small percentage of patients with degenerative brain diseases. This phenomenon is not disease specific, but rather shows certain traits that promote creativity in individuals without prior training in the newfound skills, representing an apparent or real gain of function. Lower HMSE scores do not seem to influence creativity, suggesting that this highly specialized function is independent of global cognitive abilities. The creative domain varies among individuals, with music being the most preserved domain.

Engaging in creative activities has a pharmaco-sparing effect during periods of agitation, but as the disease progresses, these skills are eventually lost. Interestingly, caregiver burden does not seem to be significantly impacted by the patient's creativity. Imaging assessment using VBM showed regional GM enhancement in the patient group compared to healthy controls, particularly in areas such as the right angular gyrus. Stronger correlations were found in Dorsolateral PreFrontal Cortex (DLPFC) and Inferior Parietal Lobe (IPL) connectivity (F stat: 6.42, beta: 0.27, *P* value: 0.001). In addition, connectivity between Angular Gyrus (AG) and IPL also showed significant correlation (F stat: 3.31, beta: 0.46, *P* value: 0.01). There was also significant functional connectivity between DLPFC and AG (F stat: 2.78, beta: 0.08, *P* value: 0.02).

Neuropsychological tests revealed temporal lobe involvement, as most patients had poor memory scores. However, our study showed significant involvement of the dominant frontal lobe, with relative preservation of language functions. These results suggest that creativity can emerge from specific networking patterns, independent of the underlying disease. For example, the non-dominant angular gyrus is linked to creativity in normally creative individuals as well. Albert Einstein's brain also showed a larger non-dominant angular gyrus and expanded prefrontal cortex.[18]

Another study by Hahm et al.[19] examined the neural correlates of creative thinking using the Torrance Tests of Creative Thinking and found greater activation in bilateral brain regions, including the left anterior cingulate, and bilateral frontal, parietal, temporal, and occipital regions. Our study is based on our results on default mode network, which no study has done before. Previous reports were not based on default mode network analysis, and ours is the only complete study to the best of our knowledge.

Our findings suggest that higher volume of the non-dominant angular gyrus and its circuits with the inferior parietal lobule and DLPFC may play a role in sustaining creativity even in

patients with degenerative diseases. Functionally, the language domain in these patients was better preserved, indicating a potential bihemispheric influence. Temperament and Character Inventory (TCI) scores for traits such as novelty seeking, persistence, and self-transcendence in these patients suggest that these traits, along with circuits between the dominant angular gyrus, inferior parietal lobule, DLPFC, and language areas in the dominant hemisphere, may be disinhibited as frontal lobe functions decline. This disinhibition may lead to the expression of creative skills, which disappear as global cognitive decline progresses.

Unraveling these mechanisms could open the door to novel therapeutic options that promote facilitative circuits and neurotransmitters. New insights into the mechanisms of apoptosis may reveal why some functions decline while others are facilitated, creating targets for therapeutic exploitation. Engaging patients in creative activities clearly helps delay the use of antipsychotics in these individuals.[19,20]

Strengths of the study

This study had several strengths, including the consistency of care and analysis: a single clinician saw all cases, one radiologist reported all MRI results, one specialist reported all VBM data, and one psychiatrist interpreted all fMRI results. This was also a prospective study with follow-up, the first of its kind in the literature to cover such a broad range of parameters based on patients' baseline functioning. Specific diagnostic criteria, such as Diagnostic and statistical Manual of Mental disorders- IV (DSM-IV) and National Institute of Neurological Disorders and Stroke (NINDS) and the Association Internationale pour la Recherche et l'Enseignement en Neurosciences (AIREN) (NINDS-AIREN), were applied for clinical diagnoses, supported by appropriate laboratory testing. Creativity screening was performed using the Creative Achievement Questionnaire, a well-known and validated tool. VBM and fMRI default mode network analysis was possible in 50% of the patients.

Limitations of the study

Limitations included the small sample size, short study period, and follow-up duration. Not all patients were amenable to complete workup, and a control group of normally creative individuals could not be recruited. The collaborating investigators were not blinded, and the study could not investigate the brain regions involved in specific domains of creativity due to the low number of patients and their conditions. Another limitation of our study was that as our objective was to identify creativity and its neural substrate in patients who qualify for major cognitive disorder, this study was not done in a disease-specific way. Determining the general prevalence of creativity was not the objective of the study. Creativity is a uniquely defined skill when present and can be in many domains; this alone was identified.

Conclusion

This study suggests that during the repair process, special remapping may cause unique skills to emerge, potentially representing neofunctional plasticity or disinhibited plasticity—a transient phase where default creativity is expressed as repair circuits activate while goal-related functions decline. It is well known that some areas temporarily undergo compensatory hypertrophy. Plasticity can be neofunctional as reported in patients with subjective cognitive decline, the stage which could be the forerunner of Mild cognitive impairment (MCI). Here insight is retained as in these groups of patients, there is compensatory overactivity of prefrontal cortex, and neofunctional networks with creative potentials could be a factor. This is the rationale behind our hypothesis supporting a "repair" process. Unique traits identified, along with VBM and fMRI features, support the possibility of neofunctional plasticity.

Creativity is innate in nature, the way we are made. However, we set goals for survival and suppress our innate skills. In this context, when disease disrupts our set goals, it is possible that our true creative skills, which were inhibited by these goals, become expressive through disinhibition.

Future research should focus on unraveling these mechanisms, as they may lead to novel therapeutic options by targeting facilitative circuits. The emergence of new functions may have rehabilitative roles, at least during the period they persist, and may also have a pharmaco-sparing effect in behavior management. Investigating the role of growth factors in degeneration could become a target for drug research.

Future directions: Further studies should include a larger number of patients, disease-based segregation of creativity, and identification of specific brain regions and their neurochemical environments. In addition, the role of novelty-seeking gene interactions should be explored.

Acknowledgement

We acknowledge with gratitude our patients and caregivers for the cooperation rendered for the study. We thank the director of our institute for giving permission to conduct this study. We thank the ethical committee for the ethical clearance.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Sternberg RJ, Lubart TI, Kaufman JC, Pretz JE. Creativity. In Holyoak KJ, Morrison RG, editors. Cambridge Handbook of Thinking and Reasoning. Cambridge: Cambridge University Press; 2005.
2. Seeley WW, Matthews BR, Crawford RK, Gorno-Tempini ML, Foti D, Mackenzie IR, et al. Unravelling Bolero: Progressive aphasia, transmodal creativity and the right posterior neocortex. Brain 2008;131:39–49.
3. Carson SH, Peterson JB, Higgins DM. Reliability, validity, and factor structure of the creative achievement questionnaire. Creat Res J 2005;17:37-50.
4. Tiwari SC, Tripathi RK, Kumar A. Applicability of the Mini-mental State Examination (MMSE) and the Hindi Mental State Examination (HMSE) to the urban elderly in India: A pilot study. Int Psychogeriatr 2009;21:123–8.
5. Raina SK, Chander V, Raina S, Kumar D. Feasibility of using everyday

abilities scale of India as alternative to mental state examination as a screen in two-phase survey estimating the prevalence of dementia in largely illiterate Indian population. Indian J Psychiatry 2016;58:459–61.
6. Mathuranath PS, Cherian JP, Mathew R, George A, Alexander A, Sarma SP. Mini-mental state examination and the Addenbrooke's cognitive examination : Effect of education and norms for a multicultural population. Neurol India 2007;55:106–10.
7. Kumar VK, Kemmler D, Holman ER. The creativity styles questionnaire-revised. Creat Res J 1997;10:51–8.
8. Cloninger CR, Svrakic DM, Przybeck TR. A psychobiological model of temperament and character. Arch Gen Psychiatry 1993;50:975–90.
9. Hébert R, Bravo G, Préville M. Reliability, validity and reference values of the zarit burden interview for assessing informal caregivers of community-dwelling older persons with dementia. Can J Aging 2000;19:494–507.
10. Rogers BP, Morgan VL, Newton AT, Gore JC. Assessing functional connectivity in the human brain by fMRI. Magn Reson Imaging 2007;25:1347-57.
11. Magalhaes R, Marques P, Soares J, Alves V, Sousa N. The impact of normalization and segmentation of resting-state brain networks. Brain Connect 2015;5:166-76.
12. Sladky R, Friston KJ, Trostl J, Cunnington R, Moser E, Windischberger C. Slice-timing effects and their correction in functional MRI. NeuroImage 2011;58:588-94.
13. Goto M, ABE O, Miyati T, Yamasue H, Gomi T, Takeda T. Head motion and correction methods in resting-state functional MRI. Magn Reson Med Sci 2015;15:178-86.
14. Alakörkkö T, Saarimäki H, Glerean E, Saramäki J, Korhonen O. Effects of spatial smoothing on functional brain networks. Eur J Neurosci 2017;46:2471-80.
15. Poldrack RA. Region of interest analysis for fMRI. Soc Cogn Affect Neurosci 2007;2:67-70.
16. Ratnavalli E, Brayne C, Dawson K, Hodges JR. The prevalence of frontotemporal dementia. Neurology 2002;58:1615–21.
17. Alladi S, Mekala S, Chadalawada SK, Jala S, Mridula R, Kaul S. Subtypes of dementia: A study from a memory clinic in India. Dement Geriatr Cogn Disord 2011;32:32-8.
18. Falk D, Lepore FE, Noe A. The cerebral cortex of Albert Einstein: A description and preliminary analysis of unpublished photographs. Brain 2013;136:1304–27.
19. Hahm J, Kim KK, Park S, Lee H. Brain areas subserving torrance tests of creative thinking: An functional magnetic resonance imaging study. Dement Neurocogn Disord 2017;16:48–53.
20. Chandra SR, Viswanathan LG, Wahatule R, Shetty S. The tale of the storyteller and the painter: The paradoxes in nature. Indian J Psychol Med 2017;39:817-20.