

NEUROSCIENCE OF CREATIVITY 2017



Friday, March 24, 2017

8:30 am – 5 pm

San Francisco Conservatory of Music

50 Oak Street

San Francisco, CA 94102

Osher Salon

Satellite conference to Cognitive Neuroscience Society, 2017

Visit us at: <http://tsfnc.org/>

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Final Schedule for SFNC 2017

8:30-8:45: Introductory Remarks

8:45-9:30: Keynote 1: [Anjan Chatterjee](#), University of Pennsylvania
“Abstraction of Forms and Forms of Abstraction”

9:30-10:15: Keynote 2: [Mariale Hardiman](#), Johns Hopkins
“Creativity in Education”

10:15-11:00: Keynote 3: [Robert Bilder](#), UCLA
“Creative Brains: On the Edge of Chaos”

11:00-11:30: General Discussion

11:30-12:30: Lunch (on your own)

12:30-2:30: Poster session

2:30-2:50: Invited talk: [Allan L. Reiss](#), Stanford University School of Medicine
“The Neuroscience of Creativity and its Enhancement”

2:55-3:15: Invited talk: [Dan Schwartz](#), Stanford University
“Inductive Creativity”

3:20-4:45: Data Blitz Session

4:45-5:00: Concluding Remarks

[Alumit Ishai](#), Director of the Cognitive Neuroscience Program at NSF will present on strategies and opportunities for obtaining research funding during the poster session.

Information on data blitz presentations: Presentations should be 8 minutes long with 2 minutes for questions. A separate email will be sent with instructions to upload your Power Point slides approximately 48 hours in advance of the meeting.

Information on poster presentations: Posters can be either 3 feet long by 4 feet wide, or 4 feet long by 3 feet wide. Materials for displaying the posters will be provided.

Registration: Registration will be free this year. However to have an accurate head count, we ask that you quickly register for the meeting by [following this link](#).

KEYNOTES

Abstraction of forms and forms of abstraction

Anjan Chatterjee

Elliott Professor of Neurology

Department of Neurology, University of Pennsylvania, Philadelphia, PA

Abstract

The hypothesis that much of cognition is embodied is ascendant in contemporary cognitive neuroscience. However, strong versions of this view raises an obvious question, how do we abstract? I will focus on two kinds of abstraction that might be relevant to creativity. First, I will explore the psychological and neural reality of schematic representations. Such representations have an intermediate status between richly textured pictorial representations and purely symbolic lexical representations. Second, words themselves, despite being symbolic, can have concrete referents or be used figuratively as is the case for metaphors. I will discuss the neural instantiation of metaphor processing as they evolve in their use. In both cases, these abstractions invite flexibility and generativity that are critical to many forms of creative thinking.

Creativity in Education

Mariale M. Hardiman

Professor of Education, Interim Dean

Johns Hopkins University School of Education, Baltimore, MD

Abstract

The emerging focus on the need for a workforce capable of innovative thinking and problem solving has influenced educators to rethink curriculum and instruction at every level, from early childhood to higher education. While educators are encouraged to design teaching activities that promote creative thinking, many in the research community debate the very definition of creativity and how (or even if) it can be measured. It is within this context that researchers and educational practitioners would do well to join forces to consider what creativity means in an educational context. This talk will show how some educators are approaching the notion of teaching creative thinking within an instructional framework that, at its core, promotes teaching with and through the arts.

Creative Brains: On the Edge of Chaos?

Robert M. Bilder

Professor-in-Residence

Department of Psychology, University of California-Los Angeles, Los Angeles, CA

Abstract

The Michael E. Tennenbaum Center for the Biology of Creativity at UCLA's Semel Institute began its investigations of creative cognition with a unique focus: to examine the basic scientific foundations of creative cognition by interrogating molecular, cellular, and neural systems that could be studied across multiple paradigms and diverse species. Our investigations were rooted in the premise that creativity confers an adaptive advantage and that its expression is tied to variation in neural system activity and the corresponding cognitive functions. Literature reviews led us to narrow the focus of our work to a series of themes linked to creative cognition, and that could be studied across species. We examined generation abilities in songbirds, working memory and response inhibition in rodents, and all these themes together with personality characteristics and psychopathology, in humans. These studies highlighted the importance of dynamic balances within each cognitive dimension (e.g., generation vs. incubation, inhibition vs. disinhibition, and flexibility vs. stability within working memory). With support from the John Templeton Foundation, we were then able to extend this work to examine "Big C" creative visual artists, scientists, and a "smart control group" to determine the relevance of these findings to those known for world-class creative production. Findings from this study support the idea that the core elements of creative cognition are preserved not only across "Big C" and "little c" humans, but also across species. Some distinguishing characteristics of Big C humans suggest further that creative cognition may emerge at the boundary between highly entropic (random, unpredictable) cognitive activity, and more redundant (orderly, predictable) states, reminiscent of what Stuart Kauffman referred to as the "Edge of Chaos." This concept may advance understanding of long-standing questions about the links of creativity and madness, and suggests systematic approaches to interventions that might promote creative achievement.



INVITED TALKS

The Neuroscience of Creativity and Its Enhancement

Allan L. Reiss

Howard C. Robbins Professor

Department of Psychiatry & Behavioral Science

Director of the Center for Interdisciplinary Brain Sciences Research (CIBSR)

Department of Radiology

Stanford University School of Medicine, Palo Alto, CA

Abstract

This talk will cover progress on understanding the brain basis of creativity and how attempts to enhance creative capacity at the behavioral level can change brain function.

Inductive Creativity

Daniel L. Schwartz


Professor, Nomellini-Oliver Chair in Educational Technology

I. James Quillen Dean of the Graduate School of Education

Stanford Graduate School of Education, Palo Alto, CA

Abstract

Inductive creativity is a tremendous driver of learning and scientific discovery. It fuels the discovery and explication of pattern, and it yields novel understanding. I will demonstrate the learning benefits of inductive creativity, how to use it productively, and what interfering threats to avoid



DATA BLITZ TALKS

1

A Dual Process Model of Creativity: Jazz Improvisation, Expertise, and Creative Cognition

David S. Rosen

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Danial Mirman

University of Alabama - Birmingham

Youngmoo E. Kim

Drexel University

Roy H Hamilton

University of Pennsylvania

John Kounios

Drexel University

Research on creative cognition reveals a fundamental disagreement about the nature of creative thought, specifically, whether it is primarily based on automatic, associative (Type-1) or executive, controlled (Type-2) processes. We posit that Type-1 and Type-2 processes make differential contributions to creative production dependent upon domain expertise. We tested this hypothesis with jazz pianists who, through experience and training, amass deeply ingrained musical patterns and implement various strategies to improvise novel melodic phrases and rhythms. fMRI studies of music improvisation report that domain expertise is characterized by deactivation of the right-dorsolateral prefrontal cortex (r-DLPFC), which is accompanied by a network of increased functional connectivity including bilateral DLPFC, dorsal premotor cortices (PMD), and pre-supplementary motor areas (p-SMA). Thus, we use right-lateralized non-invasive, transcranial direct current stimulation (tDCS) localized over r-DLPFC (F4) with the reference electrode on the contralateral mastoid (1.5mA, 15 min.) to modulate jazz pianists' choices, behaviors, and ultimately, their creative processes while improvising. Pianists improvised to an array of chord changes with drum and bass accompaniment in sham, cathodal and anodal conditions. Jazz experts rated each improvisation for creativity, aesthetic appeal, and technical proficiency. Neither anodal nor cathodal stimulation increased ratings compared to sham; however, a significant interaction between anodal tDCS and expertise emerged, such that stimulation benefitted musicians with less experience but hindered those with more experience. We interpret these results as evidence for dual process theories of creativity, in which novices and experts differentially engage DLPFC in pursuit of creativity.

Support:

ExCITE Center Seed Research Grant

2

Finding the neural correlates of middle childhood “slump” in creativity using functional near-infrared spectroscopy

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Atanas Stankov

Stanford University
Meredith Schreier
Stanford University
Allan Reiss
Stanford University

Little is known about the underlying neurodevelopmental processes that contribute to a child's creative capacity. Of particular interest is the decline in creativity during middle childhood. Longitudinal neuroimaging studies are required to understand whether a decline in creativity is due to the burden of social norms, educational training, or typical brain development. Here, we present preliminary results from a cohort-sequential semi-longitudinal study using functional Near-infrared Spectroscopy (fNIRS). A total of 56 children (n=24 3rd-graders and n=32 4th-graders) were assessed longitudinally at two time-points. Creativity was evaluated using the standardized Torrance Test of Creative Thinking (TTCT). The fNIRS data from bilateral prefrontal cortices were collected while children engaged in the TTCT and a control drawing-task. As expected, 3rd-graders scored higher on TTCT during the end of their grade, while 4th-graders had a decline in TTCT scores towards the end of their grade. Based on previous work, we hypothesized that the 4th-grade decline in creativity could be associated with a greater need for "conformity" from classroom expectations and peer pressure. We operationalized conformity in terms of variability in task-related functional connectivity (FC). Thus, less FC variability would imply greater conformity. Significant grade by time interaction was observed for both TTCT and control conditions ($p < 0.05$), such that 4th-graders had reduced variability in FC towards the end of their grade, whereas no changes in FC variability were observed for the 3rd-graders. Taken together, our data suggest that longitudinal neuroimaging studies could provide insights into the neural basis for the 4th-grade decline in creativity.

Support:

Child Health Research Initiative (CHRI), Stanford University School of Medicine

3 Neural Mechanisms of Imagination

Darya Zabelina
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Jessica Andrews-Hanna
University of Arizona

The ability to form abstract mental representations – the ability to imagine – plays an important role in a wide range of behaviors, including learning and empathy. Despite this, empirical research on imagination has historically been limited. The present investigation takes an interdisciplinary approach linking first-person phenomenology to the brain basis of imagination. In the first stage of the project participants (N = 40) responded to thirty-five experience sampling notifications (via text) over seven days, and described the nature of their thoughts at the moment of notification. Individual differences in daily thoughts will be examined in relation to individual differences in imagination as measured by our newly-developed Imagination Quotient (ImQ) scale. The second goal of the study is to investigate neural underpinning of imagination and attention and their link to trait-imagination and creativity. A newly-developed fMRI paradigm

first uses a machine-learning technique (MVPA) to locate brain regions that are activated when participants (N = 40) view pictures of faces and houses (FFA and PPA, respectively). Participants are then asked to imagine faces and houses, and the degree to which the FFA and the PPA are activated while participants imagine faces and houses is our measure of imagination. Results will shed light on the neural mechanisms of imagination. In addition to imagination, this paradigm also allows us to assess the nature of participants' attention, and how it relates to imagination and creativity. Findings will be relevant for educational, corporate, and other applied settings.

Support:

Templeton Foundations' Imagination Institute

4

Hippocampal Variability and Functional Connectivity Associated with Episodic Processing During Divergent Thinking

Roger E. Beaty

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Yoed N. Kenett

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Mathias Benedek

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Creative cognition involves flexibly combining concepts stored in memory to form novel and useful associations. Neuroimaging research has recently highlighted the involvement of memory systems in creativity, with a growing number of studies reporting activation of regions within the brain's default network. However, the default network is thought to support both episodic and semantic memory retrieval, so the extent to which default activity during creative cognition reflects episodic or semantic processing remains unclear. We sought to dissociate contributions of these memory systems to creative idea production by inducing an episodic or semantic retrieval orientation prior to performance on a divergent thinking task during functional magnetic resonance imaging (fMRI). Independent component analysis (ICA) identified several clusters corresponding to default subnetworks, which were differentially associated with divergent thinking as a function of memory induction. Compared to the semantic induction, the episodic induction was related to increased BOLD signal variability—an index of neural and cognitive flexibility—within the hippocampus and medial prefrontal cortex (mPFC). We also found that these default subnetworks were more functionally connected during divergent thinking, but only in the episodic induction condition. These findings point to the involvement of constructive episodic processes in creative cognition, and indicate that the hippocampus may support idea production through its flexible interaction with cortical networks.

Support:

John Templeton Foundation (RFP-15-12); National Institute of Mental Health (R01 MH060941)

5

Selective Attention to Global Stimuli Induces Analytic Problem Solving

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Mark Beeman

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Attention putatively mediates the distinctions between local versus global visual processing and between analytic versus insight problem solving. Processing local features of hierarchical displays requires narrow attention, whereas processing global features requires spatially broad attention. Similarly, solving problems analytically requires narrow and selective conceptual attention, whereas solving with insight is thought to require conceptually broader (and likely less selective) attention. Two experiments investigated whether and how attention to local versus global stimuli modulates problem solving. Participants completed Compound Remote Associates problems, then a modified hierarchical letter task, followed by more problems. If processing local features narrows attention, participants should increase analytic solving; however, detecting local targets only slightly (non-reliably) increased analytic solving. If attending to global features broadens attention and weakens selection, then participants should increase insight solving. Alternatively, if processing global features requires selective attention to the large (global) letter (while inhibiting local letters), participants should increase analytic solving. Results support the latter hypothesis: Participants who detected target letters at the global level reliably increased analytic solving ($p < .01$ in each experiment), without affecting insight solving. Additionally, the congruency effect (slower responses when the two levels conflicted) was larger, suggesting more selective attention was required, when responding to global letters ($p < .05$). Finally, across individuals, the size of the congruency effect correlated with initial problem solving processes: smaller congruency (better selection) with more analytic solving ($r = -.16$, $p = .05$), and larger congruency with more insight solving ($r = .22$, $p = .05$). Thus, in our paradigm, processing global letters requires selective attention, and induces more analytic solving.

6

BOLD signal variability and internally directed cognition

Reece P. Roberts

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Donna Rose Addis

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In a range of externally directed tasks, intra-individual variability of fMRI BOLD signal (fMRI-var) has been shown to be a stronger predictor of cognitive performance than mean BOLD signal (fMRI-mean). fMRI-var's strong association with cognitive performance is hypothesised to be due to it capturing the dynamic range of neural systems. While increased fMRI-var is speculated to play a role in creative thought, there is a lack of research investigating how fMRI-var is

related to performance in tasks requiring cognitive flexibility during internally directed cognition. To investigate the relationship between fMRI-var and creative cognition, we first performed task partial least-squares (PLS) analyses that contrasted fMRI-var and fMRI-mean during two future imagination conditions, differing in the amount of cognitive flexibility required: a congruent condition in which autobiographical details (people, places, objects) comprising an imagined event belonged to the same social sphere (e.g. university) and an incongruent condition in which details belonged to different social spheres. Next, we used behavioural PLS to determine how individual differences in performance in future-imagination and divergent thinking tasks relates to fMRI-var and fMRI-mean. The task-PLS results showed that the incongruent condition resulted in widespread reduction in both fMRI-var and fMRI-mean, in largely non-overlapping regions. The behavioural PLS analysis showed that, for both conditions, performance in future-imagination and divergent thinking tasks was generally associated with increases in fMRI-mean and decreases in fMRI-var. Together, the results suggest that unlike tasks requiring externally directed cognition, better performance in tasks requiring creative internal mentation is associated with less (not more) variability.

Support:

Marsden Fund grant (12-UOA-254) and Rutherford Discovery Fellowship (RDF-10-UOA-024) awarded to Donna Rose Addis

7

Jazz Improvisation as a Model of Creativity: Converging Evidence from Behavioral Performance and Diffusion Tensor Imaging

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Creativity has been defined as the ability to produce work that is novel, high in quality, and appropriate to an audience. One model of creativity in real time comes from musical improvisation, such as in jazz music, in which individuals spontaneously create novel auditory-motor sequences that are aesthetically and emotionally rewarding. Here we present a combined behavioral and MRI (DTI) study in which we compare jazz improvising musicians against non-improvising musicians and non-musician control subjects. Behavioral tests include the Torrance Test of Creative Thinking, and a musical improvisation-continuation task, in which subjects were given short musical motives and asked to continue each motive by improvising. The TTCT showed higher originality scores in jazz musicians, and statistical measures of fluency and entropy correlated with expert ratings for musical performances, both showing higher scores in jazz musicians. We further used probabilistic tractography and Tract-Based Spatial Statistics (TBSS) on Diffusion Tensor Imaging data to compare jazz musicians against non-jazz musicians and non-musicians. TBSS results showed higher Fractional Anisotropy (FA) in the cingulate cortex and corpus callosum in jazz musicians ($p < .05$ TFCE-corrected). Tractography showed

increased volume in the arcuate fasciculus in all musicians; however only jazz musicians showed larger tracts between the cingulate cortex and corpus callosum and the inferior frontal gyrus. Results suggest that connectivity between lateral structures (such as the arcuate fasciculus) and mesial structures (cingulate cortex and corpus callosum) is crucial for integrating domain-general and domain-specific components of creativity.

Support:

Imagination Institute

8

Brain structural and functional correlates of Openness and Intellect: Implications for the Contribution of Personality to Creativity

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Openness to experience is the Big Five personality factor most consistently associated with individual differences in creativity. Recent evidence has demonstrated that this factor consists of two distinct aspects—Intellect and Openness. Whereas Intellect reflects perceived intelligence and intellectual engagement, Openness reflects engagement with fantasy, perception and aesthetics. In two studies, we investigated the extent to which Openness and Intellect are differentially associated with variations in brain structure and function—the latter measured in the context of a verbal divergent thinking task. The results of Study 1 (N = 185) demonstrated that Openness was correlated inversely with cortical thickness in left middle temporal gyrus (MTG, BA 21) and superior temporal gyrus (BA 39 and 41), and in right inferior frontal gyrus (IFG, BA 45) and fusiform gyrus (BA 19/37). In contrast, Intellect was unrelated to cortical thickness. Next, using the above foci as regions of interest (ROIs) in an fMRI paradigm, the results of Study 2 (N = 44) demonstrated that Openness covaried with brain activation in left MTG and right IFG during divergent thinking. In contrast, Intellect (whole-brain analysis) was unrelated to brain activation during divergent thinking. In conjunction, our results across two studies help establish the convergent validity of left MTG and right IFG as regions related both structurally and functionally to individual differences in Openness. Given the respective roles of MTG and IFG in memory and cognitive control, we discuss the implications of our findings for the contribution of personality to creative cognition.

Support:

John Templeton Foundation, Department of National Defence



POSTER SESSIONS

1

Instruction, feedback, and heuristic elicitations of original ideation in divergent thinking.

Garrett Jaeger

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A theoretical framework of embodied cognition was the impetus for developing an experimental utility to help observe creativity in situ. A bootstrapped methodology distilled already present data to map cognitive processes that occur during divergent thinking (DT). An online experiment leveraged software scripting to provide dynamic feedback on performance during DT task items. Participants were assigned to conditions that, when compared to each other, revealed order effects during DT. This microgenetic approach warranted a methodological modularity that could partition item-level effects in DT through formulated pairings of instructions and feedback. Participant responses to DT task items were time-stamped, providing insight on the pace and trajectories of creative ideation. A response indexing system further facilitated analysis of these sensitive data, uncovering how switches in task types and alterations to item modularity affect creative ideation. Methodological advancements provided as much insight on divergent thinking as the hypotheses investigated. Significant effects on item-level constructs, such as the onset of original ideation, encouraged future explorations of creativity that integrate embodied and situated cognition.

2

Investigating a New Class of Cognitive Qualities- Creative Cognition, Insight, and Aesthetic Judgment: A Quantitative Analysis of the Neuroscientific Evidence for the Theory of Multiple Intelligences

Branton Shearer

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Multiple intelligences theory ((Gardner, H. (1983/1999) *Frames of Mind*, Basic Books: NY)) was one of the first modern theories of intelligence to be based in part on neural evidence. A recent extensive analysis of accumulated neuroscience evidence (420 reports) concluded that each of the eight intelligences possesses its own unique neural architecture (Shearer and Karanian, 2016). This analysis also clarifies the relationship between general intelligence and the multiple intelligences (MI) along with educational implications. The relationship between creativity and intelligence has long been a matter of debate (Sternberg, 2006). MI theory describes each intelligence as a composite of both convergent problem-solving and divergent thinking behaviors displayed in everyday life. This investigation examines neural architectures for a proposed new category of Cognitive Qualities (CQ) that includes Creative Cognition, Aesthetic Judgment and Insight / Intuition associated with each of the eight intelligences. Based on an analysis of 94 neuroscientific reports it was concluded that the category of Cognitive Qualities shares several neural features with general intelligence (frontal and temporal cortices, dorsolateral PFC, inferior frontal gyrus, default mode network and the limbic system) but also has a distinctive neural configuration (subcortical structures, occipital, motor cortex, basal ganglia, striatum, and several motor-related regions). A similar pattern was evidenced among the

three hypothesized cognitive qualities with shared neural features and meaningful distinctions aligned with theoretical expectations. These data indicate that a more in-depth neural analysis is warranted. Both theoretical and practical implications for a personalized educational cognitive neuroscience framework are discussed.

3

Creating Educational Alternatives: Encouraging the S.T.E.A.M. in S.T.E.M.

Monica Lopez-Gonzalez

La Petite Noiseuse Productions and Adjunct Faculty, Johns Hopkins University (monica@lpnproductions.com)

A renewed push for S.T.E.M. education is on the rise. Similarly, research in artificial intelligence is regaining unprecedented traction as intelligent systems become more human-like. At the same time, Arts education is struggling. The core of these initiatives is interdependent: the very need to innovate teaching methods that incorporate more hands-on, experiential learning is just as important as fully characterizing creative thinking processes in all its many rich contexts to foster innovation. Unfortunately, the above continue to remain disconnected. I will present a novel educational framework inspired by the revolutionary empirical study of creative, artistic behavior I have conducted outside of the traditional laboratory and clinical space that merges questions in language, music, and emotion perception with real time idea emergence and problem-solving. More precisely, I have used live musical improvisation within film and scripted theatrical productions to map out a cognitive behavioral model of spontaneous, creative behavior. As an educator who has developed and teaches unique art perception and cognition courses –from precollege to postgraduate levels– my research has directly informed my teaching style. Specifically, I integrate Art in S.T.E.M. to design multidisciplinary projects within the students' curriculum that involve a mix between filmmaking and research design and investigation. My courses' outcomes reveal the optimum results of learning: concept understanding, translation, application, and communication. As a consequence of these results, I will also discuss the theoretical implications of such an educational framework to improving questions and methods within neural-based studies on creative thinking.

4

Human Brain Dynamics Supporting Emergence of Sudden Insight

Ying Choon Wu

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Scott Makeig

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Sudden insight results from enlarging or restructuring a problem solution space, allowing a previously inaccessible solution to emerge into the imagination – which is commonly known as an 'Aha!' experience. This study examines how EEG dynamics during problem solving can support insight and solution discovery. 256-channel EEG was recorded as healthy adults solved computerized 'Wheel-of-Fortune' language puzzles. Each trial began with a series of blank spaces indicating the positions of letters in a common phrase. At randomly jittered intervals (1.5-

3s), single letters in the phrase, randomly selected by the game application, replaced the blanks. Participants pressed a button when they knew the full phrase and spoke their solutions aloud. Next, they rated the degree of sudden insight experienced when reaching the solution. Pre-cleaned EEG data were decomposed into underlying source contributions by adaptive mixture independent component analysis (AMICA). Brain-based independent component (IC) scalp maps were modeled as projections of single equivalent dipoles, and event-related spectral perturbations (ERSPs) were computed for each such IC in 1.5-s epochs following each letter clue presentation. Measure Projection Analysis (MPA) identified a subspace of model brain voxels exhibiting consistent cue-onset ERSP patterns across ICs with nearby equivalent dipoles. Alpha suppression in anterior right and bilateral parietal IC clusters was found to vary with degrees of subjective insight. Spectral power changes were also found beginning at least three letters before participants articulated the correct solution. These results imply that problem solving in this task is a prolonged process with distinct brain dynamic pre-conditions.

Support:

Swartz Foundation

5

Transcranial Electrical Stimulation to Promote Creativity: Neuroethical, Legal and Social Issues, Tasks, and Approaches

Adam Weinberger

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James Giordano

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Psychological and neuroimaging studies are aimed at elucidating putative neural networks involved in certain types of creative cognition. Based upon such assessments, there is growing interest and momentum in examining – and using - forms of transcranial electrical stimulation (tES) to promote, and/or optimize creative cognition. While viable, at least in certain experimental settings, questions arise as to whether and when to utilize such interventions, in whom, and under what conditions? Thus, while employing tES under clinical supervision may afford defined parameters for safety and benefit, there are still questions of whether this represents a “treatment” or an “enhancement”, and if and how these interventions will be provided or subsidized as well as what socio-economic implications may arise out of such patterns of use. Additionally, potential use of tES to foster creativity in pediatric patients incurs concerns about benefits versus burdensome effects upon neuro-cognitive development. Issues of both adult and pediatric tES use are exacerbated by a growing direct-to-consumer market (with fuzzy boundaries in FDA regulation of certain aspects of medical versus non-medical indications and use), and a do-it-yourself community that remains partially occult, and relatively difficult, if not impossible to regulate, at least at present. Herein, we define key areas and dimensions of use of tES to affect creative cognition, and explicate specific neuroethico-legal and social issues

(NELSI) inherent and derivative to each. We address capacities and limitations of extant ethics and regulations, and propose a framework and principles to guide current and near future use.

Support:

A.W. and A.G. are supported by grants from the National Science Foundation (DRL-1420481) and The John Templeton Foundation (ID 51971).

6

Developing A Standardized Test for Creativity Based on the Alternative Uses Task

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Generating alternative uses for everyday objects has been a valuable tool toward the assessment of creativity in cognitive research. However, there has yet to be a multi-form standardized version of the Alternative Uses Task that can be used in different experimental contexts. The aim of the current project was to create such a test. During test development, we selected 240 high-resolution images of everyday objects from Bordeur et al.'s (2014) Bank of Standardized Stimuli (BOSS). In the first phase of the task's development, we presented these stimuli to 500 participants on Amazon's Mechanical Turk (MTurk) and asked them to generate an alternative use for each object. We then classified the responses into categories based on the function indicated in each response. We found that the number of different uses generated for each of these objects ranged from 48 to 202. Based on these frequency norms, new responses to the stimuli from this task can be classified on a continuum that can capture the novelty of the response. In the second phase of the task's development, we divided the test in 4 forms with 60 objects in each version. We then assessed the reliability of each form using response onset times and response omissions. Healthy participants ($N = 45$) completed all 4 forms of the task online, in a randomized fashion, for course credit. The mean response onset time (first mouse click) across versions of the task was 2.80 seconds ($SD = 1.26$) and the mean number of response omissions was 3.56 ($SD = 4.24$). Based on the response omission differences among the 4 forms, we re-categorized the items and verified the standardization process, creating 4 versions of the task that are statistically equivalent to each other on both measures. We highlight opportunities for using this valid and reliable test of creative thinking in neurocognitive studies of creativity.

Support:

Imagination Institute

7

Suggested Neuroscientific Investigations of Creativity Suggested by New Theories of Creativity

Mark A. Runco
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My last presentation to SfNC, in 2016, suggested that neuroscientific studies of creativity (NSC) needed to focus more on measures that have meaning in the natural environment. I related this to the issue of external validity. I also questioned research that used timed tests or single item tests, both of which are contrary to a large amount of research on the creative process. In this 2017 presentation I would shift gears and, instead of pointing to problems in the existing NSC, I would point to several new ideas that should be considered in the near future, in NSC. Each of these lines of research follows from new thinking about the creative process. The first idea recommended here follows from the theory of “personal creativity” and its definition of the creative process as the “construction of original and useful meaning.” The second line of thought suggested here follows from a new theory that started with the idea of ideational flexibility, instead of utilizing diverse conceptual categories, instead avoids conceptual categories all together. This new theory of flexible creative thinking fits well with data outside the labs showing highly creative people to tolerate or even favor contradictions and paradoxes in their creative problem solving. The first theory suggested above, focused on the construction of meaning, might mesh with previous neuro scientific investigations of episodic memory. Even more provocative is that it may fit with recent findings about neurogenesis in the hippocampus.

8

Smaller N400 Amplitudes are Reflected in Creative Individuals

Kristina Pfeifer

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Recalling uncommon information is thought to be a unique characteristic within creative individuals (Mednick, 1962). To test this theory we examined the amplitude of the N400, which becomes larger in negativity when processing unrelated semantic information (Bentin et al., 1985). Due to the ease in which creative individuals produce meaning from unrelated associates (Benedek et al., 2012), smaller N400 amplitudes were predicted in response to remote word pairs. Participants (N = 45) were asked to try and form an association while viewing related, indirect and unrelated word pairs while electroencephalography was recorded from 9 electrode sites. Three measures of creativity were examined separately: divergent thinking, creative personality, and scientific creative achievement. N400 amplitude was largest for unrelated word pairs, intermediate for indirect word pairs, and smallest for related word pairs, with the difference between conditions greatest at electrode site P4. Based on this finding, which is consistent with previous N400 studies on word reading (Federmeir & Kutas, 1999), electrode site P4 was used for analysis. Subtraction waveforms yielded two conditions of interest: the unrelated

effect (unrelated minus related) and the indirect effect (indirect minus related). A significant positive correlation was found for the indirect effect indicating that those high in scientific creative achievement, divergent thinking and creative personality had smaller N400 amplitudes (all $r_s \geq .307$). For the unrelated effect, the same positive correlation was found for scientific creative achievement and creative personality (all $r_s \geq .355$).

9 (also a data blitz talk)

A Dual Process Model of Creativity: Jazz Improvisation, Expertise, and Creative Cognition

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Research on creative cognition reveals a fundamental disagreement about the nature of creative thought, specifically, whether it is primarily based on automatic, associative (Type-1) or executive, controlled (Type-2) processes. We posit that Type-1 and Type-2 processes make differential contributions to creative production dependent upon domain expertise. We tested this hypothesis with jazz pianists who, through experience and training, amass deeply ingrained musical patterns and implement various strategies to improvise novel melodic phrases and rhythms. fMRI studies of music improvisation report that domain expertise is characterized by deactivation of the right-dorsolateral prefrontal cortex (r-DLPFC), which is accompanied by a network of increased functional connectivity including bilateral DLPFC, dorsal premotor cortices (PMD), and pre-supplementary motor areas (p-SMA). Thus, we use right-lateralized non-invasive, transcranial direct current stimulation (tDCS) localized over r-DLPFC (F4) with the reference electrode on the contralateral mastoid (1.5mA, 15 min.) to modulate jazz pianists' choices, behaviors, and ultimately, their creative processes while improvising. Pianists improvised to an array of chord changes with drum and bass accompaniment in sham, cathodal and anodal conditions. Jazz experts rated each improvisation for creativity, aesthetic appeal, and technical proficiency. Neither anodal nor cathodal stimulation increased ratings compared to sham; however, a significant interaction between anodal tDCS and expertise emerged, such that stimulation benefitted musicians with less experience but hindered those with more experience. We interpret these results as evidence for dual process theories of creativity, in which novices and experts differentially engage DLPFC in pursuit of creativity.

Support:

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10

A new measure for lifespan creative engagement: Development and validation

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Prior research has shown that creative activities, such as dancing, painting, and singing, may have a positive impact on the aging brain (e.g., Noice & Noice, 2014). These activities can have a range of beneficial effects on one's physical, mental, and social well-being. While creative activities have been employed in different ways in previous cognitive interventions, critical factors of creative activities for cognitive development in aging adults have not been clearly defined. Wu, Rebok, and Lin (in press) propose that six factors define optimal creative intellectual engagement: 1) open-minded input-driven learning, 2) individualized scaffolding, 3) growth mindset, 4) forgiving environment, 5) serious commitment to learning, and 6) learning multiple skills simultaneously. Currently, there are no extant measures that accurately assess levels of creative intellectual engagement. The current study reports the development of a new measure of intellectual engagement, the Lifespan Cognitive Development Questionnaire, which includes six scales designed to measure different aspects of intellectual engagement. Across two studies, we found that the scale reliabilities ranged from $\alpha=.493$ (learning multiple skills simultaneously scale) to $\alpha=.744$ (forgiving environment scale). The results of an exploratory item factor analysis were not fully in accord with theoretical expectations. The questionnaire serves as an initial effort to assess intellectual engagement and future work will focus on developing additional items that better represent the theoretical factor structure.

11**Sleep On It – The Impact of Problem Reactivation during Sleep on Problem Solving****Kristin Grunewald**

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Numerous scientific breakthroughs have been associated with sleep including Otto Loewi's experiment that demonstrated neurons communicate via neurotransmitters and Dmitri Mendeleev's organization of the periodic table. Additionally, several experiments have demonstrated enhanced problem solving or greater insight into a problem's structure after sleep

compared to similar periods of wake (e.g. Sio et al., 2003; Wagner et al., 2005). However, the mechanism for sleep's facilitation of problem solving remains unknown. We hypothesize that the reactivation of the problems during slow-wave sleep underlies the facilitation. To test this hypothesis, we employed targeted memory reactivation (TMR) to selectively reactivate specific problems during sleep. Participants completed an evening session in the lab where they attempted to solve puzzles. Each puzzle was paired with a unique sound that played throughout the solving attempt. Participants then took a device home that monitored their sleep and, when they were in slow-wave sleep, played some of the sounds that were associated with their unsolved puzzles. In the morning, participants returned to the lab and reattempted all puzzles that they did not solve the prior evening. Results suggest that in the morning participants were more likely to solve puzzles whose paired sound had been played overnight than puzzles whose paired sound had not been played. This result supports our hypothesis that the reactivation of problems during sleep enhances problem solving.

Support:

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12

Inspired by art: Higher ratings of felt inspiration in a creative writing task following aesthetic vs. non-aesthetic prompts

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Experiences of inspiration are an essential "ignition" for creative thought. Moments of inspiration have phenomenological similarities to moments of being aesthetically moved, and creators often speak of being inspired by other creative works. We tested the hypothesis that moving aesthetic experiences enhance inspiration. Twenty-five participants took part in a creative writing task in which they were given twelve writing prompts. Each writing prompt was either a painting (an aesthetic prompt) or a list of three unrelated words (a non-aesthetic prompt). Aesthetic prompts were selected from a set of 20 paintings using ratings of aesthetic experience made by each participant in an earlier task. After seeing the writing prompt, participants were given 3 minutes to type a short, original vignette inspired by the prompt, with the instruction to not simply describe the prompt itself. At the end of each writing period, participants rated the degree to which they had felt inspired. We found a significant effect of prompt type on feelings of inspiration (Cohen's $d = 0.77$), such that participants felt more inspired by aesthetic prompts than by non-aesthetic prompts. Our results suggest that aesthetically moving stimuli are better able to evoke inspiration than non-aesthetic stimuli, and that exposure to aesthetic experiences, both in and out of the lab, may be a straightforward way to increase the incidence of moments of creative inspiration.

13

Diurnal Rhythms in Freedom of Thought

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Circadian rhythms can have a strong influence on our daily lives. Recent research suggests that there are time-of-day variations in neural activity in brain regions linked to the attentional orienting system (Marek et al., 2010). These findings may have implications for related phenomenon, such as mind wandering and creativity, which is less understood from the perspective of diurnal patterns. Mind wandering has been characterized as the dynamic “movement of thought” which includes how constrained versus unconstrained the mind is (Christoff et al., 2016). Thoughts that are more constrained are less likely to move freely, but it is unclear how this might fluctuate throughout the day. We conducted an experience sampling study to test whether there are diurnal patterns in free movement of thought. Participants answered probes on their cell phones throughout the day for five days. A total of 128 participants answered, on average, 67 probes yielding 8,610 probe responses in full. Indeed, the pattern of results suggests that participants experience marked fluctuations in freedom of thought throughout the day, beginning from the time they wake. Thoughts were less constrained within the first two hours of being awake. Participants then experienced a dip in their freedom of thought after having been awake for eight hours. These findings may eventually help us understand what times of day we can let our minds be free to wander, perhaps facilitating creative processes.

Support:

CIHR

14

Neural signatures of joint action observation in expert dancers and novices.

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Performing joint actions is a central aspect of social interactions. Whereas much research has been dedicated to understanding the psychological and neural mechanisms of performing joint actions, few studies have assessed the impact of watching joint actions on passive observers.

Here, we investigated the neural mechanisms that underlie the perception of joint action in dance using inter-subject correlations (ISCs) and fMRI. In dance, performers synchronize their individual movement to produce aesthetic appeal. We directly measured movement synchrony among 10 dancers performing a 30-minute choreography using wrist accelerometers and cross-recurrence analysis. 14 expert dancers and 11 novices passively watched a video recording of the choreography in the scanner. Whole brain ISCs across the entire performance revealed the strongest correlations in medio-temporal visual and primary auditory cortex. These correlations were stronger and more widespread among professional dancers than novice observers, suggesting reduced variability in visual and auditory processing of the observed actions in expert observers. Only experts exhibited additional synchronization in the superior parietal cortex, in line with an involvement of the human action observation network in joint action perception. A time-windowed ISC analysis included continuous measures performed synchrony and stimulus features of the video to clarify which aspect of the dance performance best predicted synchronization among spectators. For both expert and novice spectators, dynamic ISCs across large swaths of the brain were best predicted by performed synchrony among performers, rather than visual or auditory information of the video recording itself. Our findings show that the human brain is tuned towards extracting kinematic parameters of behavioural coordination in groups and suggest that the appeal of watching synchronous movement may partly lie in witnessing successful cooperation between people.

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15

Exploring the Relationship between Brain Activity, Stress, and Perceptions of Challenge and Threat on Performance, Engagement and Affective Responses to Creativity Tasks

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The primary purpose of the present study was to explore links between brain activity, brain asymmetry, stress and creativity (convergent and divergent). A secondary aim was to explore subsequent outcomes of task engagement and affective responses. A cross-sectional design used electroencephalography (EEG) to assess resting brain activity, self-report methods to measure stress, perceptions of challenge and threat, task engagement and the affective responses to the task. A selection of three verbal, non-verbal and practical tasks was used to assess creativity, namely the Remote Associates Test, the double-circles task (adapted version of TTCT) and a novel tactile task. 66 students (M age= 22 years, n= 36 females) were initially tested for baseline EEG. The three tests of creativity were then presented and assessments were taken on perceived stress and perceptions of challenge/threat. Finally, self-reported task engagement and affective responses were recorded. Frontal brain activity correlated positively with elaboration on the double-circles task. Threatening perception correlated negatively with originality on the tactile task. Brain activity and right side dominance correlated positively with perceptions of challenge. Additionally, brain activity correlated positively with stress and negative affect and right side

dominance with positive affect. Finally, stress, threatening perception and negative affect were all positively related. The key findings support most of the research hypotheses. Still, there are limitations to be considered and the brain activity-creativity and affect-creativity relationships remain unclear. Therefore, further research is suggested.

16

Musical Creativity and the Dream State: A Neurotheoretical Meditation

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The neuroscience of musical creativity is a young but emerging field, with no more than a few dozen studies on the subject to date (reviewed in Bashwiner, forthcoming). It is too early for any sort of coherent synthesis to emerge with respect to what musical creativity “is” in the brain, but a number of fascinating questions arise. For instance, how do improvisation and composition differ from one another, and how do they differ from performing and listening? In musical behaviors such as these, how do the sensory apparatus and motor apparatus interact? Do the predictive “efference copies” sent from one to the other in performance and listening situations also typify composition and improvisation? Do the implicit (procedural) and explicit (declarative) memory systems differ in this regard? Do the basal-ganglia and cerebellar motor systems differ? What role do affect regions play in motivating and guiding creative musical behaviors, and how do these regions interface with “executive” regions like dorsolateral prefrontal cortex? Finally—and perhaps most interestingly—is there a special mental state that composers and improvisers seek to enter into when creating, and if so what characterizes it neuroscientifically? Does it bear more than a superficial resemblance to the dream state, with which it is often compared? These are big questions, but the topic warrants them. Rather than adding a new piece to an already complex puzzle, this presentation surveys the phenomenon as a whole—gathering together overlooked pieces, and offering a theoretical model for how they might all fit together.

17 (also a data blitz talk)

BOLD signal variability and internally directed cognition

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In a range of externally directed tasks, intra-individual variability of fMRI BOLD signal (fMRI-var) has been shown to be a stronger predictor of cognitive performance than mean BOLD signal (fMRI-mean). fMRI-var’s strong association with cognitive performance is hypothesised to be due to it capturing the dynamic range of neural systems. While increased fMRI-var is speculated to play a role in creative thought, there is a lack of research investigating how fMRI-var is

related to performance in tasks requiring cognitive flexibility during internally directed cognition. To investigate the relationship between fMRI-var and creative cognition, we first performed task partial least-squares (PLS) analyses that contrasted fMRI-var and fMRI-mean during two future imagination conditions, differing in the amount of cognitive flexibility required: a congruent condition in which autobiographical details (people, places, objects) comprising an imagined event belonged to the same social sphere (e.g. university) and an incongruent condition in which details belonged to different social spheres. Next, we used behavioural PLS to determine how individual differences in performance in future-imagination and divergent thinking tasks relates to fMRI-var and fMRI-mean. The task-PLS results showed that the incongruent condition resulted in widespread reduction in both fMRI-var and fMRI-mean, in largely non-overlapping regions. The behavioural PLS analysis showed that, for both conditions, performance in future-imagination and divergent thinking tasks was generally associated with increases in fMRI-mean and decreases in fMRI-var. Together, the results suggest that unlike tasks requiring externally directed cognition, better performance in tasks requiring creative internal mentation is associated with less (not more) variability.

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18

Neuroimaging of dyadic creative design thinking using portable functional near infrared spectroscopy (fNIRS)

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Everyday creativity often occurs in teams, especially in the workplace. Despite this, most studies on the neuroscience of creativity have focused on individual creativity. In the current investigation we utilized functional near-infrared spectroscopy (fNIRS) to assess coherence in brain activation between two people engaged in collaborative creative design. Participants were asked to collaborate with the goal of creating a product that addresses a specific problem. We used ultra portable fNIRS to simultaneously measure brain activity in two people while they were engaged in this collaborative creative design thinking. Preliminary analysis employed analyses that identify inter-brain synchronization between dyads. Identification of inter-brain synchrony during creative collaborative design can advance our understanding of team creativity and add to the existing neuroscientific body of knowledge on individual creativity.

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19

Creative Cognition under Performance Pressure: Investigating How Anxiety Affects Attentional Styles and Creativity

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Creative cognition involves different attentional resources and strategies in its processes. One way to conceptualize these strategies is in terms of divergent thinking (open-ended production, with leaky attention) and convergent thinking (narrowing evaluation, with selective attention). Existing creative tasks depend on these thinking styles differently--for example, the Alternative Uses Task (AUT) requires continued generation of responses to an open-ended cue. Similarly, Compound Remote Associate Problems (CRAs) require divergence to rapidly access distant associations between words, but also problem-solving that converges on a correct answer. Even within the CRAs, solving styles differ in their use of convergent/divergent thought: solving by insight requires low-level activation of many concepts which eventually converge to a solution, while analytic solving is a more directed, step-by-step method to find a solution. Because these thinking styles can be connected to attention, and attention can be modulated by moods such as anxiety, I investigated how performance pressure and its resulting anxiety affect creative cognition. In the presented studies, participants performed CRAs and AUTs under high- or low-pressure conditions. Although the pressure manipulation failed, results relating the constructs were found. Multiple regressions of analytic and insight solving of CRAs, working memory measures, and baseline anxiety were used to predict the 3 AUT subscores. When controlling for working memory, baseline anxiety, and analytic CRA solving, insight CRA solving was negatively associated with AUT Category Shifts ($p=.0295$) – that is, people who solved CRAs via insight were less likely to shift categories when producing AUT responses. Implications will be discussed.

Support:

Northwestern University

20

Linguistic Creativity & The Language-Ready Brain

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Human communication is unique in two respects, which contribute to its unbounded creativity: the ability to memorize thousands of words, each using an arbitrary relationship between meaning and sound, and the ability to recombine words in a hierarchically dependent fashion.

Since Chomsky (1966) proposed the language-readiness of the neonate brain, scientists have attempted to understand the neural grounding of linguistic theory. Since Wernicke's classification of the primary language regions, new findings on localization of linguistic functions in the brain using PET and fMRI have become commonplace. However, localization remains only one aspect of understanding the linguistic brain. Non-invasive neuroimaging techniques have made several positive contributions, including fMRI studies comparing activation patterns in normal and impaired populations (Dronkers et al. 2000), TMS investigations teasing apart abstract vs. embodied principles (Berent et al. 2015), and ERP evidence for a wide range of differential responses within 100-600ms to linguistically contrasting stimuli (Xiang et al. 2009). Indiscriminate neuroimaging, however, has still not proven very useful. Recent studies have questioned both the general methodology of neuroscience in this regard (Jonas & Kording 2017), and their application to linguistics (Embick & Poeppel 2015). Given the amount of granularity mismatch that often exists between the levels of representation used in the neural and linguistic sciences, we respond to a call for a parts list (Bosker 2016) that can be used to explore the internal functional specialization of brain regions to specific linguistic operations and neurobiologically contrast different dependencies, thus providing a neuronal explanation for language-readiness in humans.

21

Assessing the transfer of spatial training to spatial creativity in adolescents

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Spatial creativity and spatial intelligence may be related. This study was conducted as part of a large NSF-funded project on both behavioral and neural effects of a spatially-based high school course. Participants were asked to mentally rotate component objects to create new inventions (Creative Invention Task; Finke, 1989) before and after enrolling in the specialized course. Early analyses comparing scores on the Creative Invention Task to those of a standard mental rotation task suggests that spatial creativity and intelligence are, in fact, linked. The data suggest that learning to think spatially may lead to increased ability to be creative in the spatial domain. This exciting result would constitute meaningful transfer; students were never trained on the Creative Invention Task as part of their course but changes in spatial ability related to performance on the creativity assessment. We also investigated whether the shape and arrangement of the component objects involved in invention creation impact the extent to which they can be successfully manipulated in order to create truly novel invention concepts. Our data indicate that the features of the component objects facilitated creativity in differential ways. Taken together, these findings could allow teachers and policy-makers to create spatially-based curricula that can lead to broad

gains on abilities that students were never specifically trained on, such as spatial creativity. Additionally, our item-level examination of the Creative Invention Task could support the development of new measures of spatial creativity by highlighting features that appear to promote or suppress creative engagement.

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22

Associations between verbal, figural, and behavioral attributes of creativity and sleep disturbance

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Alterations of the noradrenergic system (NE), among other neurotransmitter systems, are known to give rise to disturbed sleep. Additionally, these neurotransmitter systems are implicated in creative processes. For instance, administration of propranolol, a beta-adrenergic antagonist, has been found to enhance cognitive flexibility, a component of creativity. Thus, this investigation sought to determine whether presence of sleep disturbance impacts performance on creativity tasks. A total of 54 individuals (25 male, average age=19.65, SD=1.84, range=18-30) completed the Abbreviated Torrance Test for Adults (ATTA; verbal & figural creativity), the Scale of Creative Attributes and Behaviors (SCAB; creative attributes and behaviors), the Pittsburgh Sleep Quality Index (PSQI), and the Beck Depression Index (BDI-II). High sleep quality (HSQ) and low sleep quality (LSQ) groups were created based on a median split of the global PSQI score to represent the independent variable. Initial analyses indicated a significant difference between the HSQ and LSQ groups on the BDI-II, thus, BDI-II scores were used as a covariate in subsequent analyses. ANCOVA revealed a significant difference between the HSQ and LSQ groups on the ATTA verbal creativity task as well as the total SCAB score. The results suggest that individuals with disturbed sleep quality may have increased verbal creativity and tend to engage in creative acts more often than those with high sleep quality. Future studies will be needed to determine whether this is driven by differences in neurotransmitter system function or other factors.

Support:

Middle Tennessee State University Department of Psychology

23

A novel coding scheme for assessing responses in an alternative uses task: An embodied approach

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Divergent thinking tasks are perhaps the most common method to measure an individual's creative ability. In the classic version of this task, participants are required to generate as many different uses they can think of to common items, such as a brick or newspaper, in a fixed amount of time. Participant's responses are then scored on different aspects of their performance, such as fluency, uniqueness, originality, or flexibility of their responses. However, what strategies do participants use when generating these responses? To date, only one attempt has been made to examine these strategies. In this study, we move a step forward in this direction, by proposing a new classification scheme of different strategies that are utilized to generate DT responses. Our scheme is based on an embodied cognition approach, which has been linked in the past to creative cognition. As DT tasks require participants to generate uses, an embodied cognition perspective is a powerful approach to examine and shed novel light on the strategies being utilized by participants in this task, and how they may relate to individual differences in creativity. We demonstrate the feasibility of our approach on a previously collected dataset of DT responses.

24

The Big C Project: Personality and Psychopathology Profiles

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As part of a broader investigation of brain and behavior, As part of a broad investigation of brain and behavior, the UCLA 'Big C' Project studied whether "Big C" (world-class) artistic, jazz, and scientific creativity is linked with schizotypal and autistic features, and whether temperamental traits are associated with creativity, personality and psychopathology.. With the Schizotypal Personality Questionnaire (SPQ), Social Responsiveness Scale (SRS), and the International Personality Item Pool Representation of the NEO PI-R (IPIP-NEO), We examined more than 30 individuals each in three groups: 34 Big C Visual Artists (VA), 39 Big C Scientists (SCI), and a Smart Comparison Group (SCG) matched on VA and SCI's age, sex, race/ethnicity, parental education, and/ IQ estimates, and . We also examined 14 Big C Jazz Musicians (MUS) as part of a follow up study with the Schizotypal Personality Questionnaire

(SPQ), Social Responsiveness Scale (SRS), and the International Personality Item Pool Representation of the NEO PI-R (IPIP-NEO).. Big C groups had internationally prominent creative reputations and markedly higher Creative Achievement Questionnaire scores within their domains. VA and MUS had significantly greater SPQ scores in CCognitive/PPerception compared to SCI (VA, MUS > SCI) and. VA also showed significantly higher Disorganization SPQ factors compared to SCI (and nominally greater scores than SCG). VA and MUS reported higher levels of ideas of reference (VA, MUS > SCI). VA had scored higherand in Disorganization, unusual perceptions, and odd speech (VA > SCI). . VA also showed significantly higher Disorganization SPQ factors VA compared to SCI (and nominally greater scores than SCG)significantly scored higher in SRS Restricted Interests and Repetitive Behavior (VA > SCI, SCG) and Social Communication (VA > SCG) and SPQ odd speech (VA > SCI). . VA also had odd speech and more socially divergent tendencies. VA had significantly higher scores in SRS subscales of Social Communication, Social Motivation, Restricted Interests and Repetitive Behavior compared to SCG. Except MUS, the other three groups had significant differences in openness (VA>SCI>SCG). Both VA and SCI were significantly more achievement-striving than SCG, with the scientists higher than the visual artists (SCI, VA > SCG). The All Big C groups also reported significantly higher scores on liberalism compared to SCG (VA, MUS, SCI > SCG).. Except MUS, the other three groups had significant differences in openness (VA>SCI>SCG). Both VA and SCI were significantly more achievement-striving (SCI, VA > SCG) and active (VA, SCI > SCG). VA and SCI reported significantly higher scores on activity (VA, SCI > SCG); while only VA had significantly higher scoregreater on imagination and artistic interests than SCI and SCG than SCI and SCG (VA > SCI, SCG). These results complement and extend past findings of high magical ideation and openness associated with everyday creativity achievement in healthy individuals. Compatible with the hypothesis of “subclinical” psychopathology associated with creativity, theseThese results also open questions about whether there are valuable and potentially adaptive aspects of psychopathological traits and what may be driving this association in exceptional visual artists and jazz musicians.

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25

Trait-like Resting-State EEG Predicts Subsequent Problem-Solving Strategy Preference

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People use different processing strategies to solve problems. Previous research distinguishes between solving problems analytically, that is, in a conscious, deliberate manner, versus insightfully, in which the solution appears abruptly in awareness (the “Aha” phenomenon). Prior work provides little evidence whether the tendency to solve problems using one or the other of

these strategies constitutes a stable, trait-like cognitive style. We tested this hypothesis by assessing whether individuals evince a consistent preference for a particular solving strategy. We recorded participants' resting-state electroencephalograms (EEGs) on 4 occasions. At the end of the third and fourth sessions, participants attempted to solve a series of short verbal problems (compound remote associates during session 3 and anagrams during session 4). Based on participants' trial-by-trial reports of their anagram solution strategies, individuals were categorized as predominantly relying on an insight or analytic solving strategy. Resting-state EEG of participants in the analytic group showed greater EEG beta power over midline and right inferior-frontal regions compared to insightful participants; participants in the insightful group showed greater beta power over left superior parietal cortex compared to those in the analytic group. Group differences in solving strategy and resting-state EEGs assessed with anagram problems generalized to the compound remote associates problems. Overall, these results demonstrate the behavioral and neural consistency of these cognitive styles over both time and type of problem, and support the hypothesis that insightfulness results from chronic relative frontal hypoactivation and concomitant parietal disinhibition whereas analytic solvers exhibit chronic relative frontal hyperactivation and parietal inhibition.

Support:

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26

Adolescents' ability to imagine protagonists' thoughts and feelings for complex, but not simple, social stories are associated with neural connectivity at rest, and predict subsequent long-term memory for stories

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Imagining others' internal cognitive or affective states is more complex in the context of abstract, values-oriented social situations rather than concrete commonplace social circumstances. We hypothesized that adolescents' proclivities toward social imagining would be associated with resting connectivity in the default mode network (DMN), as the DMN is known to support imagination and feeling abstract social emotions. Since the DMN is also involved in remembering, we hypothesized that social imagining would promote long-term memory. As such, we asked 53 adolescents (mean age 15.99 years; 27 female) to describe their feelings to 10 abstract and 10 concrete social stories in an interview. Resting-state DMN connectivity was identified using independent component analysis from a 7-minute resting state scan. Two years later participants reported their memories for the stories. For abstract social stories, controlling

for age and verbal IQ, social imagining was associated with DMN connectivity to the ventromedial prefrontal cortex and with DMN connectivity to the right anterior insula (thresholded at $p < 0.05$ corrected for multiple comparisons). Social imagining also predicted memory for the stories two years later $F(1, 47) = 6.40$, $P = 0.02$. No such relationships were found for concrete social stories. Thus, adolescents may vary in neural and psychological readiness to deeply imagine about others, and greater ability to imagine may facilitate memory. Preliminary analyses suggest DMN connectivity may mediate the relationship between social imagining for abstract stories and memory—a hypothesis our future research will investigate. Overall, current findings suggest differences in ability to imagine about others may facilitate learning.

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27

Flexibility of thought in creative individuals: A percolation analysis

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Flexibility of thought is theorized to play a critical role in the ability of high creative individuals to generate novel and innovative ideas. However, this has been examined only through indirect behavioral measures. We computationally quantify and examine the flexibility of thought in low and high creative individuals using network analysis and percolation theory. Percolation theory examines the robustness of networks representing complex systems to random attacks or failure. Here, we use network percolation analysis (removal of links in a network whose strength is below an increasing threshold) to examine the robustness of the semantic memory networks of low and high creative individuals. Robustness of a network indicates its flexibility, and thus can be used to quantify flexibility of thought as related to creativity. This is based on the assumption that the higher the robustness of the semantic network, the higher its flexibility. Our analysis reveals that the semantic network of high creative individuals is significantly more robust to network percolation, and that this higher robustness is related to differences in the structure of the network, compared to the network of low creative individuals. This higher robustness is highly related to the relatively stronger links connecting between different components of similar semantic words in the network. Thus, we directly and quantitatively examine the relation between flexibility of thought and creative ability. Our findings support the associative theory of creativity, which posits that high creative ability is related to a flexible structure of semantic memory.

Exploring the Relationship between Distinct Styles of Daydreaming and Creativity

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There is increasing evidence suggesting that daydreaming (mind wandering) can be a source of inspiration and creativity. However, daydreaming is an umbrella term encompassing a wide variety of stimulus- and task-unrelated thoughts differing in content, style, and affective tone. Little is understood about what particular aspects of daydreaming are conducive to creativity. To address this question, we conducted a series of studies. First, we performed two studies (N = 195; N = 219) to develop a better scale to assess distinct styles of daydreaming. Participants recalled their most recent daydream and rated it on a number of items. Items were reduced using exploratory and confirmatory factor analyses, yielding a short scale distinguishing six distinct styles of daydreaming. Next, we performed an experience sampling study (N = 132) to examine how the different daydreaming styles relate to creative inspiration and behavior. Using a smartphone application, participants were probed at pseudo-random moments throughout the day over a period of five days and asked to report on their daydreams. At the end of each day, self-reported creative inspiration and behavior were assessed. The data were analyzed using a linear mixed-effects model approach to isolate between-person and within-person effects. The results showed that, both at the between-person level and within participants, two of the six daydreaming styles assessed through our newly-developed scale uniquely predicted creative inspiration and behavior. Specifically, personally meaningful daydreams and daydreams with a bizarre character predicted creative inspiration and behavior, whereas other, more mundane styles of daydreaming did not.

Support:

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Delusional and Creative Thinking: Are Both Driven by Unusual Perceptual Experiences?

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Findings within the creativity literature suggest a link between delusional thinking and creativity.

The Peters Delusions Inventory (PDI), a measure of delusional thinking in healthy populations, has previously been used to examine abnormal belief in creative professionals. This measure has also been used to investigate the relationship between delusional thought and altered prediction error signals: a neural marker of uncertainty which suggests abnormalities in perceptual processing. These converging lines of research suggests an explanatory framework for understanding the connection between creativity and delusional thinking, as driven by abnormal perceptual experiences. However, previous studies have provided incomplete evidence for the putative relationship between abnormal perceptual processing, delusional thinking, and creativity. The present study examined connections between these phenomena and attempted to clarify the relationship between creative and delusional thought by including well-established self-report measures of creativity, as well as two canonical behavioral measures of creativity. Our results indicate that endorsement of delusional thoughts (PDI) is significantly correlated to all self-reported creativity measures and self-reported unusual perceptual experiences (UE). Additional analysis revealed that UE uniquely predicts creative behavior. Furthermore, a path analysis suggests that UE is more strongly associated to both creative behaviors and PDI than they are to each other. These findings offer preliminary support for the hypothesis that UE may be driving both delusional thoughts and some forms of creative behavior. Future research will look to manipulate these variables in order to draw causal connections.

Support:

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30

Funding Opportunities at the National Science Foundation

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This poster will provide an opportunity to learn about the National Science Foundation (NSF) two merit review criteria, Intellectual Merit and Broader Impacts, as well as various funding opportunities that exist for cognitive neuroscientists. An overview of a number of NSF programs and interdisciplinary competitions will be presented, including CAREER awards and standard research proposals in core programs such as Cognitive Neuroscience, Perception Action and Cognition, Developmental Sciences, Science of Learning and Social Psychology. Additionally, funding opportunities in the context of NSF Understanding the Brain, such as Integrative Strategies for Understanding Neural and Cognitive Systems (NCS), and Collaborative Research in Computational Neuroscience (CRCNS) will be presented.

Support:

National Science Foundation



Acknowledgments



About the San Francisco Conservatory of Music

Founded in 1917, the San Francisco Conservatory of Music is the oldest conservatory in the American West and has earned an international reputation for producing musicians of the highest caliber. Its faculty includes nearly 30 members of the San Francisco Symphony as well as Grammy and Latin Grammy Award-winning artists in the fields of orchestral and chamber performance, classical guitar, and jazz. The Conservatory offers its 400-plus collegiate students fully accredited bachelor's and master's degree programs in composition and instrumental and vocal performance. SFCM was the first institution of its kind to offer world-class graduate degree programs in chamber music and classical guitar. Its Pre-College Division provides exceptionally high standards of musical education and personal attention to more than 200 younger students. SFCM faculty and students give nearly 500 public performances each year, most of which are offered to the public at no charge. Its community outreach programs serve over 1,600 school children and over 6,000 members of the wider community. Notable alumni include violinists Yehudi Menuhin and Isaac Stern, conductor and pianist Jeffrey Kahane, soprano Elza van den Heever, Blue Bottle Coffee founder James Freeman and Ronald Losby, President, Steinway & Sons - Americas, among others. The Conservatory's Civic Center facility is an architectural and acoustical masterwork, and the Caroline H. Hume Concert Hall was lauded by *The New York Times* as the "most enticing classical-music setting" in the San Francisco Bay Area. For more information, visit sfc.edu.

National Science Foundation

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