SOCIETY FOR THE NEUROSCIENCE OF CREATIVITY

5TH ANNUAL MEETING

SFNC 2019

SAN FRANCISCO
CONSERVATORY OF MUSIC
MARCH 22, 2019

SCHEDULE

8:00 AM	**Registration**
8:30 AM	**President's Opening Remarks: Adam Green** (Sol Joseph Recital Hall)
8:45 AM	**Keynote 1: Mary Helen Immordino-Yang**, University of Southern California, "Neuropsychological studies of social-emotional meaning-making: Insights for creativity research and education"
9:15 AM	**Keynote 2: Charles Limb,** University of California, San Francisco, "Neural Substrates of Musical Improvisation"
9:45 AM	**Break**
10:00 AM	**Talk Session 1**
11:30 AM	**Blitz Session 1** (move to Osher Salon with room 207 for overflow on the Deleage Level)
12:00 PM	**Poster Session and lunch** (Atrium)
2:15 PM	**Talk Session 2**
3:45 PM	**Break**
4:00 PM	**Blitz Session 2**
4:30 PM	**Keynote 3: James Kaufman,** University of Connecticut, "Creativity: Models, Measures, Concepts, and Questions from Psychology"
5:00 PM	**Keynote 4: Russell Poldrack,** Stanford University, "Toward an ontology of creativity: Lessons from the study of self-regulation"
5:30 PM	**Concluding Remarks**
6:00 PM	**Education-Focused Design Workshop** (Osher Salon by invitation only)

TALK SESSION 1

1. Creativity studies need a better map - a road to integration of knowledge from different fields of scientific inquiry

Milena Z. Fisher, The Creativity Post (milena.fisher@gmail.com)

Understanding creativity from a vantage point of one discipline will not provide epistemologically sound answers to questions. Much as we were not able to describe cognition in the realm of one discipline, so too are we not able to crack the enigma of creativity by only using one set of scientific tools. In this talk, I will address several, broad methodological questions: does creativity research suffer from a premature codification problem?; is art and artistic behavior a good proxy for understanding creativity?; what is an actual role of randomness and divergent thinking in high-level creativity? However, the main focus of a presentation will remain on the progress made in "algorithmic" approaches to creativity. First I will probe an alternative taxonomy of creativity proposed by Maggie Boden (combinational, exploratory and transformative as three modes of creativity). Second I will traverse the basis of computational creativity (principles used to build creative and co-creative agents) and last, but not least I will attempt to scrutinize fundamentals of creative AI (in particular the formal theory of creativity, fun and intrinsic motivation by Juergen Schmidhuber) There are many difficult questions left unanswered by psychology that have left us stumped when attempting to teach creativity in the classroom and in the boardroom. We need to attempt a proper and deep integration of findings from multiple disciplines concerned with the subject of creativity. The tension between their ontological and epistemological frameworks can produce a body of knowledge that is at once rigorous, applicable and relevant. I hope to engage the audience in this multifaceted discussion.

2. Impaired capacity for creative thinking in frontotemporal dementia

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Tamara Paulin, Macquarie University, Sydney
Greg Savage, Macquarie University, Sydney
John R. Hodges, University of Sydney

Neurodegenerative disorders offer unique insights into the neurocognitive mechanisms that must be functional to support higher-order cognitive processes. A pervasive feature of the behavioural variant of frontotemporal dementia (bvFTD) syndrome is that of mental rigidity, manifesting in the inability to generate effective strategies when confronted with novel problems. Our previous studies in bvFTD reveal a marked incapacity to generate novel future events as well as an inability to perceptually decouple from the immediate environment during periods of monotony. Here, we explored the capacity for creative thinking in 14 bvFTD patients in comparison with 14 matched healthy Controls. Participants completed the Alternative Uses Task (AUT) as an index of divergent thinking, and the Means-End Problem Solving (MEPS) task to assess flexible problem-solving. Irrespective of task, bvFTD patients showed compromised performance relative to Controls, manifesting in significantly fewer, and less novel, alternate uses on the AUT ($p < .001$). Similarly, bvFTD patients took significantly fewer steps, and demonstrated reduced effectiveness, in solving social dilemmas on the MEPS ($p < .001$). Our results provide evidence of marked impairments in creative thinking in bvFTD. We suggest that degeneration of prefrontal and right anterior temporal structures, characteristic of this syndrome, likely mediates the compromised performance observed here.

3. Investigating the neural dynamics of divergent thinking

Yoed N. Kenett, University of Pennsylvania (yoedk@sas.upenn.edu)

What are the neural dynamics that drive creative thinking? Recent studies have revealed much insight into the neural mechanisms of creative thinking through the investigation of divergent thinking. Specifically, the interaction between the executive control, default mode, and the salience brain networks have been shown to be an important marker of individual differences in creative ability. However, how different brain regions within these systems might be recruited dynamically during the creative process remains far from understood. I will present how the application of two state-of-the-art network neuroscience methodologies—network control theory and dynamic network reconfiguration—to investigate divergent thinking sheds unique novel light on this issue. Network control theory offers tools to investigate how whole brain structural connectivity theoretically "controls" neural dynamic brain states in relation to behavior. Dynamic network reconfiguration offers tools to investigate how the functional architecture of a brain network changes during task performance. At the structural connectivity level, our network control theory analysis has uncovered the roles of the right inferior frontal junction—an area mediating internal and external attention—and sensorimotor brain regions in driving brain dynamics related to individual differences in divergent thinking. At the functional connectivity level, our dynamic network reconfiguration analysis has uncovered how generating creative uses in a divergent thinking task led to higher brain reconfiguration compared to generating common characteristics, but also related to a more stable core of default mode brain regions.

4. Fixation, inhibition and the neurocognitive development of creative idea generation

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Anaëlle Camarda, CGS, Mines ParisTech

Creativity is crucial during circumstances in which individuals must generate new solutions to solve an unknown problem. In such circumstances, people tend to propose solutions that are built upon the most common and accessible knowledge within a specific domain, leading to fixation effects, whereas other classes of more creative solutions could be explored. According to the triple system's model of creativity, the difficulty to generate creative ideas results from a specific failure to inhibit intuitive responses generated automatically by the intuitive and heuristic System 1 –leading to a fixation effect-, and to activate the deliberative and analytic System 2 to explore more creative solutions. This model posits that inhibitory control is a core process to overcome fixation effects and generate original solutions in a creative task. Therefore, the aim of this presentation is to provide empirical evidence in support of the triple system model of creativity. In a series of experimental studies in children, adolescents and adults, we have demonstrated that 1) fixation effects develop with age and change with the introduction of external cues such as examples of solutions 2) overcoming fixation to explore creative solutions involves inhibitory control and the ability to detect that initial responses that come quickly to mind are not original, 3) this conflict detection ability develops with age during adolescence and 4) overcoming fixation is related to modulations of brain networks' activations within the frontal and the parietal cortex involved in cognitive control and semantic associations, respectively.

5. Introducing sequential and coherent processes for school leaders for nurturing creativity in the classroom and within the school

Larry Audet, Ministry of Education Dubai
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Creativity has become one of the major outcomes desired by countries that value creativity and innovation, yet many education leaders do not have the knowledge or skills to effectively introduce it to their teachers. It is impossible to simultaneously introduce all aspects of creativity into professional development and reach any degree of organizational coherence. In order to become an effective leader of creativity, the practitioner needs practical, evidence-based guidance for creating a professional development sequence. Machine learning models reveal new findings from the author's research on KEYS Survey© data. KEYS measures employee perceptions of the work-climate stimulants and barriers to their individual and collective creativity. Findings from predictive and causal models provide leaders with a rational for decision-making when introducing creativity into their organization. Leaders should focus on management practices first. Analyses reveal that creative outcomes are more likely to occur when teachers perceive supportive management practices, such as providing teachers with challenging work that calls for their best efforts; allowing freedom and autonomy in their practice of work; allowing teachers to form creative work-groups; and, recognizing them for their efforts. Once management practices are in place, leaders can focus efforts on: modeling risk-taking; providing optimal amounts of preparation time; and, evaluating teachers fairly. This research provides a coherent step-by-step process in which leaders can begin to introduce, modify, enhance, support, and model for teachers so that creativity can be sustained within the fabric of the culture of the school.

TALK SESSION 2

1. Structural brain differences underlying higher and lower creative achievement

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David M. Bashwiner, University of New Mexico
Donna Bacon, University of New Mexico
Ranee A. Flores, University of New Mexico
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Relatively few studies have assessed brain correlates of "everyday" creative achievement in cohorts of normal subjects. Our group first showed that scores on the Creative Achievement Questionnaire (CAQ) were associated with lower cortical thickness within the left lateral orbitofrontal gyrus (LOFG), and increased thickness of the right angular gyrus (AG)(Jung et al., 2010). Subsequent studies found CAQ scores to be associated with decreased volume of the rostral anterior cingulate cortex (ACC)(Chen, et al., 2014), and that artistic and scientific creativity was associated with decreased and increased volumes within the salience and executive control network respectively (Shi et al., 2017). We sought to establish structural differences between lower versus higher "everyday" creativity in a large cohort (N=248). Subjects were young (Range = 16-32; Mean age = 21.8; s.d. = 3.5) all of whom were administered the CAQ, and underwent structural MRI on a 3 Tesla scanner. CAQ scores were split at the median (Median CAQ = 12; range = 1 – 178). Cortical thickness, area, and volume measures were obtained using FreeSurfer. High and Low CAQ subjects were compared, controlling for age, sex, and total intracranial volume. Volume was associated with CAQ score (High < Low CAQ) within left/right lateral occipital regions, and right rostral middle frontal region. Higher creative achievement was associated with decreased volume in regions extending from the frontal pole through the occipital

cortex, mediated by a complex interplay between decreased thickness and area. Such relationships will be discussed within the context of network understandings of creative cognition.

2. Brain activity patterns during creative idea generation in eminent and non-eminent thinkers

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Constanza Jacial, Drexel University
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Andrew B. Newberg, Thomas Jefferson University Hospital

An influential model of the neural mechanisms of creative thought suggests that creativity is manifested in the joint contributions of the Default Mode Network (DMN; medial PFC, lateral and medial parietal cortex, and the medial temporal lobes) and the executive networks within the dorsolateral PFC. Several empirical reports have offered support for this model by showing that complex interactions between these brain systems account for individual differences in creative performance. The present study examined whether the engagement of these regions in idea generation is modulated by experience, as measured by one's eminence in a creativity-related field. Twenty (n = 20) healthy participants eminent in their respective fields (i.e., writing, neuroscience, music, comedy) and twenty (n = 20) age- and education-matched non-eminent but successful in their profession control participants were administered a creative generation task (an adaptation of the Alternative Uses Task) and a control perceptual task, while undergoing functional magnetic resonance imaging (fMRI). The participants' verbal responses were recorded through a noise-canceling microphone and were later coded for accuracy and task compliance. Behavioral and fMRI analyses revealed commonalities between groups, but also a distinct pattern of activation in default mode and executive brain regions in the eminent relative to the non-eminent participants during creative thinking. We interpret these findings in the context of the well-documented contributions of these regions in the generation of creative ideas as modulated, in this study, by a lifetime of experience in creativity-related fields.

3. The cost of a cell phone: Social media notifications may be especially costly for creative people

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Carl E. Stevens, University of Arkansas
Giorgio Ganis, University of Plymouth
Darya L. Zabelina, University of Arkansas

Prior research indicates that cellular phone use, and even the mere presence of a phone, can have detrimental effects on people's attention and cognitive control related to driving, working, learning, and social interactions (Thornton et al, 2014). People who are more creative in the real world may be especially prone to such distractions, as they have more diffused attention compared to their less creative counterparts (Zabelina, 2017). The present study examined individual differences in cognitive control in response to cellular phone notifications in creative people. Participants completed an oddball paradigm (adapted from Zabelina & Ganis, 2017), in which they viewed hierarchical letter stimuli and identified target letters in frequent and rare target trials, requiring an upregulation of cognitive control. Just prior to target presentation, participants heard either a cellular phone notification, or control sounds. We predicted that individual differences in creativity would relate to lower levels of cognitive control (slower RTs and more negative N2), particularly on trials with cellular phone notifications compared to trials with control sounds. Overall, participants responded slower and had more negative N2 on trials with the phone (vs. control) sounds. Interestingly, and as predicted, participants with more real-world creative achievements had a larger N2 Oddball effect in the phone (vs. control) sound condition, indicating that social media use, including cellular phone

notifications, may be likely to result in larger depletion of cognitive control resources in more creative people.

4. EEG evidence that creative talent and flow are related, but only for trained creative thinkers

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Elizabeth A. Nowicki, University of Western Ontario, Faculty of Education
Marc F. Joanisse, University of Western Ontario

We used EEG, consensual assessment, and the Alternate Uses Test to investigate the nature of creative flow in the context of musical improvisation. As reported earlier (Lopata, Nowicki & Joanisse, 2017), we monitored EEG upper alpha power while contrasting music tasks with high and low creative demands, and correlated EEGs with expert ratings of improvised performances. Our findings showed right frontal upper alpha synchronization was greater during the high creative tasks, and was correlated with performance quality, but only for musicians with previous formal training in improvisation. We interpreted right frontal upper alpha as an indicator of creative state engagement (i.e., creative flow). Here, we elaborate these findings by sharing partial correlation analyses involving the Alternate Uses Test Originality and Fluency indices to shed light on the role of creative aptitude as a mediating variable in the relationship between frontal alpha and creative performance. The summation of our findings show the relationship between alpha and performance to be mediated by AUT originality scores thereby suggesting that creative flow may be related to creative talent and that both are developed through training, but only for people with aptitude for original thinking. These findings support and will be shared in the context of Francois Gagne's (2004) Differentiated Model of Gifts and Talents, wherein natural abilities are proposed to be cultivated into talents through developmental pathways including formal training

5. Examining the brain basis for collaborative improvisation using a 3-person fMRI hyperscanning paradigm

Hua Xie, Stanford University
Amber Howell, Stanford University
Meredith Schreier, Stanford University
Kristen E. Sheau, Stanford University
Mai K. Manchanda, Stanford University
Malte Jung, Cornell University
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Allan L. Reiss, Stanford University

To reveal the neural correlates of collaboration, we employed a game-like improvisation paradigm, based on PictionaryTM (Saggar et al., 2015 Scientific Reports), where 3 participants interacted with each other in real time by sketching on an MR-safe tablet. To our knowledge, this is a first study to employ 3-person fMRI hyperscanning to study the neural correlates of collaboration. Thirty-six participants (27.4 ± 5.0y; 16F) were recruited and randomly assigned to twelve triads. Each triad was simultaneously scanned while engaging in the improvisation drawing paradigm. For each verb, the paradigm consisted of four phases: independent, control, inspiration, and collaboration drawing. The fMRI data were collected by three identical 3T GE scanners with a 32-channel head coil using a T2*-weighted contrast (TR = 2s). General intelligence was assessed using Wechsler Abbreviated Scale of Intelligence-II (WASI-II) and creative capacity using the Torrance Test of Creative Thinking (TTCT-F). Here, we report GLM results from contrasting collaborative with independent drawing. This primary contrast revealed increased activation in posterior cingulate cortex and precuneus (PCC/pC), right superior temporal sulcus (R STS), right superior frontal gyrus (R SFG), left temporal pole (L TP), left

anterior insula (L AI), right angular gyrus (R AG) and bilateral caudate. Further, a significant correlation was observed between individual's creativity score and mean beta contrast estimates from L TP (pFDR=0.03) and L AI (pFDR=0.04). In sum, our preliminary results highlight the role of mentalizing network during collaborative improvisation and a putative role of creativity during collaboration.

BLITZ SESSION 1

1. Effects of stress on functional connectivity during problem solving

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John Hegarty, University of Missouri and Stanford University
Bradley Ferguson, University of Missouri
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Michael Tilley, Central Methodist University
Shawn Christ, University of Missouri

Psychosocial stress impairs verbal problem solving requiring cognitive flexibility, an effect modified by genetic susceptibility to stress. Herein, we assessed effects of stress on FC in brain regions activated during verbal problem-solving, exploring effects of genes as well as gender. 45 participants were genotyped for presence of at least one copy of the stress-susceptible short (S)-allele of the serotonin transporter gene promotor region, or homozygosity for the long (L)-allele. fMRI was performed in two separate sessions. FC was assessed during the compound remote associate (CRA) task, interleaved with the Montreal Imaging Stress Test to induce stress at one session, or a no stress control task during the other, in counterbalanced order. As with previous work, a trend towards a stress x genotype interaction effect on CRA solution latency (p=0.06) was observed. A stress x gender x gene interaction was found for FC between left inferior frontal gyrus (LIFG) and left middle temporal gyrus (LMTG) (p=0.03), driven by a greater FC increase in S-allele females (p=0.03), but a greater FC increase in L-allele males (p=0.04) with stress. For L-allele participants, LIFG-LMTG FC changes related to CRA performance changes with stress (p=0.035). For S-allele participants, LMTG-L posterior cingulate FC changes related to performance changes with stress (p=0.029). Gender and genotype both affect FC associated effects of stress on problem solving. Effects of stress on performance are also associated with changes in LMTG connectivity. Future work will need to assess effects of interventions, and potential as a biomarker for cognitive effects of stress

2. Memory reactivation during rapid eye movement sleep facilitates remote associations

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Karen Konkoly, Cardiff University
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Penny Lewis, Cardiff University

Sleep can be broadly divided into rapid eye movement sleep (REM) and non-REM sleep, of which the deepest stage is slow wave sleep (SWS). The role of SWS in memory is well-established, whereas the role of REM is less clear. This study uses a between-participant design to examine the differential impact of targeted memory reactivation of an associative memory task during REM or SWS. Thirty-two participants (16 in the REM reactivation group and 16 in the SWS reactivation group), learned to match sounds to 40 semantically related scenes. Participants then learned to independently associate

two faces with each scene-sound pair. Following learning, participants' sleep was monitored and half of the sounds were replayed to them either in REM or in SWS. In the morning and in a two-week follow-up, both learned face-scene associations and remote face-face associations were tested. A time x group x replay ANOVA on remote associations showed a main effect of replay ($F(1, 30) = 5.54$; $p = 0.025$; partial $\eta^2 = 0.156$). Further analyses revealed that this was due to better performance (% correct) of the REM group on the replayed compared to the non-replayed items in the remote associations test. At the two-week follow-up, this replayed/non-replayed difference was significant ($t(15) = 2.76$; $p = 0.014$; Cohen's $d = 0.691$). These results suggest that memory processing occurs during REM sleep, and we can trigger it using learned sounds. They further suggest that REM sleep replay may play a role in creative processes.

3. Cueing creative problem solving during sleep: Links to restructuring

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Ken A. Paller, Northwestern University
Mark Beeman, Northwestern University

Anecdotes and previous research suggest that sleep may serve as a particularly useful incubation period for creatively solving problems. People are more likely to find hidden shortcuts and infer implicit hierarchical structures after a period of sleep compared to a similar period awake. Extrapolating from memory research, this benefit could emerge from the reactivation and reorganization of problem information. We adapted a paradigm shown to reactivate and strengthen memories during sleep, to test its effect on problem solving. Across two evening sessions, participants attempted to solve puzzles, each paired with a unique sound cue. Overnight, half of the unsolved puzzles' associated sounds were presented outside of participants' awareness while they slept. The following morning, when participants re-attempted their previously unsolved puzzles from the night before, they solved more cued than uncued puzzles. A second experiment replicated this initial finding, and additionally contrasted solving puzzles that did versus did not contain misdirecting information that induced fixation. In this experiment, the cueing effect was larger for the induced-fixation puzzles. Taken together, these results suggest that cueing facilitated the reactivation and restructuring of the puzzle memory. That is, although targeted memory reactivation generally strengthens memory, either memory for the misdirecting information was selectively decreased, or restructuring selectively strengthened memory for more useful puzzle elements and their relevant connections.

4. Disinhibition during musical improvisation is linked to creative ability

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Yuya Takeshita, Hokkaido University
Shinya Kuriki, Hokkaido University
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Musical improvisation has been frequently used in neurophysiological studies to examine the neurocorrelates of creative cognition. However, how brain activity during musical improvisation actually corresponds to creative ability remains relatively unexplored. Understanding this relationship may help explain why enhancements of creativity and sociability are often observed in association with practical and therapeutic musical improvisation training. Neurophysiological studies regarding musical improvisation and creative cognition have often implicated the importance of brain activity in right prefrontal areas associated with inhibition control, such as: rostral-middle-frontal (RMF), pars-opercularis (POP), pars-triangularis, pars-orbitalis, and even the precentral gyrus (PrCG). We hypothesized that functional ability in these areas may be an essential component of creative

cognition, and that brain activity there during musical improvisation may differ according to creative ability. We examined the creative ability and brain activity in inhibition areas of 14 improvisationally experienced musicians via magnetoencephalography during musical improvisation. Creative improvisers played more notes during improvisation, and exhibited declined theta activity indicative of disinhibition. Further correlation analyses indicated a direct relationship between this disinhibitory activity and creative ability. These results suggest that disinhibition is a cognitive strategy whose implementation is enhanced according to creative ability, thus making inhibition control brain function and creative ability important targets for monitoring the effects of musical improvisation training.

5. Creative engagement to make meaning: Metaphorical thinking through the affective body-mind

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In this presentation, I explore the concept of creative engagement in learning and present design considerations and exemplars for classroom instruction in middle school. Creative engagement builds on interdisciplinary models of embodied cognition, affective neuroscience, educational psychology, and creativity theory. Invoking embodied philosophy of mind, alongside recent affective neuroscience theory can illustrate the role of the bodily emotional response to meaningful learning, especially through metaphorical thinking of abstraction through the body-mind. Arts integrated instructional techniques that use the visual arts, music, movement, and dramatic enactment in learning naturally hold great potential to engage embodied emotions and expression as a medium for learning. In this presentation, I provide arts integration exemplars to understand the educational implications of embodied meaning-making in creative engagement. Through this presentation, I reformulate the problem of learner engagement in school to look beyond the need for autonomy, belonging, and competency to include the need for creative meaning making and the role the arts can play in that process. This multidisciplinary integration of theories provides a set of design principles for educators. The proposed framework can harness the power of the creative process in embodied meaning-making, especially during adolescence when learners' bodies have a heightened emotional need for belonging and autonomy.

6. Creativity and the anthropocene: How the creative brain relates to the history and future of humanity

Nathaniel Barr, Sheridan College (nathaniel.barr@sheridancollege.ca)

The term ‘Anthropocene’ is invoked to describe the extent to which this era of our planet is defined by human impact. In considering the advancements that have led us into this epoch, evolutionary and historical evidence makes clear that the creative brain is at the crux of understanding how and why we arrived in the Anthropocene. Though this time is marked by unprecedented prosperity, it is also wrought with risks that threaten the well-being and even existence of our species. Pollution, climate change, misinformation, inequality, economic and social disruption due to emerging technologies, political polarization, and large scale conflict can all be traced to the workings of the creative brain in the past, and also demand creative solutions going forward. Creativity is central to understanding our past and for securing our future. Given this centrality, and the scope and severity of challenges we collectively face, the imperative to study creativity and the creative brain is arguably greater than ever before. Not only is basic research required, we must also invest in applied interventions and training to enhance creativity, and re-design education to reflect both the newest evidence from the forefront of creativity research and the realities of the Anthropocene. This wide ranging talk will consider a novel assemblage of evidence connecting the creative brain to the most pressing contemporary

challenges facing humanity, and present new ideas for how to maximize the impact of creativity research in modern society.

BLITZ SESSION 2

1. Using topological data analysis to reveal the neural correlates of team improvisation in a 3-person fMRI hyperscanning paradigm

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Amber Howell, Stanford University
Meredith Schreier, Stanford University
Kristen E. Sheau, Stanford University
Mai K. Manchanda, Stanford University
Malte Jung, Cornell University
Allan L. Reiss, Stanford University

In this work, we examined neural correlates of team improvisation using a PictionaryTM based experimental paradigm (Saggar et al., 2015 Sci. Rep.), where 3 participants interacted with each other in real-time by sketching on an MR-safe drawing tablet. Sketches were later rated for usefulness and originality. Thirty-six participants (age: 27.4 ± 5.0y; 16F) were recruited and randomly assigned to create twelve triads. Each triad was simultaneously scanned while engaging in the improvisation drawing paradigm using three identical MR scanners and acquisition protocols. The paradigm consisted of four conditions: independent, control, inspiration, and collaboration drawing. Using previously developed topological data analysis based Mapper approach (Saggar et al. 2018 Nature Comm.) we examined synchrony across participants' brain activity during team interaction. The whole-brain BOLD signals were temporally concatenated across three players within a triad and input to the Mapper algorithm, which resulted in a graphical representation where a node represented whole-brain activity at any time point(s) across triad and an edge between nodes represented similarity between whole-brain activation at those time point(s). Mapper-generated graphs for each triad were annotated by player number and participation coefficient (PC) was estimated. Higher PC suggest higher brain synchrony across participants. A repeated measures ANOVA revealed significant effect of condition ($F(5,55)=5.18$, $p=0.001$), and post-hoc results confirmed that PC was highest for collaboration as compared to other independent drawing. Thus, suggesting higher inter-player synchrony during collaborative improvisation.

2. Creativity and machine learning: Divergent thinking EEG analysis and classification

Carl E. Stevens Jr., University of Arkansas (cesteven@uark.edu)
Darya L. Zabelina, University of Arkansas

Prior research has shown that increased power in the alpha range (8-13 Hz) of the EEG spectrum is characteristic of increased creativity, both between individuals and between conditions that differ in creative demand (Jauk et al., 2012). The current study investigates the extent to which more and less creative brain states can be differentiated by applying machine learning to EEG data. Participants completed an alternate use task in the lab (adapted from: Abraham et al., 2014; Jauk et al., 2017). Cue words prepared participants to think of normal or uncommon (more demanding) uses for objects prior to the names of common items (i.e., brick) appearing on screen. We hypothesized that reaction time and alpha power would be greater for uncommon uses. We also hypothesized that a machine learning algorithm would reliably classify new data as belonging either to the normal or uncommon condition

once the network had been trained. Participants responded faster in the normal condition (M = 1.99s, SD = 0.53), compared to the uncommon condition (M = 9.23s, SD = 3.99, $p < .001$). Neural network training was used to cluster independent components of activity. For the uncommon condition, a frontal midline cluster showed greater power in the gamma range (47, 63, and 70 Hz; $p < .01$). Though not statistically significant, alpha power was also greater in the uncommon condition. Additional data are being collected to determine the robustness of state classification. Future research will seek to implement neurofeedback to train individuals to maintain optimally creative states.

3. The Big-C project: graph theory analysis reveals Big-C scientists display more random patterns of functional connectivity than controls during tasks of divergent thinking

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Ariana Anderson, UCLA
Kendra Knudsen, UCLA
Susan Bookheimer, UCLA
Robert Bilder, UCLA

Divergent thinking (DT) and convergent thinking (CT) are considered crucial for creative thinking, yet patterns of functional connectivity associated with these abilities remain largely unknown. The Big-C Project examined whether exceptionally creative ('Big-C') people display unique patterns of functional connectivity during DT vs. CT tasks. We predicted that graph theory metrics would reveal greater global and local network connectivity in Big-C people. We analyzed 66 participants, including 21 Big-C Visual Artists (VIS), 21 Big-C Scientists (SCI), and 24 Smart Comparison Group (SCG) people matched on age, sex, and estimated IQ. Functional MRI were collected during the Alternate Uses Task (AUT; DT measure), Remote Associates Task (RAT; CT measure), and resting state (REST). MRI and graph theory analyses were conducted with the FSL software package, Brain Connectivity Toolbox, and R statistical package. Graph theory metrics included modularity, small worldness, local efficiency, and clustering coefficients. Local metrics were compared across six networks: default mode, dorsal attention, frontoparietal, salience, ventral attention, and visual. Compared to SCG, SCI showed lower small worldness during REST ($p = 0.05$, $t = -2$, $DF = 63$) and lower local efficiency and clustering coefficients during AUT ($p = 0.04$, $t = 2.5$, $DF = 63$; $p = 0.04$, $t = 2.5$, $DF = 63$, respectively). Our results reveal substantial overlap in functional connectivity across Big-C and SCG groups during CT tasks, but suggest that SCI may differ during rest and during DT tasks, which may be facilitated by more random network architectures.

4. Development and validation of a new test of scientific creative thinking

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Richard Daker, Georgetown University
Baptiste Barbot, Pace University
Adam Green, Georgetown University
Roger Beaty, Pennsylvania State University

Creativity is a critical component of success in STEM and fostering creative thinkers is a primary goal of educators from kindergarten through graduate school. However, the strong historical association of STEM exclusively with technical, rather than creative, thinking skills has left STEM creativity severely under-researched, such that there is presently no validated tool that educators and education researchers can use to identify what teaching strategies and classroom curriculum effectively fosters scientific creativity. Therefore, we developed and validated the Scientific Creative Thinking Test (SCTT), which assesses three abilities relevant across scientific domains: research question generation, hypothesis generation, and experimental design. Our goal for the pilot study was to test whether SCTT

performance relates to real-world creative scientific behavior, beyond what can be explained by basic science knowledge and general cognitive ability. In a sample of undergraduate students at Penn State University (n = 115; 30% STEM majors), structural equation modeling (SEM) revealed a large effect of science knowledge on scientific creative behavior: β = .512, p = .001. Critically, the model revealed a similarly large effect of scientific creative thinking on scientific creative behavior: β = .552, p = .022. These results provide preliminary support for the validity of the scientific creative thinking test: participants who produced more original research questions, hypotheses, and experimental designs reported higher levels of scientific creative behavior, controlling for basic science knowledge and general cognitive ability.

5. Brain functional connectivity of creativity: Psychophysiological interaction of convergent and divergent thinking

Abhishek Uday Patil, National Chiao Tung University and Vellore Institute of Technology (patil.abhishek32@gmail.com)
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Creativity is defined by many researchers and every researcher has ways to define the same. In general, creativity is defined as a cognitive process which involves generation of useful and novel ideas which can be used to solve problems. Such cognitive processes can be defined by two components: convergent thinking (i.e. collecting various thoughts and ideas to find the best solution for a particular problem) and divergent thinking (i.e. defining multiple solutions to solve a particular problem). Meta-analytic work by many researchers of functional magnetic resonance imaging (fMRI) studies in creative thinking tasks like convergent and divergent thinking have reported frontal and parieto-temporal activations which are associated to the creative cognitive processes. However, the differential and strong interactions of the brain networks have not been reported yet. In this fMRI study, we investigated dynamic interactions of functional brain connectivity during convergent and divergent thinking tasks by applying the psycho-physiological interactions (PPIs). Twenty-five healthy participants performed the Chinese-word remote Associates task (CAT) to characterize the convergent thinking process and the Alternative Uses Tasks (AUT) for divergent thinking process. In whole brain analysis, CAT had activations in the left fronto-parietal region whereas AUT had activations in the bilateral cortical regions of the brain. In the PPI analysis, the hippocampus was connected positively to the superior and inferior frontal gyrus, insula, precuneus, superior parietal lobule and a few temporal region stipulating retrieval and selection of the semantic memory whereas in the AUT, the hippocampus was positively connected to right posterior parietal lobule enabling participants to integrate thoughts related to selecting remotely associated concepts. Our findings provide evidence that functional connectivity of convergent and divergent creativity involve distributed but differential dynamic interactions of brain regions that reflect the specialized network-based processing of diverse creative thinking.

POSTER SESSION

1. Individual differences in the neural localization of semantic networks

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Divergent thought is a hallmark of creativity. This ability to connect disparate concepts is critical for insightful analogies and innovative designs. Given two separate concepts, one way to quantify their divergence is by calculating the semantic distance (SD) between them. The SD between two concepts indicates the similarity of their meaning, as well as the overall pattern of associations with other concepts. SD is operationalized by approaches such as latent semantic analysis (LSA), in which a large corpus of text is analyzed for pairwise lexical co-occurrences, where greater co-occurrence indicates smaller SD between terms. In theory, conceptual networks defined by SD should vary between individuals on the basis of their idiosyncratic thought patterns. One source of variation relates to habits of using language to encode conceptual information. Here, we use LSA and fMRI to identify the specific neural architecture of semantic networks, and to reveal how these networks differ between individuals. Using a representational similarity analysis (RSA) approach, we generate a model of SD networks (via LSA values), and then evaluate multivariate patterns of brain activity for their correlation with this model in response to viewing isolated concepts. Individual differences were assessed on the basis of performance on a task that indicates a bias towards attending to verbal representations of concepts. Results demonstrate that the neural localization of semantic maps differs between participants as a function of how frequently each individual relies on verbal information. These findings reveal that semantic networks organized by SD are localized distinctly between individuals.

2. Effects of idea generation module on students' creative self-efficacy

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Education in the 21st century places the creative component as a fundamental element to ensure that graduates produced are able to fulfill the roles expected of them. The development of self-efficacy in employing creative habits among students is expected to optimize their creative performance. This study was conducted to identify the effects of creative idea generation module on students' creative self-efficacy. The module emphasizes students' awareness of their thinking process as well as the use of metacognitive strategies and thinking tools to generate ideas. This study employed a quasi-experimental pretest-posttest non-equivalent control group design. A total of 74 students were involved in the study, both from science and social science streams. Creative self-efficacy was measured based on 2 main sub-components i.e., creative thinking self-efficacy and creative performance self-efficacy. Tests were conducted before and after the training to observe the effects of the intervention on students' creative self-efficacy. Research findings show that students' creative self-efficacy can be enhanced through training aimed at developing divergent thinking skills thus helping them to have positive belief that ultimately help to enhance their creativity.

3. The developing creative brain: A functional magnetic resonance imaging (fMRI) investigation of musical improvisation in school aged children

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Most experiments on the neural correlates of musical creativity have examined adults, with an emphasis on trained musicians for whom improvisation represents a core behavior. Relatively little is known, however, about the neural substrates that underlie amateur or developing creativity in non-expert children. In this study, children (n = 12, ages 9-11) with limited musical training performed an improvisational task on an fMRI-compatible piano using a paradigm based on the pentatonic scale. To our knowledge, this is the first neuroimaging investigation of musical creativity in children. Preliminary results suggest that musical improvisation in comparison to rote musical performance is associated with significant relative deactivation of neural structures: widespread deactivation was observed in limbic (posterior cingulate cortex, hippocampus) and parietal (angular gyrus, precuneus) areas. Focal deactivation in the primary motor cortex and left posterior dorsolateral prefrontal cortex (DLPFC, BA 8) was seen as well. Small areas of focal activation were identified in the right premotor cortex and left middle frontal gyrus. Although certain regions (cingulate cortex, premotor areas, DLPFC, and frontal cortices) are thought to be important for improvisation in adults, specific outcomes vary according to study. Here, we found a similar network of regions involved during musical improvisation in children, but with less widespread deactivation of prefrontal cortex in comparison to expert musicians, potentially representing the impact of age and/or expertise on the neural substrates that underlie musical creativity.

4. Resting State Functional Connectivity Underlying Musical Creativity

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Compared with other forms of creative behavior, creative musical behavior (such as improvisation) is unique in a number of respects: it is rapid, motorically demanding, and temporally precise; at the same time it is purely "symbolic," with a syntax to its patterning but no evident "semantics"; and yet, despite this lack of semantic meaning, music can be highly emotionally potent. In line with this perspective, the twenty or so functional imaging studies of improvisation conducted over the past decade (reviewed in Bashwiner 2018, Bashwiner and Bacon 2019) have consistently implicated motor-planning, symbol-manipulation, and emotion regions, as well as default-mode regions (these latter associated with creativity generally, not specific to music). Corroborating such findings by way of structural imaging in a large cohort (N=256), our research group recently reported enhanced cortical surface area (or subcortical volume) in structures associated with each of these categories (motor-planning, limbic, and default), with the most statistically significant region (by size) located in left superior frontal cortex (Bashwiner et al. 2016). The present study builds upon and extends this previous work with an examination of the seed-based resting state functional connectivity of this left superior frontal region, which was found to connect with a contralateral region in right superior frontal cortex, regions in both left and right premotor cortex, and a region believed to be integral to studies of creativity generally and musical creativity specifically—the left inferior frontal gyrus (see Beaty 2015)—but not implicated in our prior investigation into surface area.

5. Verbal insight revisited: Evidence for preceding unconscious processing in solutions with AHA! experience

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Solutions with AHA! experience have been assumed to be the consequence of restructuring of a problem which usually takes place shortly before the solution. However, evidence from priming studies suggests that solutions with AHA! are not spontaneously generated during solution but already relate to preceding unconscious processing. In this study, we investigate this hypothesis using a modified compound remote associates paradigm incorporating semantic priming. We investigate whether a) differential brain activity of problems that are later solved with or without AHA! can already be observed within the first seconds after problem presentation and b) whether this early difference in activity is a function of semantic priming. In addition, we compare the first three seconds of each trial to the end (solution) to get a more complete picture of the solution process. We observe more activity in bilateral anterior insulae within the first three seconds after trial start in problems that are later solved with than without AHA! while no influence of semantic priming was observed. In contrast, there is more brain activity in bilateral anterior insulae during solutions that are solved without than with AHA!. This timing (after trial start / during solution) x solution style (with / without AHA!) interaction is significant. This suggests that solutions with AHA! relate to preceding unconscious processing which are independent of the priming influence. We argue that solutions with and without AHA! differ according to how early solution-relevant processing takes place. We discuss the role of the anterior insula in the context of attentional processes necessary for problem solving.

6. Getting rid of those red herrings – Suppression of intruding pre-potent answers during the creative process

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Whether creative cognition tasks involve finding remote associates, divergent alternative uses, conceptually distant analogies, or creative solutions to problems, the critical step of suppressing incorrect prepotent responses (i.e., close associates, common alternatives, local analogies, or uncreative solutions) is involved. Suppression of unwanted memories has been studied in depth (e.g., Anderson et al., 2004; Anderson & Green, 2001; Anderson & Hanslmayr, 2014; Banich & Depue, 2015; Benoit & Anderson, 2012), and much is known about the neural correlates of this inhibitory process, which involves the engagement of DLPFC, which downregulates hippocampal activity during intrusions in the think-no-think paradigm (Levy & Anderson, 2012). Our creative cognition studies have involved negative priming with red herring stimuli (misleading clues), producing fixation effects in solving word fragments and Remote Associates Test problems (e.g., Beda & Smith, 2018). In the present study we asked whether the suppression of prepotent red herrings in word fragment completion involves the same neural processes as those reported by Levy and Anderson (2012). We used positively and negatively primed word fragments to produce two outcomes to compare in an fMRI scanner: 1. The solution is the prepotent answer that automatically comes to mind (positively primed), and, 2. The prepotent red herring intrudes and must be overcome to solve the problem (negatively primed). We present behavioral results and corresponding fMRI imaging data for this study.

7. Differentiating effects of improvisational and non-improvisational musical training on functional connectivity

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Jazz improvisation offers a model for creative cognition, as it involves the real-time creation of a novel, information-rich product. Previous research has shown that when jazz musicians improvise, they recruit Default Mode (DMN) regions including the medial prefrontal cortex and Executive Control (ECN) areas including the lateral prefrontal cortex. Here, we ask whether these task-fMRI findings might arise from intrinsic differences in resting state functional connectivity. We performed a combination of seed-based analysis and Independent component analysis (ICA) comparing groups of improvisationally trained musicians, classically trained musicians, and the minimally musically trained. We also compared the relative contributions of improvisational and non-improvisational musical training to connectivity patterns. Seed-based analysis consistently indicated higher connectivity in DMN and ECN regions in musically trained individuals as compared to MMT controls. This included higher connectivity (cluster threshold $p<0.05$, p-FDR corrected) in the classical group between the mPFC and the frontal orbital cortex, precuneal cortex, and pars triangularis of the left inferior frontal gyrus, as well as greater connections in the improvisational group between the left lateral prefrontal cortex and bilateral lingual gyrus, cuneal cortex, and intracalcarine cortex. Meanwhile, ICA revealed differential contributions of improvisational and non-improvisational musical training to intrinsic DMN connectivity.

8. How does social evaluation influences creative idea generation in children, adolescents and adults?

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Creativity defined as the ability to think of something truly new (i.e., original, unexpected), and appropriate (i.e., useful, adaptive concerning task constraints) is a fundamental process that influences many areas of our daily life and is important for instance for education and scientific reasoning. Considerable efforts have been devoted at identifying the influence of social contexts (e.g., effect of the presence of peers or adults) in the domains of reasoning and decision making, but surprisingly there are to date few study that have examined whether social contexts may facilitate (or constrain) creative ideation and whether the effect of social contexts on creativity change with age. This study aimed at examining how social pressure (i.e. an adult evaluator) affect the ability to generate creative ideas to a problem in children, adolescents and adults. Participants were asked to perform a creative task that involves designing a method to drop a hen's egg from a height of 10 meters (32 feet) to ensure that it does not break. Participants completed the creative task under either a social pressure condition, i.e., in the presence of an adult evaluator, or in the control condition, i.e., task performed alone. Results showed that the presence of adults decreases fluency and originality in children whereas social scrutiny have a stimulation effect among adolescents. The present findings expand our understanding of the development of the influence of the social context on creative ideation.

9. Task-general and task-specific brain activation in novel ideas generation

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Recently empirical studies and review suggest novel ideas stem from domain-general creative cognition that relies on a consistent pattern of brain activity and connectivity, however it remains unclear whether the special creative processes that depend on task context can be differentiated from neural activity. Here, we supposed that common neural correlates may reflect a general creative thought process, whereas differential neural activations may reflect a special creative process that relied on task requirement. To this end, participants were asked to generate one most novel association [novel using (NU) and novel metaphor (NM)] or general association as control conditions [general using (GU) and general metaphor (GM)] for objects during fMRI. We observed the novel association recruited activation in bilateral IFG, dorsomedial prefrontal cortex (dmPFC), left DLPFC and left IPL compared with control conditions. Separately, NM activated the left IPL and dmPFC compared with GM, whereas NU activated the right IFG, dmPFC, left DLPFC and left IPL compared with GU. Crucially, the common engagement regions of NM and NU includes the left angular gyrus (ANG) and the dmPFC, recruited regions in novel conditions. Under novel condition, NM activated the left-lateralized regions involving in semantic memory process, such as temporal pole, MTG, ANG and rostral IFG compared with NU, whereas NM activated a set of regions involving in episodic memory process, such as PCC, SPL, anterior IPL, DLPFC and parahippocampal gyrus. These results indicate that novel ideas generation is not supported by domain-general creative cognition, but special cognition processes related to creative thought.

10. When do Aha! moments occur during science learning?

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Creativity, especially scientific creativity, often involves expanding or transforming the boundaries of one's current understanding to make new connections. In this sense, creativity and learning may reflect similar cognitive processes in certain circumstances. Notably, the Aha! experience, which has mainly been studied in the context of creative problem-solving, is also thought to be a phenomenon associated with learning. However, little empirical work has investigated when and for whom Aha! moments may occur in naturalistic learning contexts. Across two experiments, participants were asked to self-report Aha! moments when learning about principles in Biology, such as symbiosis or mimicry, from sets of three divergent examples. In the problem-¬oriented condition, participants saw the three examples, and were asked to generate their common principle before being told the biological term for the shared principle. In the direct instruction condition, participants were told the correct biological term for the shared principle directly before being shown the three examples. Participants were significantly more likely to report Aha! moments in the problem-oriented condition. Additionally, the number of Aha! experiences was positively correlated with participants' motivation to learn Biology and a more general measure of motivation to seek out knowledge and new experiences in the problem-oriented condition, but not the direct instruction condition. These results suggest that problem-oriented instructional activities may prompt Aha! experiences, and that the likelihood of Aha! experiences may vary with individual differences in curiosity and interest.

11. Innovation in nonverbal neuropsychology: Aphasia and creative arts therapies

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Aphasia describes the broad experience of disrupted language production or comprehension acquired after structural changes in the brain. These changes, usually associated with stroke, tumor or cortical degeneration, are often associated with co-morbid symptoms, such as emotional dysregulation, partial paralysis, and difficult social, occupational, and community relationships. Although common approaches to research and rehabilitation with persons managing aphasia highlight conversation and semantic retrieval, the diversity of symptoms and responses are well-suited for a comprehensive neuropsychological intervention. This research proposal considers the question: Does participating in a creative arts psychotherapy program influence cognitive and psychological rehabilitation outcomes for a person managing aphasia? Using quantitative and qualitative methods guided by an integrative, relational neuropsychology, this innovative research explores the complexity of experiences accompanying language loss and neurorehabilitation through two single-subject case studies where participants engage in a 6-8 session creative arts psychotherapy program. Discussion includes the feasibility and utility of an integrative, interdisciplinary approach to aphasia therapy and contributes to research in clinical neuropsychology, relational theory, and creative arts therapy.

12. Creativity anxiety in computer science: Does creative anxiety predict performance in computer science classes?

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Creative thinking and creative innovation is at a high premium across many fields in science and industry (World Economic Forum, 2016). Yet it is common to see individuals hesitate when asked to come up with creative solutions to problems—even within their own areas of expertise. Educationally relevant anxieties, like math anxiety, have been shown to impact performance in education across domains. Recently, as measured through the Creative Anxiety Scale (CAS), creativity anxiety has been demonstrated to exist across diverse content domains and even predicted individual differences in creative achievement (Daker, Cortes, Lyons, and Green, under review). When one thinks of creative domains, computer science is not typically the first to come to mind. Yet creativity is essential for developing effective and efficient codes—especially at the highest levels of computer science. We were interested in determining how creative anxiety affects computer science achievement as a field that is not typically thought of as creative but in fact requires substantial creativity. At the beginning of the fall semester, we administered the CAS (along with a myriad of other questionnaires and tasks) to students in computer science classes at Georgetown University. We assessed how creativity anxiety and measures of creative ability predicts success in computer science courses and discuss possible implications for computer science education and STEM education more broadly. This study highlights the importance of creativity in STEM fields and emphasizes the gravity of creativity anxiety in academic performance.

13. Cognitive correlates of performance on the remote associates test: A meta-analysis

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The Remote Associates Test (RAT) was developed by as a measure of creative thinking, in which participants are presented with three seemingly unrelated cue words and are asked to find a fourth target word that is directly related separately to all three. Over the years, two versions of this task have been applied: (a) the classic RAT, in which any type of linguistic relationship, such as semantic, synonymic, or functional relations between the cue words and the target word is allowed, and (b) compound RAT (CRAT), in which the target word forms a compound with all of the cue words. The latter homogenization of the item content has been introduced to reduce task-complexity which might introduce potential confounding of the thought process. Recent exploratory findings indicated that these two RAT versions are only weakly correlated (around r = .22). Here, we present a meta-analysis on RAT and CRAT, in order to assess how well these tasks relate to various cognitive processes, such as convergent thinking, verbal ability, and insight problem solving. We found that both tasks exhibit different correlational patterns across various cognitive domains: While the RAT correlated more strongly with insight problem solving and verbal fluency tasks, RAT and CRAT correlated equally high with different facets of intelligence. The latter findings are in line with the idea that regardless of item-type the RAT presents a measure of convergent thought, whereas classic RAT items were found to be better indicators of insight problem solving ability.

14. Resting state functional connectivity predicts individual differences in creativity anxiety

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Recent research has demonstrated that anxiety about thinking creatively (i.e., creativity anxiety) is associated with lower levels of creative self-efficacy, creative self-overlap, and creative achievement and that it manifests within diverse content domains from STEM to the arts. Creativity anxiety thus has potentially far-reaching effects, particularly with the emergence of the innovation economy, so characterizing this trait at the neural level is a research priority for creativity research. The present research employed connectome-based predictive modelling (CPM) to assess the relationship between resting state functional connectivity and creativity anxiety. Controlling for relevant measures of creativity and general anxiety, we found that differences in connectivity predicted unique differences in creativity anxiety. These findings are consistent with work showing that resting state functional connectivity predicts individual differences in creative ability and provide initial insight into the neural basis of creativity anxiety.

15. From deep learning to deep reflection: Machine learning Investigations of the neuroscience of creativity

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Because computational models enable us to manipulate variables and observe the effects in a more controlled manner than in real life, they have proven useful for investigating questions concerning

how the creative process is affected by particular parameters. This lays the groundwork for determining what brain areas or circuits plays the role of those parameters. A deep Learning (DL) neural network is a brain inspired machine learning technique, i.e., it extracts and organize information from data for non-linear transformations. It uses multi-layer processing, i.e., it transforms input at different levels, from a high-level, 'gestalt' level to low-level, pixel-based level. A DL network is convolutional: each node (neuron) responds to restricted region of, e.g., a visual field. It works by identifying points of resonance between images based on similarity in abstract feature space, and combining them. Using an original synthesis of deep learning based convolutional neural networks and cognitive based computational art rendering systems, we will discuss implications for human creativity and how it is realized in the brain. We will discuss our in-progress novel DL architecture. Its rationale is that to go from 'deep' learning in the sense of 'multilayer' to 'deep' learning in the sense of 'reflected upon from many perspectives' like a creative person does, the processing has to be a sphere, with the least abstract, sensory input coming in from the outermost onion skin layer and increasingly more 'abstract' processing at increasingly 'deeper' layers of the sphere. With this architecture you could model how cross-domain creativity (as when a book inspires a song) is possible.

16. The neurocognitive theory of dreaming: The where, when, how, what, and why of Dreams

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The neurocognitive theory of dreams has neural, cognitive, and behavioral levels (dream reports). Dreaming is supported by an augmented portion of the default network, occurs when six specific conditions are met, and develops only slowly in children, who do not report adultlike dreams until ages 11-13. Based on embodied simulation, most dreams dramatize waking personal concerns focused on family, friends, and avocations. "Symbolism" is rare. Dreams are consistent in their main contents over years and decades. There is no evidence for any adaptive function, and much evidence that raises questions about all extant adaptive theories, including social rehearsal theories. If the neuroimaging and lesion evidence are right in pointing to an enhanced portion of the default network as the neural substrate that supports dreaming, it is likely that dreaming is not creative in the waking sense of the term, even though it can be characterized as an intensified form of mind-wandering and as imagination roaming freely. As creativity research suggests, creativity happens in relaxed waking states when the default network and portions of the frontoparietal control network are interacting. Sometimes waking reflections on recalled dreams can contribute to new ideas, especially after a gradual awakening, but dreaming is an accidental by-product of natural selection for the default network. More generally, many cultures have invented uses for dreams in religious and healing ceremonies, including psychotherapy. Psychological meaning, historically invented uses, and adaptation have to be distinguished to develop an evidence-based theory of dreams that is not a form of physiological reductionism.

17. Creativity in the lenses of person-environment fit perspective

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According to the dynamic componential model of creativity and innovation, the systems model of creativity, and the person–environment fit theory, a harmonious relationship between the person and environment, named person–environment fit for creativity, promotes innovation and progress in the creative process and leads to superior creative performance. A series of studies have been conducted to explore whether individual creativity can be effectively evaluated in the lenses of person–environment fit for creativity, and to clarify the internal mechanism of cultivating creativity from personal and environmental levels. First, a sample of 2,475 community participants has been adopted for convergent, discriminant, measurement invariance, and incremental validities of the person–

environment fit scale for creativity (PEFSC). The results consolidated the application of person–environment fit theoretical framework in creativity research. Then, correlation, regression analysis, analysis of variance, and post-hoc tests results expanded the psychometric properties and classification role of PEFSC in a sample of 298 employees. Person–environment fit theoretical framework was proved can play a significant role in classifying individual creativity in the field of work. Finally, a mediation model, in which the personal force (calling) mediates the relationship between the environmental force (organization support) and creativity, was investigated in a sample of 410 employees using structural equation modeling. All these findings expanded the theory and cultivation mode of creativity, and offered important guidelines for practitioners who are focused on enhancing creativity.

18. Creative reappraisal in analogical reasoning: Exploring how creative strategies in emotion regulation influence neural and behavioral outcomes in analogical reasoning

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Emotion regulation, or the ability to manage one's own emotional response to a situation, can be crucial to social, emotional and academic success. One such strategy is Cognitive Reappraisal (CR), which involves thinking about the experience from a different perspective. Although the use of any CR strategy may be beneficial to those in emotion-inducing situations, creative strategies may be more effective in regulating the emotional response. For example, strategies that use a creative perspective to flexibly adapt to an anxiety-inducing scenario may be more effective in allowing the person to regulate their emotions than strategies that use unimaginative perspectives. In this fMRI study, participants with varying levels of anxiety completed an analogical reasoning task, using an instructed CR strategy, as well as using their own spontaneous strategy (control). We examined the creativity of self-reported strategies used by participants within the task, as well as the accuracy levels of the participant's responses when CR was applied. We predicted that greater creativity of the self-reported CR strategies would be associated with improvement in analogical thinking, especially for participants who experience more anxiety, and for whom reappraisal would be advantageous. We predicted an increase in the accuracy in the analogical reasoning task, as well as improved neural activity in brain regions associated with CR and analogical reasoning, especially for anxious participants. This study highlights the importance of creative thought on reasoning ability, illustrating how creativity applied to one's own thoughts and feelings has broader impacts for reasoning and learning.

19. Distractibility and creativity: Two sides of the same coin?

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Recent research (White & Shah, 2011) has demonstrated a positive relation between ADHD and creative achievement in adults. Still, the cognitive processes underlying this association remain to be resolved. One possible explanation is that default mode network intrusions on task-positive activity may be responsible for both distractions and creative breakthroughs. It follows that creativity should be specifically related to the inattention dimension of ADHD (rather than hyperactivity or impulsivity). Based on this model, it is logical to predict: (a) inattention and creativity are positively correlated; (b) any apparent effect of hyperactivity on creativity is mediated by inattention; and (c) the relation between inattention and creativity does not vary by ADHD diagnostic status (given the underlying

dimensionality of each construct). A preliminary behavioral investigation of 71 adults (13 with diagnosed ADHD, 49 without ADHD, 8 with self-diagnosed ADHD who were treated as a separate group, and 1 who did not report a diagnostic status) supported all three predictions. Specifically, among two candidate measures each for distractibility and creativity, ASRS inattention (Kessler et al., 2005) and Creative Achievement Questionnaire (Carson, Peterson & Higgins, 2005) scores were selected; they were found to be positively associated, $R2 = 0.28$, $p < .001$. Since the CAQ is an achievement measure, these results suggest that it may be possible for individuals with ADHD to capitalize on the cognitive profile the condition presents. Further, they suggest an approach to a cognitive neuroscience investigation of creativity in ADHD. We plan an expanded study to include longitudinal data.

20. The effects of methylphenidate on verbal creativity, verbal fluency, and problem-solving abilities in individuals with attention deficit hyperactivity disorder

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Creativity, or the ability to generate ideas that are both novel and useful, is associated with a decreased signal-to-noise ratio in the brain that results in defocused attention. Reductions in attention are the hallmark of attention deficit hyperactivity disorder (ADHD), which may facilitate divergent thinking that is essential to the creative process. One of the most common treatments for ADHD is methylphenidate (MPH), a psychostimulant that targets the dopamine and noradrenergic systems, which increases attention in ADHD. However, the effects of MPH on convergent and divergent thinking in ADHD are unclear. Therefore, the present study examined effects of MPH on convergent and divergent thinking in individuals with ADHD. Participants (N=9, range=18-40, mean age=26.3, SD=7.01, 3 females, all Caucasian) with a diagnosis of ADHD and who are currently taking MPH for their ADHD were recruited for this ongoing study. Participants attended one session while on their MPH and another where they withheld their MPH. During both sessions, participants completed problem-solving tasks (anagrams, compound remote associates) letter & category fluency assessments, and the Verbal Torrance Test for Creative Thinking (V-TTCT). Initial analyses indicate significant reductions in solution latency time for the anagrams task ($p = 0.008$), and significant increases in originality on the V-TTCT ($p = 0.049$) for the MPH session. Furthermore, trends toward significance were revealed for flexibility and the total battery score on the V-TTCT. Thus, initial results from this ongoing study suggest that MPH may increase some domains of verbal creativity and problem-solving abilities in those with ADHD.

21. Photographic images can impair creativity on the alternate uses task while inflating confidence

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When prompted to generate creative ideas, what expectations do people have about their performance? Little work has explored metacognition in relation to creativity. When given a creative thinking prompt (generating unusual uses for a spoon), an initial set of information easily comes to mind. However, the most familiar or accessible information is often the least useful when aiming for originality. Metacognitive frameworks indicate that people base predictions of performance on the subjective ease with which related information comes to mind. The present experiments tested whether the presence of object photographs in the alternate uses task (AUT) would enhance this

subjective sense of ease and inflate predictions of creativity. Prior work indicates that images can skew predictions in learning, memory, and decision making, but no work has devoted attention to the metacognitive consequences of images in creative thinking. In Experiment 1, participants predicted the ease of generating creative ideas for 60 objects, some of which were accompanied by object photos. Participants provided higher creativity ratings and were faster to make ratings in the image than no-image condition. In Experiment 2, participants actually generated uses for the objects, half of which were accompanied by object photos. Resulting measures of creativity were lower in the image condition than no-image condition, but participants' retrospective judgments indicated the opposite. These results provide a novel extension of metacognitive work showing that images inflate predictions of performance. The results also fit with prior research showing that images make objects' typical functions more salient.

22. The Relations among playfulness, social information processing (S.I.P), and social adjustment in preschool children

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Playfulness Represents a generally positive approach to life including the urge to open up and explore in an optimistic manner and believe in one's ability to act independently without the dictates of society; Play is the external expression of playfulness (Burghardt, 2005). A central and vital component of playfulness is the ability to "frame". Concerning this component, play is a frame of reference providing the opportunity to players to give cues as to how they want to be treated. Therefore, to be a good player, the individual must be able to provide and interpret social cues (Skard & Bundy, 2008). A central area of research dealing with the ability to read others' cues and their social intentions, is with the one focuses on children's S.I.P abilities. Therefore, this study focuses on the relation between playfulness, S.I.P and preschool children's social adjustment in the school environment. The sample included 69 preschool children (aged 45-77 months). Children were observed and coded for indoor- and outdoor playfulness levels, they participated in an interview examining their S.I.P (The S.I.P.I–P; Ziv & Sorongon, 2011), teachers and parents completed a set of questionnaires tapping children's social adjustment and other background information. Findings revealed positive associations between outdoor playfulness and S.I.P such that children with high levels of playfulness outdoor have shown more competent S.I.P patterns. No such associations were found in relation to indoor playfulness. Finally, more competent S.I.P patterns have predicted children's higher social skills and better adjustment as reported by their teachers.

23. Perception in creatives and schizotypes

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What is the nature of the relationship between creativity and schizotypy? Perceptual aberrations are a fundamental component of schizophrenia-spectrum conditions; however, there are few studies that have investigated the relationship between perceptual encoding and creativity. This study (N=97) aimed to determine whether perceptual aberrations are shared between individuals scoring highly in creativity and schizotypy by employing two perceptual tasks—an active auditory oddball task and a free viewing eye tracking paradigm. Three sets of images were used in the free-viewing task; aesthetic images, art images (abstract, surrealist, and expressionist), and neutral images of indoor and outdoor scenes. Creativity was measured using the figural portion of the Torrance Tests of Creativity Thinking (TTCT) and two widely used self-report scales. Creativity on the drawing task correlated with

differences in reaction time between standard and target tones on the oddball task (r=.305**) and was also correlated to two standard eye movement metrics: number of fixations and duration of fixations (r=.252* and r=.269*, respectively). This relationship was dependent on the type of image set (art, aesthetic, or neutral). Schizotypy, as measured by the Magical Ideation Scale, was negatively correlated to duration of fixations, but, again, this relationship was dependent on the type of image set. Our findings offer initial support to the hypothesis that perceptual differences may exist in creative and schizotypal individuals. Implications and limitations of these findings are also discussed.

24. Structural changes induced by creativity training

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Creativity can be described as successful novel combination of concepts, stemming from interplay between semantic knowledge, fluid reasoning, and decision making. Neuroimaging studies on creativity have found involvement of either default mode or frontoparietal networks, though general creativity training — typically practice with an alternate uses task — resulted in different changes across studies. In the present MRI study, we focused on a specific domain and examined structural changes associated with intensive culinary creativity training in chefs. Twenty-nine young adult chefs interning at a 2-Michelin-star restaurant participated in the current study. The experimental group underwent an intensive 3-month period of creating gastronomically innovative menus, while the control group implemented the new recipes. Before and after, all participants underwent structural MRI scanning and performed tests of domain-general creativity outside the scanner. Results revealed longitudinal changes in the experimental group, including cortical thickness increases in left IFG pars triangularis (semantic processing), right MFG (fluid reasoning) and a decrease in ACC (decision-making), along with increased connectivity between temporal and parietal regions and frontal areas via long-range fibre tracts left cingulum and right SLF. Further, improvements in domain-general creativity were strongly associated with increased structural connectivity and with thinning of the ACC, but not with increased cortical thickness in semantic regions, which is more likely to be domain-specific. These results are consistent with previous findings and provide initial support to our creativity model.

25. Functional contributions to general and specific creative problem solving

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Recent research on divergent thinking – a commonly used measure of creativity – suggests it comprises two main types of cognitive processes: associative thinking, an uncontrolled and spontaneous process; and cognitive control, involving executive functions such as cognitive flexibility and fluency. Previous neuroimaging research using divergent thinking tasks has shown that the caudal and rostrolateral prefrontal cortex (rlPFC), parietotemporal regions and the default mode network are central nodes associated with this measure of creativity. In this functional magnetic resonance imaging (fMRI) study we investigated the functional dynamics underlying creative processes associated with solving novel general and specific (e.g., culinary) problems in a sample of 24 healthy adult chefs and matched controls. Based on prior evidence, we hypothesized that semantic knowledge (general and specific) and fluid reasoning would influence creativity associated with a professional

domain, and therefore also collected data using fMRI localizers (i.e., using semantic knowledge and fluid reasoning tasks). In the main problem-solving fMRI task, results revealed a role for frontoparietal areas in addition to the inferior frontal gyrus, lateral temporal cortex and rlPFC areas also identified using the independent fMRI localizers. Functional activation and connectivity between these areas was stronger for domain-specific (kitchen related) than for domain-general problem solving in chefs compared to control participants. Our findings suggest that specific semantic knowledge and fluid reasoning are critical aspects for creative problem solving, supporting our model of creativity.

26. How creativity training modulates electrophysiological responses to novel metaphors

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Creativity training has been shown to improve performance in divergent thinking tasks (cf., Fink et al., 2006). Using a pretest-posttest design (with intermediate training), we investigated whether creativity training modulates electrophysiological (EEG) responses to novel metaphor comprehension. At pretest and posttest, participants read literal, nonsense, and novel metaphorical sentences and made judgments about their meaning while undergoing EEG recording (following Rutter et al., 2012). Participants were randomly assigned to one of two creativity training sessions: (1) TRIZ training, a systematic creativity method that guides the concept generation process using solution patterns derived from problems similar to the ones at hand (Ogot and Okudan, 2007), and (2) sketching training, emphasizing sketching techniques during ideation. Data collection is half-way (and will be completed well before the conference) and first analyses from 10 participants per training group show a gradual modulation of the N400 component, with most negative N400 amplitudes in response to nonsense sentences, followed by metaphorical and literal sentences. Critically, training differentially modulated responses to literal and metaphorical sentences in the posttest, with reduced N400 to literal sentences following the TRIZ training. The P600 associated with metaphorical sentences was modulated in the TRIZ training only, suggestive of more effective semantic reanalysis of novel metaphors following TRIZ vs. sketching training. Overall, our study provides first evidence demonstrating that TRIZ creativity training may effectively modulate EEG responses to literal and novel metaphorical sentences.

27. An Investigation of EEG parameters in negative creativity

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In general, past neuroscientific work in creativity has studied parameters associated with positive creativity. Negative creativity implies using creative means to reach a socially negative goal, without the deliberate intent to harm others and the behavioural correlates of negative creativity include dark personality traits like deception. As creativity has been related to EEG parameters of alpha synchronization (ERS), and deception has been associated with alpha desynchronization (ERD), we assess the patterns of alpha activity in negative creativity. Positive-creative, negative-creative, and low-creative participants (N = 36) were identified and recruited on the basis of their performance in behavioural studies. EEG was recorded during creative performance on six real-world divergent thinking situations. EEG results showed a combination of alpha ERS and ERD in frontal areas across both hemispheres for the entire sample. This was interpreted as being due to differing task demands in real-world divergent thinking, as opposed to earlier research using the Alternate Uses Task.

Although statistically significant differences based on the three conditions were not obtained, trends indicated neural markers (left frontal alpha ERD) associated with deception in negative creativity, but not in positive or low creativity. To the best of our knowledge, this experiment was one of the first to adapt a real-world divergent thinking task in an EEG setting. It was also the first to examine neural correlates of positive and negative idea generation. The current findings facilitate scoping new pathways of negative creativity research with novel paradigms.

28. Community structure of the creative brain at rest

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Recent studies have provided insight into the neural mechanisms underlying inter-individual differences in creative thinking, focusing on the interactions between distributed brain systems. However, it remains unclear how creativity is associated with other brain network features, e.g. community and hub organization. We apply a data-driven approach to examine multiple community and hubs structure in resting-state functional imaging data of a large sample of participants, and how they relate to individual differences in creative thinking. First, we computed for every participant the co-assignment probability of brain regions to the same community. We found that greater capacity for creative thinking was associated with an increase/decrease in the co-assignment of medial-temporal/subcortical regions to the same community. Thus, findings creative capacity may be reflected in inter-individual differences in the system-level organization of brain networks. These findings were replicated when we divided the sample into low and high creative groups based on their creative thinking scores. Finally, we used participant-specific communities to identify network hubs—nodes whose connections form bridges across the boundaries of different communities—quantified based on their participation coefficient. We found that increased hubness of DMN/subcortical nodes were positively/negatively correlated with creative ability. Thus, creative capacity may reflect inter-individual differences in the manner in which brain communities interact with the DMN and subcortical structures. Collectively, these results posit a novel neuro-anatomical substrate underpinning creative thinking.

29. Visualizing reading and writing: Network approach for revealing the relationship between what is read and what is written

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Eye tracking devices have generated large amounts of research on reading processes but none on relationships between reading and writing. Our interest lies in the relationship between what readers pay attention to when reading and how their visual behavior relates to their text production, which promises to reveal new insights about the psychological, visual, social, and educational dimensions of literate practice. Thus, this project aims to develop an innovative analytic system to represent and analyze the correspondence (or lack thereof) between the information read and the information written. This system will combine the text mental representation tool, GIKS (Graphical Interface of Knowledge Structure), together with eye movement measures. The fully developed software will be able to automatically (1) compare cognitive network graphs derived from a lesson text that students read (reading material), eye-movement of where students looked (reading process), and text production of what students wrote (reading comprehension), and (2) find structural “patterns” of the visual data that reveal previously inaccessible dimensions of reading and writing, which has never been examined before. It is believed that this system can help answer questions about behaviors as well as cognitive constructs engaged in both reading and related writing.

30. Personality, psychopathology, and neurocognitive profiles of everyday and exceptional creativity

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We examined the association of neuropsychology with exceptional ('Big-C') and everyday creativity. We recruited 30+ people each in three groups: Big-C Visual Artists (VIS), Big-C Scientists (SCI) and a Smart Comparison Group (SCG) matched on age, sex, ethnicity, and IQ estimates. We also studied a separate comparison group (CG; N=300) not selected for Big-C creativity or IQ. All participants completed assessments of (1) neurocognition; (2) Big-5 personality; (3) psychopathology; (4) creative cognition; and (5) creative achievement. Comparisons of Big-C and other groups revealed that CG gave more common word associations than VIS, SCI, and SCG. CG scored lower than SCI on convergent thinking and design fluency indices. CG scored lower than VIS and higher than SCI on a divergent thinking measure. VIS scored higher than SCI on measures of verbal, but not figural, creativity. SCG scored higher than VIS on a working memory (WM) index. There were no group differences on list learning, intrusions, or repetitions. Within the CG group, creative achievement correlated (r =.13-.41) with measures of convergent/divergent thinking, openness, (dis)-agreeableness, empathy, schizotypal traits, verbal fluency, WM, and reading. Openness, WM, and idiosyncratic word associations accounted for 26% of the variance in CG creative achievement. Overall, these results reveal relatively subtle correlates of everyday creativity, and they raise questions about the sensitivity of lab tests for Big-C thinking. Our control for IQ between VIS, SCI, and SCG may explain the lack of group differences on certain cognitive tests. Future work may expand the scope of lab tests of "outlying" Big-C creativity.

31. Increased creative thinking in narcolepsy

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Rapid eye movement (REM) sleep and dreams have been linked to creativity. However, most studies relied on simple associative tasks and did not assess creativity per se, a process that is unlikely to be achieved in a single nap. To tackle this methodological hurdle, we called upon experts of REM sleep and dreams: subjects with narcolepsy, who present excessive daytime sleepiness, symptoms of dissociated wakefulness and REM sleep (e.g., lucid dreams), and a high dream recall frequency. Given their life-long privileged access to REM sleep and dreams, we hypothesised that subjects with narcolepsy have developed high creative abilities. To test this assumption, we evaluated, with two questionnaires, the creative achievements and the creative profiles of 185 subjects with narcolepsy and of 126 healthy matched-controls. Then, we objectively tested the creative performance of 30 subjects with narcolepsy and of 30 matched-controls. This test assesses the two key modes of creative thinking, namely divergent-exploratory thinking (i.e., finding the greatest number of solutions based on a given stimulus) and convergent-integrative thinking (i.e., integrating several elements into a coherent and original synthesis) on two domains of expression (graphic and verbal). Subjects with narcolepsy obtained higher scores than controls on the two questionnaires of creativity and on the objective test of creative performance in all the dimensions tested. Most symptoms of narcolepsy (but not treatments) were also associated with higher scores of creativity. These results highlight a higher creative potential in subjects with narcolepsy and further support a role of REM sleep in creativity.

32. Creativity in the lenses of person-environment fit perspective

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How to measure and cultivate creativity has become the focus in the cognitive and brain-based study of creativity. According to the dynamic componential model of creativity and innovation, the systems model of creativity, and the person–environment fit theory, a harmonious relationship between the person and environment, named person–environment fit for creativity, promotes innovation and progress in the creative process and leads to superior creative performance. A series of studies have been conducted to explore whether individual creativity can be effectively evaluated in the lenses of person–environment fit for creativity, and to clarify the internal mechanism of cultivating creativity from personal and environmental levels. First, a sample of 2,475 community participants has been adopted for convergent, discriminant, measurement invariance, and incremental validities of the person–environment fit scale for creativity (PEFSC). The results consolidated the application of person–environment fit theoretical framework in creativity research. Then, correlation, regression analysis, analysis of variance, and post-hoc tests results expanded the psychometric properties and classification role of PEFSC in a sample of 298 employees. Person–environment fit theoretical framework was proved can play a significant role in classifying individual creativity in the field of work. Finally, a mediation model, in which the personal force (calling) mediates the relationship between the environmental force (organization support) and creativity, was investigated in a sample of 410 employees using structural equation modeling.

33. Seeing outside the box: Salient concepts constrain visual idea production

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Generating creative ideas involves flexibly combining concepts stored in memory. Although memory provides a foundation for creative thought, it can also constrain idea production by acting as a source of interference, particularly when salient and unoriginal concepts are activated. Previous research has explored constraining effects of fixation in convergent creative problem solving, but less is known about how salient concepts impact divergent idea production in the visual domain. In the present research, we developed a novel paradigm to investigate the impact of priming salient concepts in the context of a label generation task. In an initial pilot study, participants were shown ambiguous images and asked to provide labels for them; from these labels, two subsets were selected based on their relative frequency in the sample (i.e., high- and low-frequency labels). In two experiments, we tested whether priming participants with these high- and low-frequency labels impacted subsequent idea production. Participants were primed by rating the similarity of the label-image pairs; the labels were then removed, and participants were asked to generate novel labels for the images. Across both experiments, we found that high-frequency labels had a constraining effect on idea production: participants took significantly longer to produce their first response and produced fewer total responses in the high-frequency compared to the low-frequency condition. The findings indicate that salient concepts constrain idea production in the visual domain—even when ambiguous shapes are used as stimuli. Implications for executive theories of creative cognition will be explored.

34. Investigating the mechanisms of divergent thinking: The relationship between environmental context and body posture

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Divergent thinking tasks are perhaps the most widely used method to study creativity in the lab. However, there has been little attempt to elucidate the nature of the cognitive mechanisms that might support it. Recent studies have indicated the importance of the body and environment in generating creative output from an embodied cognition perspective: Participants may simulate potential action related uses when considering alternative uses for an item. In the present study, we investigated whether body posture and environmental context influence creative output in a divergent thinking task. Participants adopted either a flexion (lifting up) or extension (pushing away) body postures and were shown images of kitchen utensils or work tools. Each image was primed with an image of either a congruent environment (i.e. a kitchen counter primed a fork) or an incongruent environment (i.e. a workbench primed a fork). Results show (N = 32) that a) body posture, specifically extension, results in faster generation of responses (reaction time onsets), especially when the object is primed by a congruent environment, and b) that extension increases sensitivity to environmental primes, increasing fluency of responses overall. Our results shed light on the cognitive mechanisms of generating creative object uses, suggesting that postures might result in an action simulation that makes the environment more or less salient in creative contexts. These results point to the role that environmental context and bodily posture have in generating creative output.

35. Creative collaboration between team-members is represented in their shared brain activity: A NIRS based hyperscanning study

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Team collaboration is an essential component of teams looking to achieve innovative ideas. This study investigated the brain-to-brain synchrony profile that occurs during creative team collaboration. In order to achieve a naturalistic study design that allowed for social face-to-face interaction and free movements, we used functional near-infrared spectroscopy (fNIRS) to measure inter-brain synchrony between two people engaged in a real-life collaborative design project geared towards innovation. In addition to neural signatures, we assessed behavioral interaction between participants while they were engaged in creative collaboration. NIRS data demonstrated significant inter-brain synchronization between a region centered on the left supramarginal gyrus and a region centered on the left dorsolateral prefrontal cortex and posterior middle temporal gyrus. In addition, these variations in inter-brain synchrony were related to collaboration and the degree of leadership exhibited by one of the team members. These results indicate that creative collaboration is related to increased association between theory of mind regions and executive function regions between team members. Our study suggests different processes that can promote increased creative collaboration between team members and can lead to more innovative ideas in a naturalistic design thinking session.

36. Embodied emotion correlates with personality traits - A study with somatosensory- evoked potentials

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The present study aimed to link the neural correlates of embodiment with personality traits such as emotional wellbeing, ability to understand emotions (namely alexithymia) and interoception using a neural index of emotions. Participants were presented with stimuli of faces expressing happiness, anger, sadness and neutral, while measuring their electrophysiological activity. An embodiment index was calculated by measuring participants' somatosensory-evoked activity by tactually probing (105 ms. post-visual facial stimuli) the state of SCx during an emotion discrimination task while controlling for visual effects (Sel et al., 2014). Additionally, we measured participant's levels of depression and alexithymia (by means of Beck Depression Inventory and the Toronto Alexithymia Scale respectively). In the Somatosensory Evoked Potential data, significant differences were found in amplitude between all four emotions (happiness, anger, sadness and neutral) over the somatosensory cortices between 100-120ms, following previous data on embodied emotion over somatosensory cortices (Sel et al., 2014). Interestingly, we also found significant correlation between depression scores and the SEPs amplitude of sad emotion (calculated by subtracting the amplitude of neutral condition from the emotion condition). These data provide novel evidence for relating neural somatosensory activity directly liked to embodied emotions (and independent form carry over visual effects), to subjective measures and personality traits, such as depression.

37. Creativity in architecture: Exploring how creativity neuroscience findings can enhance creativity during designing phase

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The first question of this research has been: what is the role of the creativity in designing original architecture? Architecture creativity is a complex cognitive process performed by agents in complex intentional plans. For a huge creative design memories (intended as acquired knowledge and single rembembrances) have a fundamental role: the implementation of creative and innovative architectural projects. Remembrances of childhood, travel, and working experiences filtered by reflections and training paths, all contribute to the development of new ideas as described in cognitive studies, interviews with architects, critical writings on architecture, etc. (Rossi, 1990; Zumthor, 2003). Now this thesis can be supported with recent findings in neuroscience field when answering to what brain processes contribute to the generation of new ideas: it has emerged that construction of new ideas builds on similar processes like the reconstruction of original ideas from episodic memory (Benedek et al, 2018). It has been recognized that designing architectures needs some grounded theoretical and phylosophical consciousnesses. Many theories and methods has been developed to explore, to enhance, to support the role of creativity in design activities. The method of the applied ontology provides a method and a tool. In previous research we have used techniques of applied ontology to build framework supports architects in annotating (recorded) memories with spatial patterns, and help them to retrieve and reinterpret these patterns for the development of creative project solutions. The focus of this contribution is about grounding these research lines to the findings of neuroscience.

38. Towards neural mechanism and evolution of creativity through divergent and convergent thought

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In the present proposal towards the mechanism of neural level and creativity the apprehension of neural level theory reflects from studies in relation to sparse, distributed, computational, architecture models and networks of memory. In connection to same it is contended that thought with creativity dimensions doesn't only generate with a single pipeline towards solution, however it is the neural

activation with congregation react with distinctive attributes. The mechanism on neural level in predictable manner for both convergent and divergent thought is distinctive towards context based solutions. Additionally, divergent thought doesn't reflects towards the generation of multiple solution or based solution, however uses schemas, prototypes as conceptual framework constrained to specific uncharacteristic features. The whole framework gives permit to be establishing ground to identify and inquire eccentric stored potentially associations, it indicates reflection towards sighting towards useful relationship of correspondence for better understanding and functionality. Thus most inventive tasks don't require many solutions, however, still require potentiality of both convergent and divergent thinking. In addition, to get multiple solutions it doesn't necessary require creative thinking and contrary some exertion with only single solution need creative thought. The present study reflects the ability to shift in creativity between convergent and divergent approach, finally concludes with the need of creativity implications for novel functionality. Keywords: Thought, Contextual focus, Convergent thought, Creativity, and Divergent thought.

39. Does stimulus format influence creativity? Effects of motor engagement on the alternative uses task

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Frequently in daily life, one is required to solve a problem or satisfy a goal under unexpected or emergency circumstances, when an object may have to be used in a manner different from its typical use. How does experience and previous knowledge about objects influence this process? Behavioral, neuroimaging, and neuropsychological studies have shown that certain aspects of object knowledge (e.g., the object's function or mode of manipulation) can be accessed independently of more abstract properties of the object (e.g., its name) and faster when participants are presented with three-dimensional objects relative to stimuli in pictorial format. Our past work has further revealed that differential retrieval of object properties as guided by stimulus format (i.e., pictures or words) can influence the number of type of responses generated in a creative generation task. Here we extended this work by examining whether visual and manual exposure to three-dimensional objects, relative to two-dimensional pictures of these objects, would allow for differential access to semantic memory under such conditions of impromptu relative to canonical goal achievement (i.e., the Alternative Uses Task, wherein a participant must come up with an unusual, relative to a typical, use for a common object). Our results showed that the combination of visual and manual exposure to three-dimensional objects interfered with the generation of uncommon uses, likely due to the facilitated access to sensorimotor object properties associated with the objects' canonical use. We discuss the implications of these results for our understanding of creativity and theories of object knowledge retrieval.

40. Selfies and self-portraits in exploring creative boundaries

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Since 2015, I have designed and taught 7 iterations of an Applied Creativity and Innovation course where undergraduate and graduate students have the opportunity to explore creativity in themselves and others. While it has been run at as a 45 hour, live course on our campus in Zagreb, it has attracted many exchange students from Belgium, Canada, Germany, France, Hungary, Ireland, Italy, Mexico, Portugal, Norway, The Netherlands, Russia, Singapore, Spain, The United States, The United Kingdom and Vietnam. The nature of the course takes them through small artistic hurdles for the mostly business oriented students. We test the boundaries of this concept of self and self perception in multiple ways throughout the semester. Indirectly, students reveal pieces of themselves like a trail of crumbs and clues in each of their works. Directly, in their selfies and then transform that image into a

self-portrait with use of collage techniques to allow artistic expression, open to interpretation. They allow themselves to be quite vulnerable as the resulting works are displayed in a curated show with dynamic peer and guest feedback. In this poster presentation, I will display samples of the outcomes of this assignment which include sample self-portraits, essays and quotes about this element of the course. Through this activity I hope to engage other researchers and education practitioners in comparing and contrasting approaches to this type of course and evoke discussion on new ways to analyze and interpret the inputs-process-outputs of self-portraits as tools of exploring creativity.

41. Building individual semantic networks and exploring their relation to creative abilities

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The associative theory of creativity suggests that creative abilities rely on the organization of semantic associations in memory. Recent research has demonstrated that semantic network methods allow testing this hypothesis. The aim of the current study was to investigate the properties of semantic networks at the individual level, in relation to creative abilities, using such methods. Individual semantic networks were estimated using a novel method, based on word relatedness judgments. To optimize the task, we first estimated a large-scale semantic network based on French association norms and selected stimuli words while controlling for the theoretical semantic distance between them and for linguistic word properties. 35 words were selected, and used in a semantic judgment task. Semantic ratings between all pairs of words were compared to the theoretical distance between them to validate our method. Semantic judgement ratings were used to estimate individual semantic networks, whose topological properties measured by several graph metrics were correlated with individual creativity scores. We found a correlation between the theoretical semantic distance and the relatedness ratings given by the participants, demonstrating the validity of our approach. Importantly, we found a close relationship between creative abilities assessed by an achievement questionnaire and divergent thinking tasks and individual semantic network metrics, replicating and extending previous similar results. These findings suggest that exploring semantic networks is a promising approach to study creativity. The relationships between semantic and brain networks will be examined in a future study.

42. Interdisciplinary perspectives on culture and creativity across levels of analysis

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Current research from different disciplines is increasingly interested in how culture influences creativity. In the first part of our poster presentation, we summarized how culture – especially a specific cultural dimension, tightness-looseness – influences creativity. Tightness-looseness is a cultural dimension which describes how many strong social norms there are in a culture and how much tolerance the culture has for deviant behaviors. We summarized both empirical and theoretical research across multiple levels of analysis and showed that cultural tightness is negatively correlated with creativity from industrial innovation on national level to individual creativity on neural level. However, there are limitations in current research. First, current cross-cultural research often fails to discriminate the different domains and assessment dimensions of creativity. Given the different directions of impacts that culture may have on different aspects of creativity, this limitation may bias

our conclusion on the cultural effects. Second, a creativity task involves not only an innovator but also an audience who evaluates the creativity behavior. It remains unclear how culture influences the assessment of creativity and how the audience's feedback, reversely, influences the innovator. Third, previous neuroscience has shown substantial individual differences in creativity. However, it remains unknown how these neural level differences are shaped by daily experience and culture environment. In the second part of our poster presentation, we addressed these limitations and suggested some future directions for cross-cultural research on the neuroscience of creativity.

43. Sleep and creativity: Differential effects on abstract and analogical reasoning

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Creativity is thought to rely on mental operations such as abstract and analogical reasoning. Sleep can facilitate insight and problem solving, yet its effect on abstract and analogical reasoning remains unknown. Therefore, the goal of this study was to determine if sleep can enhance performance on abstract and analogical reasoning tests. Our within-subject experimental design included two tasks for assessing abstract reasoning (the UK Clinical Aptitude Test (UKCAT) and a modified version of the Synthetic Visual Reasoning Task (SVRTAbs)) and two tasks for assessing analogical reasoning (the Geometrical Analogies Task (GAT) and the SVRT (SVRTAnR), with a 12 h retention interval of either wakefulness or nocturnal sleep. Unlike the SVRTAbs, the UKCAT was administered without any training or feedback and while the GAT required participants to identify if an analogy was present or not, the SVRTAnR required completing a 4-term analogy by choosing among 4 possible alternatives. Performance on the SVRTAbs improved after sleep and deteriorated in the wake condition, whereas no sleep effect was found across the retention interval for the UKCAT, with both conditions improving from test to retest. On the other hand, no benefit from sleep was observed on the GAT or the SVRTAnR. These results suggest that individuals might benefit from a sleep-containing interval between test and retest on an abstract reasoning task, but only if they are given the opportunity to learn from feedback before sleep, whereas analogical reasoning may either be more stable and trait-like, with low intra-individual variability or sleep-independent.

44. Creative Anxiety Regulation: Exploring how creative strategies in emotion regulation influence neural and behavioral outcomes in math anxiety

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The ability to regulate one's emotions and affective experience has a broad impact on well-being, health, and the ability to achieve important goals. Cognitive reappraisal (CR), or the ability to consider an emotional experience from a different perspective, has been demonstrated to be an essential skill in adaptive emotion regulation behaviors. However, there may be much variation across individuals in the creative ability to imagine alternative perspectives that change their emotional experiences in positive ways. For example, one's ability to creatively change cognitive appraisals of an anxiety-inducing situation may impact the effectiveness of regulation. In this fMRI study, we examined how teaching math anxious (MA) individuals to use CR as a strategy to regulate their anxiety regarding mathematics would influence neural math computations, math outcomes, and recruitment of regions

of the brain that support emotion regulation. We explored how participants use of self-reported creative strategies when engaging in CR would influence their ability to effectively use emotion regulation, and in turn, how this would influence neural and behavioral outcomes related to mathematics. We hypothesized that the creativity of participants' CR strategies would influence activity in a reappraisal network. For highly MA individuals, we predicted that utilizing a more creative strategy would augment the positive impact of CR in reducing anxiety-related deficits in math performance and a network of brain regions associated with arithmetic. This work illustrates the importance of creativity in regulation and educational outcomes, a potential target for future intervention.

45. Resting state brain dynamics supporting creativity

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Ying Choon Wu, UC San Diego

This study investigates how creative thinking is modulated by different kinds of task engagement. EEG was recorded as healthy adults played 2 versions of a 3D computer game involving finding a way into a locked house. In the open-ended version, participants were tasked with discovering their own creative method, whereas in the control case, they simply followed a series of instructions. The order of scenario presentation was counterbalanced across two sessions that were separated by at least one day. Immediately before and after each session, resting state EEG was recorded and the Alternative Uses Task (AUT) was administered. Following the open-ended, but not the control, scenario, alpha (8-12 Hz) and beta (15-35 Hz) power across the left hemisphere increased relative to the pre-task baseline. Fluency scores on the AUT were negatively correlated with alpha power over the left temporal area, suggesting that for some, the creative task led to resting state changes that suppressed creative thinking. We also explored the relationship between motivation and AUT performance. Participants were sorted into 2 groups by the ratio of left (LH) versus right hemisphere (RH) frontal alpha power (F8 (RH) minus F7 (LH)) in their post-task resting-state EEG. Those with positive alpha ratio scores (reflecting greater LH activation and an approach disposition) tended to experience a boost in AUT fluency after the open-ended task, whereas AUT fluency tended to decline for those with negative scores (reflecting greater RH activation and a withdrawal motivation) after the open-ended task. Open-ended tasks may benefit creative thinking in those who are positively motivated by them.

46. "I just got a popped-up-in-my-head". A qualitative analysis of the role of executive control in children's creativity

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Prof Andy Tolmie, University College London

There is continued debate about the role executive control plays in creativity, with apparently conflicting evidence. The research is dominated by quantitative laboratory tests of adults, but how applicable are findings to the real world? Can quantifying creative products tell us about process? And does the evidence extrapolate to children? This qualitative study, part of a mixed methods project, assesses children's creativity in their own homes, employing children's accounts of their creative process to generate hypotheses regarding the cognitive (particularly executive) mechanisms involved. Children aged 6-10 were drawn from a sample who had completed quantitative, lab tests of creativity. They were filmed creating a story or picture without time constraint. Immediately afterwards, video-stimulated recall and semi-structured interviews elicited their accounts of their creative process. Interviews were analysed within a theoretical thematic analysis framework. Their accounts suggest

their creativity involves a shifting balance between controlled and spontaneous processes. They describe the balance being modulated, sometimes deliberately, sometimes spontaneously, by the phase of the creative process (generative/evaluative), the domain (verbal/figural) and changing constraints, as well as by personality characteristics. A model will be presented which dissects a monolithic portrayal of the executive control/creativity relationship. It proposes that both state and trait factors modulate the influence of cognitive control on the creative process and further, hypothesizes that children's individual dexterity in handling this modulation is central to their creative ability.

47. Pupil-size and microsaccades predict different problem-solving styles

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People can solve problems through methodical analysis, or with a sudden insight (accompanied by an "Aha!" or "Eureka!" experience). Previous research has shown that these two ways of generating ideas are associated with distinct neural correlates and physiological markers. Solutions via insight correlate with a decrease of activity over the visual cortex, matched by an increased eye blink rate, and specific eye movement patterns oriented to avoid visual distractors. People adopt these behaviors when deeply absorbed in thinking, indicating a switch from external attention to internal deliberation that benefits insightful problem-solving. In this study, we hypothesized that pupil dilation and oculomotor dynamics could be a marker of this switch. The results indicated that when participants solved trials via insight (~500 msec before the answer), pupil diameter increased 15% more compared to the baseline (pre-trial fixation window), while in trials solved with analysis no increase in pupil diameter was detected. Also, an increase in microsaccades was only found in trials solved with analysis compare to the baseline (3.8 vs. 2 microsaccade/sec). Results were stable between subjects and were not biased by whether subjects gave a correct or incorrect answer. Finally, we calculated the probability of pupil size increment (insight trials = 60%+/-10% and analysis = 20%+/-5%) and microsaccadic rate increment (insight = 25%+/-10% and analysis = 57%+/-5%), within the 500 msec before the answer. Our results suggest that pupil-size and microsaccade rate may be used as complementary biomarkers of the cognitive processes engaged in problem-solving.

48. Incubation inside and outside the lab: How cognitive and affective factors influence problem solving in mathematics

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Gerardo Ramirez, Ball State University

Although incubation research frequently borrows anecdotes from real-world mathematicians, most research is conducted in a lab setting with abstract tasks that are heavily confounded with verbal fluency (e.g. RATs, anagrams). This is unfortunate, as utilizing an area such as mathematics would diversify incubation research and allow exploration of how cognitive and affective factors (e.g. need for cognition, math anxiety) can relate to incubation processes. In the current study, we used a math puzzle to test an incubation paradigm and explored how individual differences relate to solve rates both inside and outside the lab. A total of 231 students were brought into the lab and randomly assigned to a condition—a low-demand incubation condition (LD), a high-demand incubation condition (HD), or a control group. All groups had six minutes to work on the puzzle, but students in the LD and HD conditions took a break after three minutes to complete a signal detection task (LD) or complex-reading task (HD) for 2.5 minutes. If students were unable to solve the puzzle in lab, they

were provided a follow-up survey link to fill out if they solved the problem later, or if three days had passed without solving. Results showed that incubation condition was not related to problem solving within lab, but it was significantly related to solving outside of the lab. Interestingly, we found that control condition students had a greater probability of solving outside the lab compared to LD students. We also found that several factors significantly related with problem solving in the lab (i.e. math anxiety, stress of puzzle) were not related to solving the problem outside of the lab.

49. Improved motor and temporal scaling in musicians

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A fundamental feature of temporal processing is the ability to produce motor patterns at different speeds. For example we can type the same sentence or play the same musical piece at a range of different speeds. Here we quantified temporal scaling and timing precision in psychophysics experiments where musicians and non-musicians learned to produce a Morse Code sequence using finger taps. We found that musicians performed better than non-musicians both in terms of timing precision and in their ability to temporally scale--i.e., to reproduce the learned Morse code pattern at faster and slower speeds. Interestingly, both musicians and non-musicians exhibited the recently described Weber-speed effect, where absolute temporal precision was best when producing patterns at higher speeds. These results are consistent with previous studies that indicate that neural mechanisms underlying timing improve with practice, but suggest for the first time that the ability to generate the same motor patterns at different speeds also improves with extensive practice.

50. The other side of the coin: Reduced sensory gating and its influence on creativity

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Since creative people are often associated with distributed attention and a broader sensory filter, which makes it possible to perceive more and different action possibilities (Carson, Peterson, & Higgins, 2003; Reverberi, Toraldo, D'Agostini, and Skrap, 2005; White & Shah, 2006; 2011), highly creative people may show more 'leaky attention' or reduced sensory gating on a neurological level. The link between creativity and sensory gating has only been researched in one previous study (Zabelina, O'Leary, Pornpattananangkul, Nusslock, and Beeman, 2015), and has not been investigated in children at all. However, schizophrenic patients, known to have distributed attention and reduced inhibition (Gold & Thaker, 2002; Hoptman et al., 2004), do show reduced sensory gating (e.g. Oranje & Glenthøj, 2013) Previous results indicated that reduced P50 ERPs (a reduced amplitude to a second stimulus, due to conditioning effects of the preceding stimulus) were present for participants that scored high on divergent thinking, however the opposite association was present for people that scored high on a creative achievement questionnaire (Zabelina, et al., 2015). During the current study we will investigate if highly creative children show reduced sensory gating as measured by the P50 and PPI (a muted or inhibited magnitude of the sensorimotor startle reflex found when an intense stimulus is presented after a weak stimulus) paradigm in comparison to typically developing children and if sensory gating is similar in highly creative children and children with attentional difficulties. Results will be presented and discussed during the conference.

51. Cohesive flexibility of default, salience, and executive systems unreliably predicts creative performance

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Adam Green, Georgetown University

Recent research has demonstrated that the ability to think creatively is associated with a functional network comprised of default, salience, and executive systems (Beaty et al., 2018) – networks that conceivably support both creative idea generation and selection (as well their integration). This suggests that high-creative individuals may have more neural flexibility, by which they are able to dynamically shift between these different and otherwise segregated systems. Separately from this work, experimenters have begun to employ dynamic network analysis techniques to examine how patterns of functional connectivity between brain regions and networks evolve over time (Bassett et al., 2011; 2015). If such network metrics do indeed correspond to notions of cognitive flexibility, such properties – particularly for nodes of the default, salience, and executive systems – may be associated with one's capacity to think creatively. Here, we investigated whether the frequency with which nodes of the default, salience, and executive networks cohesively shift their functional patterns of communication predicted creative thinking in a large, publicly available imaging data set (SLIM). Results indicated that, while some dynamic shifts in functional connectivity are predictive of creative thinking, by and large these measures failed to correlate with creativity scores. Thus, flexibility-related metrics may insufficiently quantify variability in functional network organization. Alternative methods such as dynamic connectome-based predictive modeling may be better candidates to understand the neural basis of creativity.

52. Reduced fractional anisotropy associated with creative idea generation

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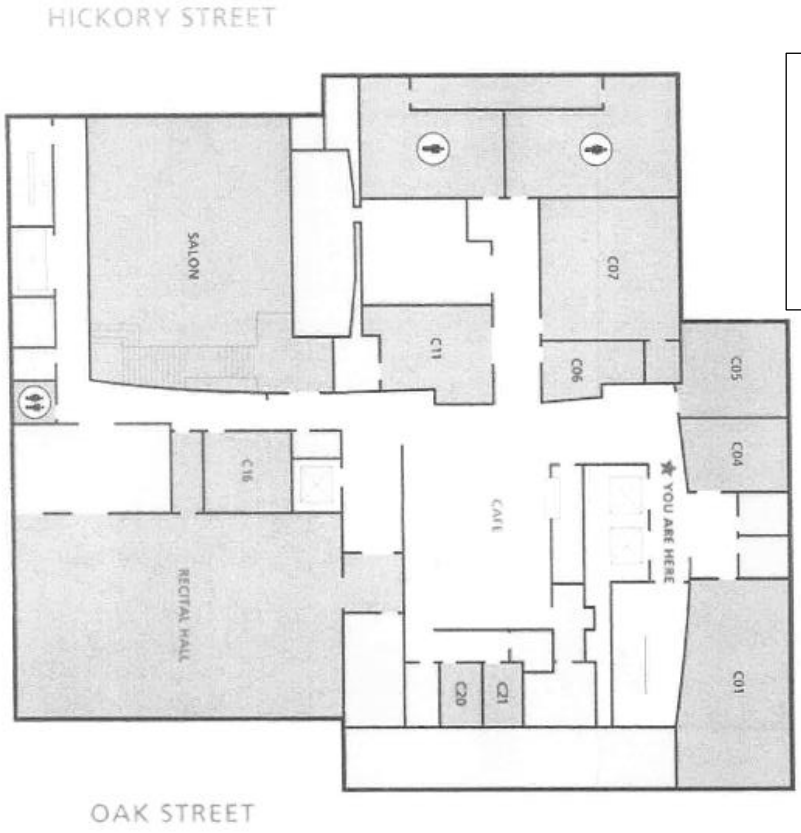
Creative idea generation tasks assess the ability to generate numerous solutions to an open-ended problem through the process of divergent thinking (DT). Very little work has been done exploring creative idea generation tasks and fractional anisotropy (FA). Our previous work has shown that higher scores on DT tasks were related to reduced fractional anisotrophy (FA) within the left hemisphere anterior thalamic radiation (Jung et al., 2010). However, Takeuchi et al., 2010b, found positive correlations with FA and DT tasks in the prefrontal cortex and genu of the corpus callosum. The present study assessed subjects studying or working in science, technology, engineering and mathematics (STEM; N =178) for correlations in white matter FA, as related to a measure of DT. Young healthy normal subjects aged (16–32 years, mean age = 22.0 ± 3.8; F = 89) were scanned on a 3 Tesla scanner using diffusion tensor imaging. Three idea generation DT measures were scored by three raters (α = .71) using the consensual assessment technique, from which a composite creativity index (CCI) was derived. We found that CCI was inversely related to FA (all $p < 0.05$, corrected for multiple comparisons using family wise error rate), within the left hemisphere inferior frontal gyrus, inferior fronto-occipital fasciculus, cingulate gyrus, inferior longitudinal fasciculus, and right hemisphere uncinate fasciculus and superior longitudinal fasciculus. These results are consistent with our previous findings, implicating lower FA in white matter regions linking broad cortical networks, now established in a much larger sample of normal healthy subjects.

San Francisco Conservatory of Music, 50 Oak st, San Francisco

First Floor Entrance Level

Second Floor Atrium and overflow room 207



Salon Level Entrance to Osher Salon

Salon Level, Osher Salon entrance

SFNC PROJECTS

Special issue on the Neuroscience of Creativity in *NeuroImage*

We are pleased to announce that **NeuroImage** and **the Society for the Neuroscience of Creativity** have joined to organize a special issue on the neuroscience of creativity.

Information can be found here:

https://www.journals.elsevier.com/neuroimage/call-for-papers/neuroscience-of-creativity-in-neuroimage

Submission opens: January 15, 2019 (portal will be open for submissions)

Submission deadline: June 1, 2019 (authors expected to submit their papers by this date)

Acceptance deadline: October 1, 2019 (Guest Editors make final decisions)

Ontology Project

The Society for the Neuroscience of Creativity is looking to develop a clearer ontology of constructs in creativity research (e.g., how do constructs relate to each other, and which tasks best capture which constructs).

To this end, we invite members of the creativity research and education community, to participate in an effort to measure how stakeholders in creativity research understand constructs relevant to creativity.

Please go to this link and complete a short survey:
https://sasupenn.qualtrics.com/jfe/form/SV_3TNRzmOHAxiZbNz

SFNC PROJECTS

Creativity Workshop for Executives

We are pleased to announce that SfNC is partnering in the organization of a creativity workshop, that will be held in Paris, October 28-29, 2019, organized by the ICM*.

The workshop is designed for executives involved in innovation, management, or leadership. It will focus on facilitating participants' individual exploration of creativity through neuroscience-based learning on these topics:

- How creativity works
- Can creativity be measured?
- How does the brain support creativity?
- Can we foster creativity?

***ICM** is an international neuroscience Institute, in the Salpetriere Hospital, based in Paris, France.

https://icm-institute.org/en/

Registration will open soon, please check the ICM or SfNC websites

Notes

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