Creativity and the brain: An editorial introduction to the special issue on the neuroscience of creativity

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NeuroImage 231 (2021) 117836

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/neuroimage

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The creative ability of the human brain, among the newest products of 3.8 billion years of evolution on Earth, may be humanity's most identity-defining feature in the age of artificial intelligence. Many of the most complex things humans do are now done—or soon will be done —far better by computers. Creativity projects to be the greatest exception. There has never been more widespread recognition that understanding and fostering human creativity is a priority for scientific research. The capacity to generate ideas that are both divergent and useful is widely recognized as valuable for learning and practice in the arts and sciences, and as a driver of the modern innovation economy. This value will only increase in the foreseeable future. Because creativity has such broad and diverse impacts, the neuroscience of creativity is being pursued by a diverse set of researchers. As is generally true in the early stages of a field, research endeavors into creativity neuroscience have often been undertaken separately by researchers siloed within sub-disciplines of psychology, education, industry, and clinical neuroscience. For the neuroscience of creativity to fulfill its considerable potential, it is important to develop greater mutual awareness and cohesion among researchers, and communication with educators and other stakeholders, so that priority directions can be identified and pursued. Meeting this need is a primary objective of the Society for the Neuroscience of Creativity (SfNC). This special issue (SI) on the neuroscience of creativity, guest-edited by a group of us who serve on the SfNC Executive Committee, is aimed at bringing together both expository and new empirical work from creativity neuroscience labs across the globe. We hope that this SI can contribute to (1) mapping the diversity of creativity neuroscience to increase mutual awareness within the field, while increasing awareness of creativity neuroscience across the broader cognitive neuroscience community; and (2) highlighting promising research directions toward stronger coalescence around methods and questions that have potential to catalyze basic understanding of how creativity occurs in the brain and how to enhance it. In this editorial, we attempt to summarize the results and theories reported in this SI, situate them within a larger cognitive neuroscience framework, and provide a modest list of research priorities for the field.

Overview of special issue

This SI attempts to provide a snapshot of current research in the neuroscience of creativity, outlining recent advances in the field. Several studies included in this SI address novel questions related to positive and negative influences on creative performance, including the impacts of stress (Nair et al. 2020) and disease (Paulin et al. 2020; Gross et al. 2019), as well as influences of mindset (Wang et al. 2019), cognitive reappraisal (Wu et al. 2019), and pharmacological intervention (Baas et al. 2020). The development of the creative brain is explored (Saggar et al. 2019) as are particular attributes of brain morphology and function found in eminent creative achievers (Chrysikou, et al. 2020a; Barrett et al. 2020). Innovative studies examined team creativity using fNIRS hyper-scanning (Mayseless et al., 2019; Lu et al., 2020), and how idea generation takes root in semantic, associative and mnemonic neurocognition (Paulin et al. 2020; Beaty et al. 2020). The neural correlates of musical creativity were investigated along multiple lines (Zioga et al. 2020; Belden et al. 2020; Rosen et al. 2020; Bashwiner et al. 2020). Other studies demonstrated the effective application of methods that have been thus far underutilized in the field, including neurogenetics (Si et al. 2020), network science (Kenett et al., 2020a; Saggar et al. 2019), oculometric signatures (Salvi et al. 2020), 7-Tesla MRI (Schuler et al., 2019), and machine learning (Stevens and Zabelina 2020). Several studies also revealed novel morphometric (Sunavsky and Poppenk 2020; Wertz et al.,. 2020a; Chrysikou, et al. 2020b; Vartanian et al. 2020), intrinsic (Schuler et al. 2019; Marron et al. 2020), task-evoked (Chen et al. 2019; Wang et al. 2019; Becker et al., 2020; Agnoli et al. 2020; Rominger et al. 2020; Benedek et al. 2020; Hartung et al. 2020; Oh et al. 2020; Roberts et al., 2020; Takeuchi et al., et al. 2020b), and structural connectivity (Wertz et al. 2020b; Takeuchi et al., 2020a) characteristics associated with individual differences in creative thinking, including connectomic analysis of the novel construct of creativity-specific anxiety (Ren et al. 2021).

Three theoretical/review papers (Zhang et al., 2020; Girn et al. 2020; Matheson and Kenett 2020) and one meta-analytically-based proof of concept for neurally-informed ontologies (Kenett et al. 2020b) helped capture how cognitive neuroscience researchers conceive of creativity and how the constructs we use can be mapped onto and constrained by brain function. The review articles address original questions including the role of metacognition and mental states in creativity. The meta-analysis explores the important issue of how best to operationally capture cognitive constructs related to creativity with a set of experimental tasks, leveraging the extant pool of neuroimaging data toward a new method for ontological development that has promise for creativity research and for all fields of cognitive neuroscience.

Many studies employed neuroimaging to examine task-induced brain activity and/or brain connectivity (10 studies employed fMRI; 3 studies used fNIRS), or explore how interindividual differences in creative abilities relate to white and gray matter regional structure (n = 7),

https://doi.org/10.1016/j.neuroimage.2021.117836

Available online 5 February 2021

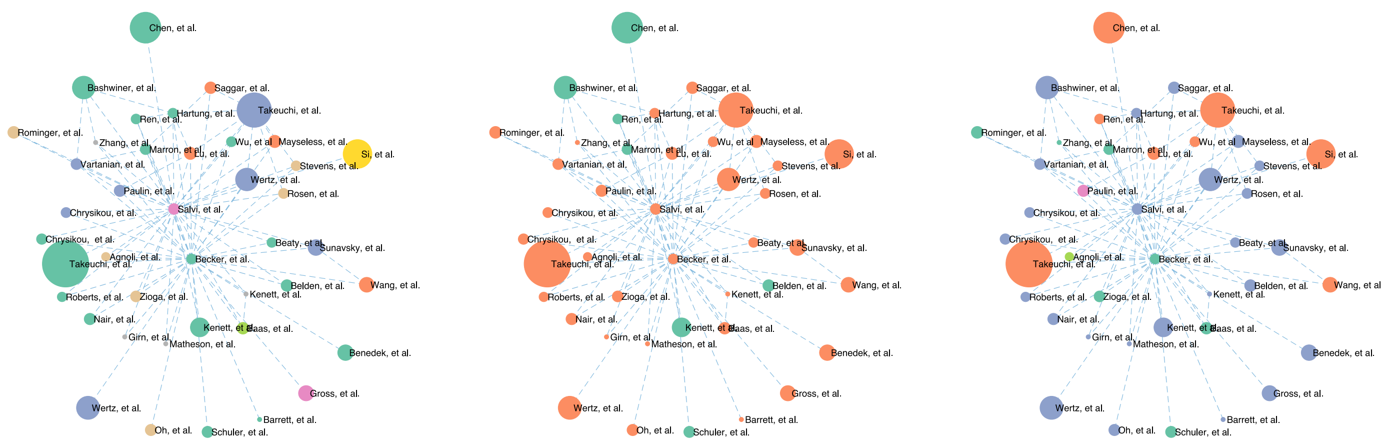

Fig. 1. Summary statistics as a graph for the 42 articles included in this special issue. The graph represents similarity across the included articles. The similarity was assessed by comparing keywords provided by the study authors for each article. Different annotations (node coloring schemes) were used to depict different aspects of each article. The left graph is annotated by the type of neuroimaging modality used, with node coloring as follows: fMRI (dark green), fNIRS (orange), structural (purple), eye-tracking (pink), pharmacological (light green), genetics (yellow), EEG (brown), and review articles (gray). The middle graph is annotated by task-type-intrinsic (at rest) vs. evoked task design, with node coloring as follows: resting-state (dark green) and task-based (orange). Lastly, the right graph is annotated by the continent of the senior author's lab, with node coloring as follows: Europe (dark green), Asia (orange), North America (purple), Australia (pink), and South America (light green). In each graph the size of node represents the number of participants used in each study.

or to measure intrinsic functional connectivity during rest (n = 7). Reflective of the field of creativity research more broadly, creative cognition was mainly assessed in the verbal domain (21 studies used only verbal tasks; 5 studies used figural tasks; 4 used a combination of assessments in different domains; and 4 used questionnaires to estimate creative achievements in real life). Creativity assessment was most frequently operationalized via divergent thinking tasks (n = 21), among which the Alternative Uses Task was predominant (used in 15 studies). Attempts to better capture the diversity of creative cognition are noteworthy in 4 studies (Baas et al. 2020; Benedek et al. 2020; Chrysikou et al. 2020a; Sunavsky and Poppenk 2020) that used a combination of measures from distinct frameworks (divergent and convergent thinking, creative achievement, openness to experience). In addition, 5 studies (Barrett et al. 2020; Bashwiner et al. 2020; Belden et al. 2020; Rosen et al. 2020; Zioga et al. 2020) represent the substantial and methodologically diverse presence of musical creativity within the field.

To better understand the scope of research covered by this special issue in terms of neuroimaging modality, demographics, and experimental design, we embedded all 42 articles in a low-dimensional space and examined the similarity between them (**Fig. 1**). To embed each article, we applied Google's Universal Sentence Encoder (Cer et al. 2018) to keywords submitted with each article. The similarity across articles was then assessed using Euclidean distance. The resulting similarity matrix was visualized in a 2-D force layout as a graph, where nodes represent articles and edges represent similarity. We annotated the generated graph using different meta-information: modality used, experimental design, and geographical location of the lab. **Fig. 1** left graph illustrates the clear prevalence of fMRI among modalities for exploring brain bases for creativity, followed by structural morphometric, and diffusion-based studies. Largest node-sizes represent consortium-level studies with >1000 participants enrolled. As shown in **Fig. 1** middle graph, evoked or task-based studies were most strongly represented within this special issue, compared with examinations of intrinsic or spontaneous correlates of creative thinking. Lastly, **Fig. 1** right graph represents geographic location of the labs contributing to the SI (based on senior author affiliations). Labs in North America are most frequently represented in the SI, followed by labs in Asia. Overall, these analyses indicate the breadth and diversity of the selection of articles included in this SI, which reflect our current understanding of the cognitive and neural mechanisms of creative thought.

Outlook and future directions for the neuroscience of creativity

Ten years ago, having a special issue on the neuroscience of creativity in a mainstream neuroimaging journal, with 42 outstanding contributions selected from a much larger set of high-quality submissions, would not have appeared likely. Even just a decade ago, understanding the neural bases of creative thinking was at the outskirts of cognitive neuroscience research. Much has changed since then. A key drivers of the movement of creativity neuroscience toward a more central position within cognitive neuroscience has been the commitment of creativity researchers to situate and examine creative thinking within better-established aspects of cognition, such as semantic and autobiographical memory, attention, mentalization, and cognitive control, e.g., (Beaty et al. 2016; Chrysikou 2018; 2019; Kenett et al. 2018; Volle 2018; Zabelina and Andrews-Hanna 2016; Xie et al. 2021; Abraham 2014). Understanding creativity necessitates understanding how these processes take place in the context of creative thinking tasks. On the other hand, creativity is more than the sum of its 'cognitive parts': A comprehensive understanding of how new ideas can come about from already existing knowledge requires a synthesis of extant findings toward a working theoretical framework of creativity neuroscience. Although pieces of this framework are evident across the excellent research featured in this SI, future work toward theoretical unification will be essential. Additionally, questions of the *where*, and—critically—*when* and *how* creativity happens within and between key neural networks, and in conjunction with activity throughout the brain still remain. Are these processes consistent across creative domains? Does the current evidence on task-evoked creativity neuroscience, much of which is featured in this SI, generalize to long-term (e.g., multi-year) creative endeavors? Critically, can creativity be enhanced by enhancing activity in the identified brain systems using non-invasive brain stimulation (e.g., Chrysikou et al. 2013; Green et al. 2017; Lucchiari et al., 2018; Radel et al. 2015) or domain-general training (Saggar et al. 2017)?

The rise of creativity neuroscience research holds strong potential to advance our understanding of more traditional cognitive neuroscience domains. By examining how memory, attention, cognitive control, and social cognition processes, among others, contribute and interact within creative cognition, we can test the validity of well-established knowledge in these subfields. Parallels between creativity research and research examining cognitive and behavioral flexibility are also beginning to emerge (Uddin, 2021). Creativity neuroscience thus presents a unique testbed for theories across all cognitive neuroscience research. Nevertheless, because fundamental research and methodologies within these domains are advancing rapidly, increased interdisciplinary collaborations among creativity neuroscientists and experts from other cognitive neuroscience domains will be required to advance knowledge.

As evident in the multiple and complementary methods employed in the studies featured in this SI, creativity neuroscience has progressed from simple 'activation-based' fMRI studies to complex network analytical paradigms. Much knowledge has been gained from these methods, and cognitive neuroscience methods continue to advance with respect to resolution and multidimensionality. Methodological advances notwithstanding an emerging research gap concerns the relationship between how we study creativity in the lab and how creativity happens in the real world. Although several studies featured in this SI examined aspects of 'real world' creativity such as team problem solving (e.g., Mayseless et al., 2020), musical creativity (e.g., (Zioga et al. 2020; Belden et al. 2020; Rosen et al. 2020; Bashwiner et al. 2020), and real-life high creative achievers (e.g., Chrysikou et al., 2020a; Chrysikou et al., 2020b), much additional work using ecologically valid, real-world tasks will be required to ensure broad generalizability of creativity neuroscience findings.

For both lab-based and real-world creativity measures, a key future direction for creativity neuroscience is the development of a clearer and more uniform ontology of creativity constructs and measurement. In order for studies to inform each other, researchers must agree on a vocabulary so that the same terms refer to the same constructs and, most importantly, use consistent measurement instruments/tasks to operationalize these constructs. In this SI, (Kenett et al., 2020b) demonstrate proof-of-concept for a novel approach to deriving a neurally-informed ontology of creativity measurement that leverages meta-analytic neuroimaging data in combination with representational similarity analysis. Approaches such as this one that leverage the ever-growing body of creativity neuroimaging data to empirically optimize the fit of tasks to constructs are promising for the future of creativity measurement.

Across these promising directions for future research, creativity neuroscience has substantial opportunity to benefit from, and contribute to, the momentum toward open science that has developed in the broader fields of neuroimaging and cognitive neuroscience (Poldrack and Gorgolewski 2014). To reduce publication bias, preregistering a study plan with details about data acquisition, exclusion criteria, and data analysis before any data have been acquired should be encouraged when practicable (Gorgolewski and Poldrack 2016; Open Science Collaboration 2016). Further, data sharing irrespective of the sample size of the study should also be encouraged. It has been convincingly argued that greater availability of data from small-sample studies could help with failing faster, developing innovative methods, improving statistical power for future studies (Mumford, 2012), as well as validating older results on newer datasets (Saggar and Uddin 2019).

There is no lack of enthusiasm for creativity neuroscience, but the growth of the field depends greatly on how effectively that energy can be harnessed. In these early days, individual studies are not always clearly contextualized in relation to existing studies, and there are instances of crosstalk and redundancy that cloud interpretation and slow progress. Scientific societies play a crucial role in the development of a field by providing platforms for sharing new ideas, establishing standards for methodological rigor, and fostering cohesion and collaboration to achieve a force multiplier-effect. SfNC was formed with the academic charter to support interdisciplinary research on the neural and cognitive bases of creativity and related processes, and to provide an inclusive forum for communicating this research so that it has maximal impacts for education, health, innovation, and artistic performance. SfNC and other organizations focused on the rigorous empirical study of creativity, and projects such as this SI that present the field both to itself and to the broader neuroscientific community, are essential for combining the energy sources surrounding creativity neuroscience to advance the field in productive directions.

Acknowledgements

We are grateful to the authors for submitting their original research to this special issue. We are also indebted to the 'unsung heroes' – reviewers, who have devoted substantial amounts of their time and expertise to improving submitted articles with their constructive feedback. We also thank the staff at the *NeuroImage* editorial office for their unending support and guidance throughout the development of the special issue.

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References

Abraham, A., 2014. Creative thinking as orchestrated by semantic processing vs. Cognitive control brain networks. Front. Hum. Neurosci. 8, 95. doi:10.3389/fnhum.2014.00095.

Agnoli, S., Zanon, M., Mastria, S., Avenanti, A., Corazza, G.E., 2020. Predicting response originality through brain activity: an analysis of changes in EEG alpha power during the generation of alternative ideas. NeuroImage 207, 116385. doi:10.1016/j.neuroimage.2019.116385.

Baas, M., Boot, N., Gaal, S.V., Dreu, C.K W d., Cools, R., 2020. Methylphenidate does not affect convergent and divergent creative processes in healthy adults. NeuroImage 205, 116279. doi:10.1016/j.neuroimage.2019.116279.

Barrett, K.C., Barrett, F.S., Jiradejvong, P., Rankin, S.K, Landau, A.T, Limb, C.J, 2020. Classical creativity: a functional magnetic resonance imaging (FMRI) investigation of pianist and improviser Gabriela Montero. NeuroImage 209, 116496. doi:10.1016/j.neuroimage.2019.116496.

Bashwiner, D.M, Bacon, D.K, Wertz, C.J, Flores, R.A, Chohan, M.O, Jung, R.E, 2020. Resting state functional connectivity underlying musical creativity. NeuroImage 218, 116940. doi:10.1016/j.neuroimage.2020.116940.

Beaty, R.E., Benedek, M., Silvia, P.J., Schacter, D.L., 2016. Creative cognition and brain network dynamics. Trends Cognit. Sci. doi:10.1016/j.tics.2015.10.004.

Beaty, R.E, Chen, Q., Christensen, A.P, Kenett, Y.N, Silvia, P.J, Benedek, M., Schacter, D.L, 2020. Default network contributions to episodic and semantic processing during divergent creative thinking: a representational similarity analysis. NeuroImage 209, 116499. doi:10.1016/j.neuroimage.2019.116499.

Becker, M., Sommer, T., Kühn, S., 2020. Inferior frontal gyrus involvement during search and solution in verbal creative problem solving: a parametric FMRI study. NeuroImage 206, 116294. doi:10.1016/j.neuroimage.2019.116294.

Belden, A., Zeng, T., Przysinda, E., Anteraper, S.A., Whitfield-Gabrieli, S., Loui, P., 2020. Improvising at rest: differentiating jazz and classical music training with resting state functional connectivity. NeuroImage 207, 116384. doi:10.1016/j.neuroimage.2019.116384.

Benedek, M., Jurisch, J., Koschutnig, K., Fink, A., Beaty, R.E, 2020. "Elements of creative thought: investigating the cognitive and neural correlates of association and bi-association processes. NeuroImage 210, 116586. doi:10.1016/j.neuroimage.2020.116586.

Cer, D., Yang, Y., Kong, S.Y., Hua, N., Limtiaco, N., John, R.S., Constant, N., et al., 2018. Universal sentence encoder for english. In: Proceedings of the EMNLP 2018 - Conference on Empirical Methods in Natural Language Processing: System Demonstrations, Proceedings doi:10.18653/v1/d18-2029.

Chen, Q., Beaty, R.E, Cui, Z., Sun, J., He, H., Zhuang, K., Ren, Z., Liu, G., Qiu, J., 2019. Brain hemispheric involvement in visuospatial and verbal divergent thinking. NeuroImage 202, 116065. doi:10.1016/j.neuroimage.2019.116065.

Chrysikou, E.G., 2018. The costs and benefits of cognitive control for creativity. The Cambridge Handbook of the Neuroscience of Creativity doi:10.1017/9781316556238.018.

Chrysikou, E.G., 2019. Creativity in and out of (Cognitive) Control. Curr. Opin. Behav. Sci. doi:10.1016/j.cobeha.2018.09.014.

Chrysikou, E.G., Hamilton, R.H., Branch Coslett, H., Datta, A., Bikson, M., Thompson-Schill, S.L., 2013. Noninvasive transcranial direct current stimulation over the left prefrontal cortex facilitates cognitive flexibility in tool use. Cognit. Neurosci. 4 (2). doi:10.1080/17588928.2013.768221.

Chrysikou, E.G, Jacial, C., Yaden, D.B, Dam, W.V., Kaufman, S.B., Conklin, C.J, Wintering, N.A, Abraham, R.E, Jung, R.E, Newberg, A.B, 2020a. Differences in brain activity patterns during creative idea generation between eminent and non-eminent thinkers. NeuroImage 220, 117011. doi:10.1016/j.neuroimage.2020.117011.

Chrysikou, E.G, Wertz, C., Yaden, D.B, Kaufman, S.B., Bacon, D., Wintering, N.A, Jung, R.E, Newberg, A.B, 2020b. Differences in brain morphometry associated with creative performance in high- and average-creative achievers. NeuroImage 218, 116921. doi:10.1016/j.neuroimage.2020.116921.

Girn, M., Mills, C., Roseman, L., Carhart-Harris, R.L, Christoff, K., 2020. Updating the dynamic framework of thought: creativity and psychedelics. NeuroImage 213, 116726. doi:10.1016/j.neuroimage.2020.116726.

Gorgolewski, K.J., Poldrack, R.A., 2016. A practical guide for improving transparency and reproducibility in neuroimaging research. PLoS Biol. 14 (7). doi:10.1371/journal.pbio.1002506.

Green, A.E., Spiegel, K.A., Giangrande, E.J., Weinberger, A.B., Gallagher, N.M., Turkeltaub, P.E., 2017. Thinking cap plus thinking zap: Tdcs of frontopolar cortex improves creative analogical reasoning and facilitates conscious augmentation of state creativity in verb generation. Cereb. Cortex 27 (4). doi:10.1093/cercor/bhw080.

Gross, M.E, Araujo, D.B, Zedelius, C.M, Schooler, J.W, 2019. Is perception the missing link between creativity, curiosity and schizotypy? Evidence from spontaneous eye-movements and responses to auditory oddball stimuli. NeuroImage 202, 116125. doi:10.1016/j.neuroimage.2019.116125.

Hartung, F., Kenett, Y.N, Cardillo, E.R, Humphries, S., Klooster, N., Chatterjee, A., 2020. Context matters: novel metaphors in supportive and non-supportive contexts. NeuroImage 212, 116645. doi:10.1016/j.neuroimage.2020.116645.

Kenett, Y.N., Medaglia, J.D., Beaty, R.E., Chen, Q., Betzel, R.F., Thompson-Schill, S.L., Qiu, J., 2018. Driving the brain towards creativity and intelligence: a network control theory analysis. Neuropsychologia 118. doi:10.1016/j.neuropsychologia.2018.01.001.

Kenett, Y.N, Betzel, R.F, Beaty, R.E, 2020a. Community structure of the creative brain at rest. NeuroImage 210, 116578. doi:10.1016/j.neuroimage.2020.116578.

Kenett, Y.N, Kraemer, D.J M, Alfred, K.L, Colaizzi, G.A, Cortes, R.A, Green, A.E, 2020b. Developing a neurally informed ontology of creativity measurement. NeuroImage 221, 117166. doi:10.1016/j.neuroimage.2020.117166.

Lu, K., Yu, T., Hao, N., 2020. Creating while taking turns, the choice to unlocking group creative potential. NeuroImage 219, 117025. doi:10.1016/j.neuroimage.2020.117025.

Lucchiari, C., Sala, P.M., Vanutelli, M.E., 2018. Promoting creativity through transcranial direct current stimulation (TDCS). A critical review. Front. Behav. Neurosci. doi:10.3389/fnbeh.2018.00167.

Marron, T.R, Berant, E., Axelrod, V., Faust, M., 2020. Spontaneous cognition and its relationship to human creativity: a functional connectivity study involving a chain free association task. NeuroImage 220, 117064. doi:10.1016/j.neuroimage.2020.117064.

Mayseless, N., Hawthorne, G., Reiss, A.L, 2019. Real-life creative problem solving in teams: FNIRS based hyperscanning study. NeuroImage 203, 116161. doi:10.1016/j.neuroimage.2019.116161.

Mumford, J.A., 2012. A Power Calculation Guide for FMRI Studies. Social Cognitive and Affective Neuroscience 7 (6). doi:10.1093/scan/nss059.

Nair, N., Hegarty, J.P, Ferguson, B.J, Hecht, P.M, Tilley, M., Christ, S.E, Beversdorf, D.Q, 2020. Effects of stress on functional connectivity during problem solving. NeuroImage 208, 116407. doi:10.1016/j.neuroimage.2019.116407.

Oh, Y., Chesebrough, C., Erickson, B., Zhang, F., Kounios, J., 2020. An insight-related neural reward signal. NeuroImage 214, 116757. doi:10.1016/j.neuroimage.2020.116757.

Open Science Collaboration, 2016. Psychological science under scrutiny: recent challenges and proposed solutions. Psychol. Sci. Under Scrut. Recent Chall. Propos. Solut..

Paulin, T., Roquet, D., Kenett, Y.N, Savage, G., Irish, M., 2020. The effect of semantic memory degeneration on creative thinking: a voxel-based morphometry analysis. NeuroImage 220, 117073. doi:10.1016/j.neuroimage.2020.117073.

Poldrack, R.A, Krzysztof, J.G., 2014. Making big data open: data sharing in neuroimaging. Nat. Neurosci. 17 (11), 1510–1517. doi:10.1038/nn.3818.

Radel, R., Davranche, K., Fournier, M., Dietrich, A., 2015. The role of (Dis)Inhibition in creativity: decreased inhibition improves idea generation. Cognition 134. doi:10.1016/j.cognition.2014.09.001.

Ren, Z., Daker, R.J, Shi, L., Sun, J., Beaty, R.E, Wu, X., Chen, Q., et al., 2021. Connectome-based predictive modeling of creativity anxiety. NeuroImage 225, 117469. doi:10.1016/j.neuroimage.2020.117469.

Roberts, R.P, Grady, C.L, Addis, D.R., 2020. Creative, internally-directed cognition is associated with reduced BOLD variability. NeuroImage 219, 116758. doi:10.1016/j.neuroimage.2020.116758.

Rominger, C., Papousek, I., Perchtold, C.M, Benedek, M., Weiss, E.M, Weber, B., Schwerdtfeger, A.R, Eglmaier, M.T W, Fink, A., 2020. Functional coupling of brain networks during creative idea generation and elaboration in the figural domain. NeuroImage 207, 116395. doi:10.1016/j.neuroimage.2019.116395.

Rosen, D.S, Oh, Y., Erickson, B., Zhang, F.(Z.), Youngmoo, E.K., Kounios, J., 2020. Dual-process contributions to creativity in jazz improvisations: an SPM-EEG study. NeuroImage 213, 116632. doi:10.1016/j.neuroimage.2020.116632.

Saggar, M., Quintin, E.-M., Bott, N.T., Kienitz, E., Chien, Y.-H., Hong, D.W.-C., Liu, N., Royalty, A., Hawthorne, G., Reiss, A.L., 2017. Changes in Brain Activation Associated with Spontaneous Improvization and Figural Creativity After Design-Thinking-Based Training: A Longitudinal FMRI Study. Cereb. Cortex (New York, N.Y.: 1991) 27 (7), 3542–3552. doi:10.1093/cercor/bhw171.

Saggar, M., Uddin, L.Q., 2019. Pushing the boundaries of psychiatric neuroimaging to ground diagnosis in biology. ENeuro 6 (6). doi:10.1523/ENEURO.0384-19.2019.

Saggar, M., Xie, H., Beaty, R.E., Stankov, A.D., Schreier, M., Reiss, A.L., 2019. Creativity slumps and bumps: examining the neurobehavioral basis of creativity development during middle childhood. NeuroImage 196 (August), 94–101. doi:10.1016/j.neuroimage.2019.03.080.

Salvi, C., Simoncini, C., Grafman, J., Beeman, M., 2020. Oculometric signature of switch into awareness? Pupil size predicts sudden insight whereas microsaccades predict problem-solving via analysis. NeuroImage 217, 116933. doi:10.1016/j.neuroimage.2020.116933.

Schuler, A.L., Tik, M., Sladky, R., Luft, C.D.B., Hoffmann, A., Woletz, M., Zioga, I., Bhattacharya, J., Windischberger, C., 2019. Modulations in resting state networks of subcortical structures linked to creativity. NeuroImage 195, 311–319. doi:10.1016/j.neuroimage.2019.03.017.

Si, S., Su, Y., Zhang, S., Zhang, J., 2020. Genetic susceptibility to parenting style: DRD2 and COMT influence creativity. NeuroImage 213, 116681. doi:10.1016/j.neuroimage.2020.116681.

Stevens, C.E, Zabelina, D.L, 2020. Classifying creativity: applying machine learning techniques to divergent thinking EEG data. NeuroImage 219, 116990. doi:10.1016/j.neuroimage.2020.116990.

Sunavsky, A., Poppenk, J., 2020. Neuroimaging predictors of creativity in healthy adults. NeuroImage 206, 116292. doi:10.1016/j.neuroimage.2019.116292.

Takeuchi, H., Taki, Y., Matsudaira, I., Ikeda, S., Kelssy, H.d., Kawata, S., Nouchi, R., Sakaki, K., et al., 2020a. Convergent creative thinking performance is associated with white matter structures: evidence from a large sample study. NeuroImage 210, 116577. doi:10.1016/j.neuroimage.2020.116577.

Takeuchi, H., Taki, Y., Nouchi, R., Yokoyama, R., Kotozaki, Y., Nakagawa, S., Sekiguchi, A., et al., 2020b. Originality of divergent thinking is associated with working memory–related brain activity: evidence from a large sample study. NeuroImage 216, 116825. doi:10.1016/j.neuroimage.2020.116825.

Uddin, L. Q., 2021. Cognitive and behavioural flexibility: neural mechanisms and clinical considerations. Nat. Rev. Neurosci. In press.

Vartanian, O., Smith, I., Lam, T.K, King, K., Lam, Q., Beatty, E.L, 2020. The relationship between methods of scoring the alternate uses task and the neural correlates of divergent thinking: evidence from voxel-based morphometry. NeuroImage 223, 117325. doi:10.1016/j.neuroimage.2020.117325.

Volle, E., 2018. Associative and controlled cognition in divergent thinking: theoretical, experimental, neuroimaging evidence, and new directions. The Cambridge Handbook of the Neuroscience of Creativity doi:10.1017/9781316556238.020.

Wang, X., He, Y., Lu, K., Deng, C., Qiao, X., Hao, N., 2019. How does the embodied metaphor affect creative thinking? NeuroImage 202, 116114. doi:10.1016/j.neuroimage.2019.116114.

Wertz, C.J, Chohan, M.O, Flores, R.A, Jung, R.E, 2020a. Neuroanatomy of creative achievement. NeuroImage 209, 116487. doi:10.1016/j.neuroimage.2019.116487.

Wertz, C.J, Chohan, M.O, Ramey, S.J, Flores, R.A, Jung, R.E, 2020b. White matter correlates of creative cognition in a normal cohort. NeuroImage 208, 116293. doi:10.1016/j.neuroimage.2019.116293.

Wu, X., Guo, T., Tan, T., Zhang, W., Qin, S., Fan, J., Luo, J., 2019. Superior emotional regulating effects of creative cognitive reappraisal. NeuroImage 200, 540–551. doi:10.1016/j.neuroimage.2019.06.061.

Xie, H., Beaty, R., Jahanikia, S., Geniesse, C., Sonalkar, N., Saggar, M., 2021. Spontaneous and deliberate modes of creativity: multitask Eigen-connectivity analysis captures latent cognitive modes during creative thinking. BioRxiv.

Zabelina, D.L., Andrews-Hanna, J.R., 2016. Dynamic network interactions supporting internally-oriented cognition. Curr. Opin. Neurobiol. doi:10.1016/j.conb.2016.06.014.

Zhang, W., Sjoerds, Z., Hommel, B., 2020. Metacontrol of human creativity: the neurocognitive mechanisms of convergent and divergent thinking. NeuroImage 210, 116572. doi:10.1016/j.neuroimage.2020.116572.

Zioga, I., Harrison, P.M C, Pearce, M.T, Bhattacharya, J., Luft, C.D.B., 2020. From learning to creativity: identifying the behavioural and neural correlates of learning to predict human judgements of musical creativity. NeuroImage 206, 116311. doi:10.1016/j.neuroimage.2019.116311.