Creative Minds Are Out of Control: Mid Frontal Theta and Creative Thinking

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Abstract

Creativity is considered to be the driving force behind innovation and progress, yet the neural signature of creative thought remains elusive. Recently, creative thinking has been associated with dynamics between large-scale intrinsic neural networks. In the current study, we investigated whether fluctuations of activity in the control network is linked to creative thinking. We designed a 'caption this' task in which participants had to provide an original and apt caption to accompany a presented picture while EEG signals were recorded. To assess changing levels of cognitive control we made use of the strong relationship between mid frontal oscillatory activity in the theta range (4-7 HZ) and top-down control. This experimental set-up allowed us to assess the relationship between trial-by-trial changes in neural measures of top-down control and fluctuations in creativity. Results demonstrate that specifically when attention needs to be internally oriented lower levels of top-down control resulted in higher levels of creativity. In addition, increased creativity related to enhanced long-range functional connectivity between occipital and mid frontal cortex when the presented picture was no longer visible. Together, our findings demonstrate that creativity benefits from lower levels of top-down control and enhanced processing of internal information.

Introduction

Creative thinking is often seen as the fountainhead of human progress, enabling us to go beyond existing patterns, emanating something novel and useful. Creative imagination has been considered to be the starting point of great art and science, allowing us to listen to Sgt. Pepper's while flying miles high above the ground. In every day life, creativity also plays an important role in problem solving, adaptation to change and the discovery of new possibilities.

Surprisingly, there is little neurocognitive knowledge about the workings of this remarkable capability of the human mind. Pursuits of linking specific brain regions to creative thinking have stranded in inconsistency thus far (Dietrich & Kanso, 2011; Dietrich & Haider, 2017). However, recent neuropsychological and neuroimaging findings seem to point to a different direction involving large-scale network interactions (Beaty, Benedek, Silvia, & Schacter, 2016; Jung, Grazioplene, Caprihan, Chavez, & Haier 2010; Chrysikou, Novick, Trueswell, & Thompson-Schill, 2011; Mell, Howard, & Miller, 2003). Instead of finding out where "creative neural activity" resides, it seems to be more fruitful to investigate how neural networks interact during creative thinking. Novel findings indicate that creative thought benefits from dynamics between traditionally opposing networks, the default-mode and control network (Jung et al., 2010; Chrysikou et al., 2011; Mell et al., 2003; McMillan, Kaufman, & Singer, 2013; Baird, Smallwood, Mrazek, Kam, Franklin, & Schooler 2012; Beaty et al., 2014; Mok, 2014; Zedelius & Schooler, 2016; Beaty et al., 2018). Default-mode network activity has been strongly linked to internally driven mechanisms when our focus on the external environment is diminished (Buckner, Andrews-Hanna, & Schacter, 2008). This internally oriented or disinhibited state is thought to facilitate creative cognition (Dietrich, 2007; Kaufman et al., 2010; Carson, 2014). For example, Chrysikou and colleagues (2013) increased creative thinking by reducing activity in the control network by means of brain stimulation, thereby unleashing default-mode network activity (Fox et al., 2005; Wokke, Talsma, & Vissers, 2015). Further, comparing brain activity while participants performed a close-ended task (common use task) vs. an open-ended task (uncommon use task) revealed a tradeoff between frontal and occipito-temporal regions, where the PFC was engaged during the common use task, while being disengaged during the uncommon use task (Chrysikou & Thompson-Schill, 2011). These findings indicate that dynamics between default-mode and control networks could play a crucial role in creative thinking.

In the present study, we investigated whether top-down prefrontal control modulates creative thinking. We recorded electroencephalographic (EEG) signals while participants performed a 'caption this' task in which they had to provide original and apt captions to accompany presented pictures. To assess the level of creativity we focused on the creative product (MacKinnon, 1987; Dietrich, 2007) and obtained creativity scores from two independent raters for each caption. To acquire a neural measure of top-down control on each trial we recorded electroencephalographic signals during the task. In the last decades, neural oscillatory mechanisms have been suggested to mediate interactions within large-scale cortical networks (Hipp, Engel, & Siegel 2011; Siegel,

Donner, & Engel, 2012). Specifically, increased mid frontal oscillatory activity in the theta range (4-7 HZ) has been labeled as a robust marker of enhanced cognitive control (Cavenagh & Frank, 2014). It has been consistently demonstrated that changes in top-down control are linked to fluctuations in frontal theta-band activity (Van de Vijver, Ridderinkhof, & Cohen, 2011; Van Driel, Swart, Egner, Ridderinkhof, & Cohen 2015; Razumnikova, 2007; Sauseng et al., 2006; Cohen & Cavenagh, 2011; Wokke, Cleeremans, & Ridderinkhof, 2017). Here, we exploited this intimate relationship by determining whether fluctuations in mid frontal theta activity and changes in functional connectivity (theta phase synchrony) correlated with variations in the level of creativity. Our novel experimental design in combination with EEG recordings allowed us to observe whether fluctuations in neural measures of top-down control related to changing levels of creativity.

Materials and Methods

Participants

Twenty-four participants (mean age= 21.5, SD= 3.2) took part in this study for financial compensations. All participants had normal or corrected-to-normal vision, and all were naïve to the purpose of the experiment. Four participants were excluded because of excessive noise in more than half of the trials (due to our long epochs, see below). One participant was excluded for not performing the task correctly. A total of nineteen participants were included for all further analyses. All procedures complied with international laws and institutional guidelines and were approved by the Ethics Committee of the Psychology department of the University of Amsterdam, and all participants provided their written informed consent prior to the experiment.

Task design

Pictures were presented full screen (1024*768 pixels) on a 17-inch DELL TFT monitor with a refresh rate of 60 Hz. The monitor was placed at a distance of ~90 cm in front of each participant so that one centimeter subtended a visual angle of 0.64°. Each trial started with a blank (1000 ms) after which a fixation-cross appeared (jittered between 700-1200 ms, in steps of 100 ms). Next, a picture was presented, which consisted of a scene or an event (see Figure 1). On each trial, we instructed participants to provide an apt and original one-sentence caption to accompany the presented picture. Participants were instructed to press the spacebar on a keyboard at the moment they came up with the content of their caption. After the spacebar press, the picture disappeared and participants could type in their response after a 500 ms delay period. Each caption was

submitted by pressing the enter key. The trial ended with a question about how the caption emerged. Participants could respond by pressing the '1' key in case the caption was thought up of in an analytical manner or the '2' key in case the caption emerged through sudden insight. Sudden insight was described as a caption that '*popped into mind*', while analytic solutions were described as coming into being after '*analytical thought and reasoning*'.

The experiment lasted ~2 hours and consisted of 200 trials divided into 10 blocks. The 200 pictures were presented in pseudo-random order. Stimuli were presented using Presentation (Neurobehavioral Systems).

At the end of the experiment, two naïve participants rated the level of creativity of each caption (3800 trials in total) by awarding a score between 1-4, where 1 represented a very low level of creativity and 4 an extremely high level of creativity. The raters were instructed that a creative caption was '*a caption that was clearly connected to the image, while describing the picture in an original and novel way. Further, the content of the caption should go beyond the information provided by the image*'. Low creativity was described as '*providing a purely factual depiction of the presented image*' and/or '*clearly not connected to the picture at all*'. We calculated inter-rater reliability (Cohen's kappa), and we observed a fair amount (Landis & Koch, 1977) of agreement ($\kappa = .267$, $p < .0005$) between the two raters. Next, we excluded all trials on which the raters differed >2 points from further analyses (a total of 15 trials across all participants).

EEG measurements and analyses

We recorded and sampled EEG signals at 1048 Hz using a Biosemi ActiveTwo 64-channel system, with four additional electrodes for horizontal and vertical eye-movements, each referenced to their counterpart (Biosemi – Amsterdam, The Netherlands). High-pass filtering (0.5 HZ), low-pass filtering (100 HZ) and a notch filter (50 HZ) were used. Next, eye movements were corrected on the basis of Independent Component Analysis (Vigário, 1997), after which the signal was down-sampled to 512 Hz. We epoched the data -3 to + 1 sec surrounding space bar response and removed trials containing irregularities due to EMG or other artifacts by visually inspecting all trials. To increase spatial specificity and to filter out deep sources we converted the data to spline Laplacian signals (Cohen, 2014). Per participant and per electrode we subtracted the average of all trials from each individual trial to obtain the non-phase-locked power (Kalcher & Pfurtscheller 1995; Donner & Siegel, 2011; Kloosterman et al., 2015). Next we used a sliding window Fourier transform (Mitra & Pesaran, 1999),

window length: 400 ms, step size: 50 ms, to calculate the time-frequency representations of the EEG power (spectrograms) for each channel and each trial. We used a single Hanning taper for the frequency range 4–25 Hz (bin size: 1 Hz [Kloosterman et al., 2015]). Power modulations were characterized as the percentage of power change at a given time and frequency bin relative to baseline power value for that frequency bin. The baseline was calculated as the mean power in the pre-stimulus interval (from -0.3 to 0 s relative to picture onset). All signal processing steps were performed using Brain Vision Analyzer (BrainProducts), Matlab (Matlab 12.1, The MathWorks Inc.), X code (Cohen, 2014) and Fieldtrip (Oostenveld, Fries, Maris, & Schoffelen, 2010).

It has been proposed that creativity relies on binding of previously unconnected representations, established by patterns of neural activity (Thagard & Stewart, 2010). Therefore, creativity might require long-range coordination between distant cortical regions (Dietrich, 2004). To investigate measures of interregional functional connectivity, we assessed the consistency of the difference of time–frequency phase values between two channels in the theta band across trials (Intersite Phase Clustering (ISPC), see Siegel et al., 2012; Cohen, 2014). We used FCz as our 'seed' electrode and paired that electrode with central electrodes Oz, POz, Cz, Fz, AFz Fpz, and dorsolateral electrodes F4/F3. We used the same preprocessing steps as described above for the time-frequency analyses. We used a baseline period of -300-0 ms before picture onset.

In this experiment, we were specifically interested in the relationship between fluctuations in mid frontal (FCz) theta power, changes in theta phase synchrony and varying levels of creativity. We therefore correlated single trial mean theta power changes (compared to baseline) in a time window of -1.5 to -1 sec, -1 to -0.5 sec, -0.5 to 0 sec, and 0 to 0.5 sec relative to space bar press with single trial creativity scores per participant. We pre-selected these four time windows to reduce the amount of comparisons in our analyses, while maintaining the ability to distinguish between different phases of the task (no data before -1.5 sec prior to space bar press was selected because the task was self paced, thereby creating unequal trial lengths). We tested these correlations against zero using one-sample t-tests. Next, we correlated mean levels of creativity with theta phase synchrony values (using FCz as a 'seed' electrode, see above), using our theta power results to base our time widow of interest upon (to limit the amount of comparisons). We corrected for multiple comparisons by adjusting the p value by fixing the false discovery rate (FDR) at 0.05 (Benjamini & Hochberg, 1995).

Finally, we tested whether insight vs. analytical solutions differed in the level of creativity. We tested mean levels of creativity for trials that were judged as analytical versus trials that were judged as insight trials, using a paired t-test (two-sided).

Results

To determine the relationship between fluctuations in top-down control and creativity, we correlated per participant trial-by-trial theta power changes (compared to baseline) with single trial creativity scores in four pre-selected time windows. We observed significant negative correlations between single trial theta power and single trial levels of creativity ($t_{(18)}$= -3.52, p= 0.001, BF_{-0}= 34.00, FDR-corrected p<0.05) exclusively in the 500 ms time period after space bar press (for the other three time windows: FDR-corrected p>0.05). In Figure 2a (left) we displayed the correlations between single trial theta power change and single trial levels of creativity (for illustration purposes we plotted values for all channels, while only examining the value for FCz). These findings demonstrate that a decrease in neural measures of top-down control (mid frontal theta power) relates to increased creative solutions, specifically in the time window when the target picture is no longer visible. To determine if the creative process was still ongoing in the 500ms after spacebar press, we computed the mean time between space bar press and first entry on the keyboard. Participants took on average 37.76 seconds to start submitting their caption after spacebar press (SD=14.79, the participant with the fastest response took on average 11.18 seconds).

To rule out that any of these effects were related to increased attention, we repeated the same analyses but now looking at alpha band (8-12 HZ) activity in the 500 ms after space bar press. We observed no significant correlation between single trial alpha power and single trial levels of creativity ($t_{(18)}$= -1.73, p= 0.101, BF_{-0}= 1.56, see Figure 2a).

Next, we were interested in whether changes in functional connectivity (theta phase synchrony, see methods) in the 500 ms period after stimulus offset related to varying levels of creativity. We observed a significant strong positive correlation between the average level of creativity and mean changes in functional connectivity between FCz and POz (r= 0.60, n=19, R^2= 0.36, p =0.007, BF_{10}= 8.58, FDR-corrected p<0.05). Correlations for all other channels did not survive the correction for multiple comparisons (FDR>0.05), see Figure 3.

Finally, we observed no significant difference between 'analytical' (Mean 2.50, SD: 0.30) and 'insight' (Mean 2.61, SD: 0.25) trials with respect to average level of creativity ($t_{(18)}$= 1.33, p= 0.198).

Discussion

In the present study, we investigated whether oscillatory measures of top-down control related to levels of creativity during an experimentally novel 'caption this' task. We observed a negative relationship between trial-by-trial mid frontal theta power changes and fluctuations in creativity. In addition, we found a strong positive relationship between frontal-occipital functional connectivity change and average levels of creativity, indicating that more creative participants demonstrated a stronger 'maintenance or extended evaluation of internal information' (Andrews-Hanna, Smallwood, & Spreng, 2014). Our findings seem to corroborate recent observations in creative thinking, suggesting a dynamic interplay between opposing intrinsic functional networks: the control network and the internally oriented default-mode network (Fox et al., 2005; Beaty et al., 2015; Beaty et al., 2018).

Previously, creative thinking has been associated with enhanced internally oriented information processing (Benedek, Bergner, Könen, Fink, & Neubauer, 2011). Here, this relationship seems to be supported by a strong positive relationship between occipital-frontal functional connectivity (theta phase synchrony) and creativity after stimulus offset (Figure 3b). It has been demonstrated that occipital-frontal functional connectivity measured in the theta range was associated with keeping (perceptual) information "in mind" (Sarnthein, Petsche, Rappelsberger, Shaw, & Von Stein, 1998; Chou, Duann, She, Huang, & Jung, 2015). Von Stein and Sarnthein (2000) observed a relationship between increased long-range (frontal-posterior) theta synchronization and working-memory retention. In their study, EEG signals were analyzed from the part of the experiment when no external stimulus was present, allowing them to observe activity during entirely internal processing. Similarly to our study, in this phase of a trial internal activity was still partly controlled by the previously presented stimulus. Increased theta synchronization between frontal and posterior cortex were specifically found during the period after stimulus offset, when perceptual information needed to be kept active or imagined. In the present study, increased occipital-frontal functional connectivity in the absence of external information (Figure 3c) indicates that after stimulus offset processing shifts towards internally oriented operations, and that the stronger this shift is the more creative the solutions become (Figure 3).

Alternatively, more creative solutions could induce enhanced functional connectivity changes, creating a stronger and longer lasting internal representation of the presented picture when the solution is more creative. Similarly, a negative relationship between mid frontal theta power and the level of creativity could stem from

the fact that more creative solutions reduce prefrontal control. However, previous work suggests that altered prefrontal activity due to brain stimulation or lesions (causally) affected creative thinking (Chrysikou et al., 2013; Reverberi, Toraldo, D'Agostini, & Skrap, 2005), arguing against a mere epiphenomenal role of frontal activity. Further, in the present study participants did not submit the caption immediately after the 500ms delay period (but instead >10 seconds thereafter), suggesting that the creative process was still ongoing in the period where we found our effects.

Oscillatory activity and creativity

Neural oscillations have been put forward as a mechanism that supports information integration and communication between large-scale neural networks (Buzsáki, 2006; Fries, 2005; Cohen, 2014). Creativity has recently been associated with large-scale network interactions (Beaty et al., 2018), and the integration of distributed neural representation (Thagard & Stewart, 2010). From this perspective, to study the relationship between oscillatory mechanisms, network dynamics, and creativity appears to be a fruitful direction to explore. Recently, it has been hypothesized that alpha oscillations are pivotal in the gating of the flow of information via inhibition of task-irrelevant network activity (Mathewson et al., 2014; Jensen & Mazehari, 2010; Klimesch et al., 2007). For instance, studies showed that a shift of attention to either the left or right visual hemifield decreases alpha in the contralateral hemisphere, and depending on task demands, alpha power increased in dorsal stream when a task relied on ventral stream processing (Jokish & Jensen, 2007; Wokke, Scholte, & Lamme 2014). Previous studies demonstrated that activity in the alpha band related to the divergent-convergent dichotomy (Fink & Benedek, 2014; Jauk, Benedek, & Neubauer, 2012; Krug, Mölle, Dodt, Fehm, & Born, 2003). However, differences in alpha power have also been strongly linked to the amount of effort or attention that is allocated to the task at hand (Klimesch, 1999). Indeed, some findings indicate that the difference between divergent and convergent thinking stems from a difference in task demands (Benedek et al., 2011). In the present study, we focused our analyses on mid frontal theta activity, however, when examining alpha power we did not observe a relation between creativity and alpha power fluctuations (see Figure 2). Similarly, Boot, Baas, Mühlfeld, de Dreu, and van Gaal (2017) did not observe a relation between convergent-divergent thinking and alpha activity. The authors argued that the use of an event-related design 'canceled out the effect of differences in the demands that (the) different tasks place on cognitive resources, rather than the fast-acting processes underlying the creative processes'. As in the present study, Boot et al. (2017) used an event related design that investigated trial-

by-trial fluctuations during a task that probed divergent vs. convergent thinking (thereby keeping processing demands constant). Interestingly, Boot et al. (2017) observed a selective decrease of delta band activity associated with divergent thinking. Previously, decreased delta-band activity over fronto-central regions has been linked to internally oriented processes and default mode network activity (Jann, Kottlow, Dierks, Boesch, & Koenig, 2010; Baird et al., 2012). These findings are in line with the present results demonstrating the importance of internally oriented network activity and creative thinking.

Measures of creativity

One of the major problems when attempting to uncover the neural basis of creativity is to adequately capture and isolate creative thinking. Most psychometric tests currently used are based on dichotomies between for instance divergent-convergent thinking or defocused-focused attention (Guilford, 1967; Torrance, 1974; Mednick, 1962; Dietrich, 2007). However, creative thinking has been associated with both sides of such divisions, making it challenging to separate instances of creative thinking from 'normal thinking'. The main problem is to determine the criterion distinguishing creative vs. normal thinking. Some have argued that research into creativity should therefore focus on the 'creative product' itself (MacKinnon, 1987). In the present study, we focused on the creative solution without looking into traditional convergent-divergent or defocused-focused attention dichotomies. This approach has clear limitations, for instance, by creating a more fuzzy/subjective definition of creativity. However, we believe that this approach is more ecologically valid. As depicted above, dichotomies such as divergent-convergent thinking or defocused-focused attention might result in clear divisions on one scale, however, when trying to capture and isolate creative thinking and distinguish it from 'normal thinking' such divisions could result in throwing away the baby with the bathwater. When using a creative product approach, it is critical that a large variation of tasks, groups and methods are being used, while keeping possible contaminating factors (such as task load) constant. Therefore, it would be interesting and important to investigate whether the present results generalize to different tasks and settings that capture different aspects of creative thinking.

In sum, the present findings demonstrate that lower levels of frontal theta (strongly associated with reduced top-down control) related to creative performance. In addition, we observed that increased creativity was associated with enhanced long-range functional connectivity between occipital and mid frontal cortex. These results

contribute to a growing amount of evidence linking creativity to large-scale network dynamics, orchestrating the balance between internally and externally oriented network activity. These findings could be important in (the) light of ongoing technological developments (i.e., portable electronic devices) reducing internal reflection by biasing external attention (Immordino-Yang, Christodoulou, & Singh, 2012), thereby possibly hindering creative thinking.

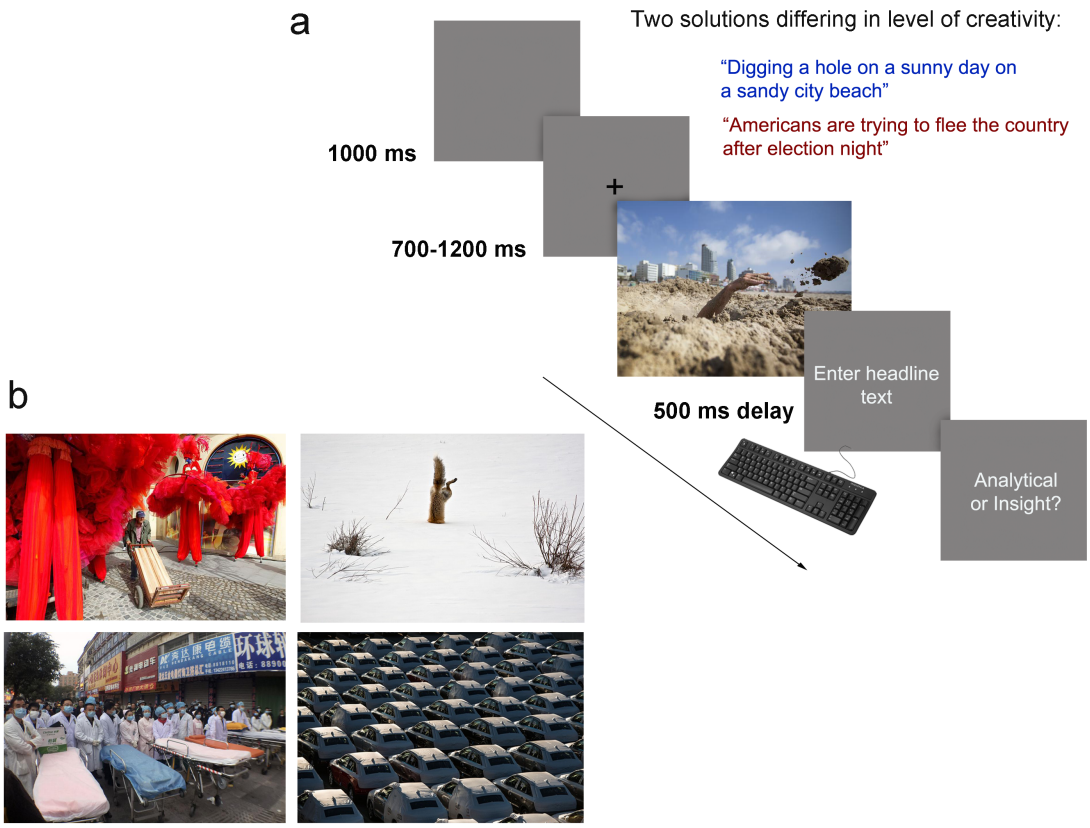

Figure 1. (a) After presentation of a picture participants were instructed to provide a caption to accompany the image. The image disappeared the moment participants pressed the space bar. After a short delay, participants were able to submit the caption. The trial ended probing the way participants constructed the caption. (b) Four examples of stimuli (in the experiment a total of 200 pictures were used)

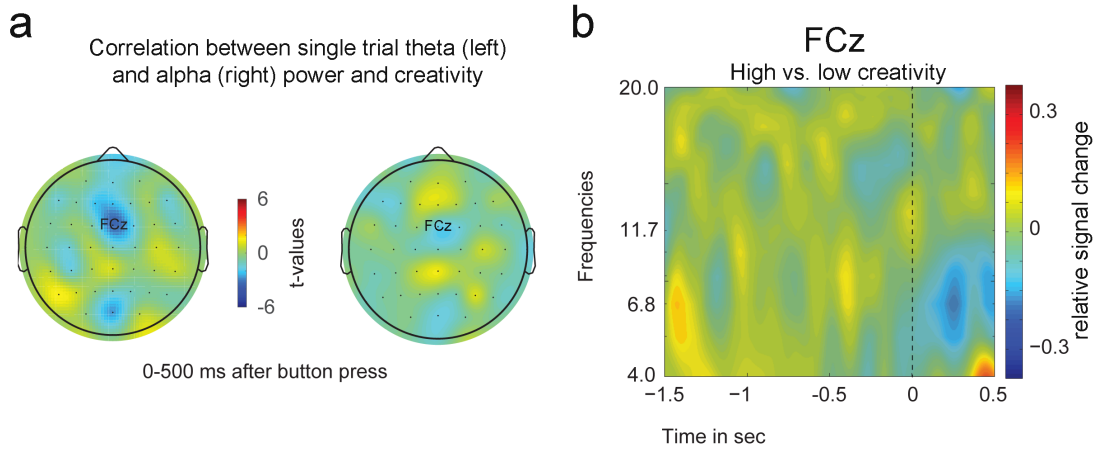

Figure 2. (a) We observed negative correlations between trial-by-trial change in mid frontal theta power and trial-by-trial varying levels of creativity. No correlation was found between alpha power change and levels of creativity. (b) Time-frequency plot of the difference between high (ratings >2) and low (ratings =<2) creative trials, relative to space bar press (time zero).

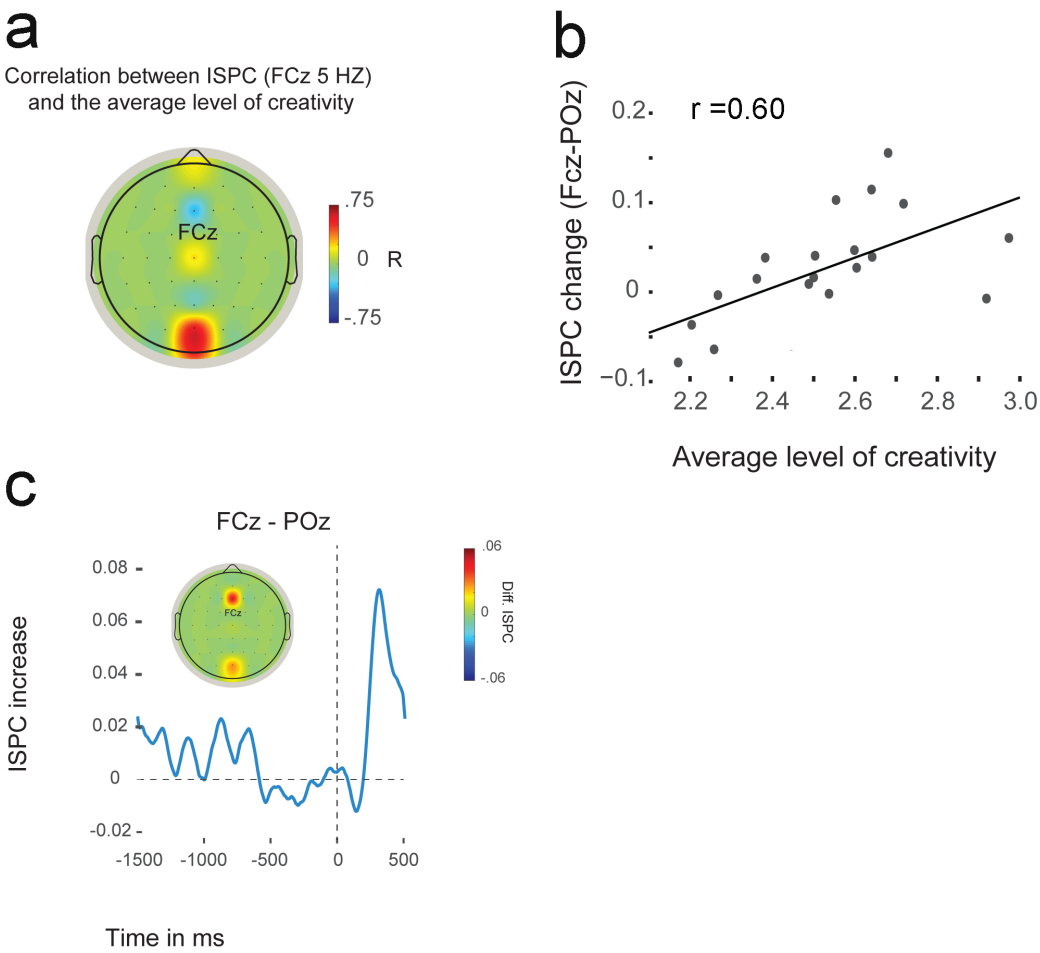

Figure 3. (a-b) We observed a strong positive correlation between functional connectivity changes between FCz and POz and the mean level of creativity. (c) Illustration of functional connectivity (ISPC) change between FCz and POz and the topoplot of mean ISPC change between FCz and all other channels in the 500 ms after space bar press.

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References

Andrews-Hanna, J. R., Smallwood, J., & Spreng, R. N. (2014). The default network and self-generated thought: component processes, dynamic control, and clinical relevance. *Annals of the New York Academy of Sciences*, *1316*(1), 29-52.

Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W., Franklin, M. S., & Schooler, J. W. (2012). Inspired by distraction: mind wandering facilitates creative incubation. *Psychological science*, *23*(10), 1117-1122.

Beaty, R. E., Benedek, M., Kaufman, S. B., & Silvia, P. J. (2015). Default and executive network coupling supports creative idea production. *Scientific reports*, *5*, 10964.

Beaty, R. E., Benedek, M., Silvia, P. J., & Schacter, D. L. (2016). Creative Cognition and Brain Network Dynamics. *Trends in Cognitive Sciences, 20(2),* 87-95.

Beaty, R. E., Benedek, M., Wilkins, R. W., Jauk, E., Fink, A., Silvia, P. J., Hodges, D. A., Koschutnig, K., & Neubauer, A. C. (2014). Creativity and the default network: A functional connectivity analysis of the creative brain at rest. *Neuropsychologia*, *64*, 92-98.

Beaty, R. E., Kenett, Y. N., Christensen, A. P., Rosenberg, M. D., Benedek, M., Chen, Q., Fink, A. Qiu, J., Kwapil, T. R., Kane, M. J., & Silvia, P. J. (2018). Robust prediction of individual creative ability from brain functional connectivity. *Proceedings of the National Academy of Sciences, 115(5),* 1087-1092.

Benedek, M., Bergner, S., Könen, T., Fink, A., & Neubauer, A. C. (2011). EEG alpha synchronization is related to top-down processing in convergent and divergent thinking. *Neuropsychologia*, *49*(12), 3505-3511.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. *Journal of the Royal Statistical Society, 57(1),* 289-300.

Boot, N., Baas, M., Mühlfeld, E., de Dreu, C. K., & van Gaal, S. (2017). Widespread neural oscillations in the delta band dissociate rule convergence from rule divergence during creative idea generation. *Neuropsychologia*, *104*, 8-17.

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network. *Annals of the New York Academy of Sciences*, *1124*(1), 1-38.

Buzsaki, G. (2006). *Rhythms of the Brain*. Oxford University Press.

Carson, S. H. (2014). Cognitive disinhibition, creativity, and psychopathology. *The Wiley handbook of genius*, 198-221.

Cavanagh, J. F., & Frank, M. J. (2014). Frontal theta as a mechanism for cognitive control. *Trends in Cognitive sciences, 18*, 8.

Chou, W. C., Duann, J. R., She, H. C., Huang, L. Y., & Jung, T. P. (2015). Explore the functional connectivity between brain regions during a chemistry working memory task. *PloS one*, *10*(6), e0129019.

Chrysikou, E. G., Novick, J. M., Trueswell, J. C., & Thompson-Schill, S. L.(2011). The other side of cognitive control: Can a lack of cognitive control benefit language and cognition? *Topics in Cognitive Science, 3,* 253-256.

Chrysikou, E. G., Hamilton, R. H., Coslett, H. B., 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. *Cognitive Neuroscience. 4(2),* 81-89.

Cohen, M. X. (2014). *Analyzing neural time series data: theory and practice*. MIT press.

Cohen, M. X., & Cavanagh, J. F. (2011). Single-trial regression elucidates the role of prefrontal theta oscillations in response conflict. *Frontiers in Psychology*, *2*, 30.

Dietrich, A. (2004). The cognitive neuroscience of creativity. *Psychonomic bulletin & review*, *11*(6), 1011-1026.

Dietrich, A. (2007). Who's afraid of a cognitive neuroscience of creativity?. *Methods*, *42*(1), 22-27.

Dietrich, A., & Haider, H. (2017). A Neurocognitive Framework for Human Creative Thought. *Frontiers in Psychology, 7,* 1-7.

Dietrich, A., & Kanso, R. (2010). A review of EEG, ERP and neuroimaging studies of creativity and insight. *Psychological Bulletin, 136*, 822–848.

Donner, T. H., Siegel, M. (2011). A framework for local cortical oscillation patterns. *Trends in Cognitive Sciences, 15,* 191–199.

Fink, A., & Benedek, M. (2014). EEG alpha power and creative ideation. *Neuroscience & Biobehavioral Reviews*, *44*, 111-123.

Fox, M. D., Snyder, A. Z., Vincent, J. L., Corbetta, M., van Essen, D. C., & Raichle, M. E. (2005). The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proceedings of the National Academy of Sciences of the United States of America, 102(27),* 9673-9678.

Fries, P. (2005). A mechanism for cognitive dynamics: neuronal communication through neuronal coherence. *Trends in cognitive sciences*, *9*(10), 474-480.

Guilford, J. P. (1967). Creativity: Yesterday, today and tomorrow. *The Journal of Creative Behavior*, *1*(1), 3-14.

Hipp, J. F., Engel, A. K., & Siegel, M. (2011). Oscillatory synchronization in large-scale cortical networks predicts perception. *Neuron*, *69*(2), 387-396.

Immordino-Yang, M. H., Christodoulou, J. A., & Singh, V. (2012). Rest is not idleness: Implications of the brain's default mode for human development and education. *Perspectives on Psychological Science*, *7*(4), 352-364.

Jann, K., Kottlow, M., Dierks, T., Boesch, C., & Koenig, T. (2010). Topographic electrophysiological signatures of fMRI resting state networks. *PloS one*, *5*(9), e12945.

Jauk, E., Benedek, M., & Neubauer, A. C. (2012). Tackling creativity at its roots: Evidence for different patterns of EEG alpha activity related to convergent and divergent modes of task processing. *International Journal of Psychophysiology*, *84*(2), 219-225.

Jensen, O., & Mazaheri, A. (2010). Shaping functional architecture by oscillatory alpha activity: gating by inhibition. *Frontiers in human neuroscience*, *4*, 186.

Jokisch, D., & Jensen, O. (2007). Modulation of gamma and alpha activity during a working memory task engaging the dorsal or ventral stream. *Journal of Neuroscience*, *27*(12), 3244-3251.

Jung, R. E., Grazioplene, R., Caprihan, A., Chavez, R. S., & Haier, R. J. (2010a). White matter integrity, creativity, and psychopathology: disentangling constructs with diffusion tensor imaging. *PLoS One*, *5*(3), 9818.

Kalcher, J., Pfurtscheller, G. (1995). Discrimination between phase-locked and non-phase locked event-related EEG activity. *Electroencephalography and clinical neurophysiology, 94*, 381–384.

Kaufman, S. B., DeYoung, C. G., Gray, J. R., Jiménez, L., Brown, J., & Mackintosh, N. (2010). Implicit learning as an ability. *Cognition*, *116*(3), 321-340.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. *Brain research reviews*, *29*(2-3), 169-195.

Klimesch, W., Sauseng, P., & Hanslmayr, S. (2007). EEG alpha oscillations: the inhibition timing hypothesis. *Brain research reviews*, *53*(1), 63-88.

Kloosterman, N. A., Meindertsma, T., Hillebrand, A., van Dijk, B. W., Lamme, V. A., & Donner, T. H. (2015). Top-down modulation in human visual cortex predicts the stability of a perceptual illusion. *Journal of Neurophysiology, 113*, 1063–1076.

Krug, R., Mölle, M., Dodt, C., Fehm, H. L., & Born, J. (2003). Acute influences of estrogen and testosterone on divergent and convergent thinking in postmenopausal women. *Neuropsychopharmacology*, *28*(8), 1538.

Landis, J. R., & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *International Biometric Society, 33(1),* 159-174.

MacKinnon, D. W. (1987). Some critical issues for future research in creativity. *Frontiers of creativity research: Beyond the basics*, 120-130.

Mathewson, K. E., Beck, D. M., Ro, T., Maclin, E. L., Low, K. A., Fabiani, M., & Gratton, G. (2014). Dynamics of alpha control: preparatory suppression of posterior alpha oscillations by frontal modulators revealed with combined EEG and event related optical signal. *Journal of cognitive neuroscience*, *26*(10), 2400-2415.

McMillan, R., Kaufman, S. B., & Singer, J. L. (2013). Ode to positive constructive daydreaming. *Frontiers in psychology*, *4*, 626.

Mednick, S. (1962). The associative basis of the creative process. *Psychological review*, *69*(3), 220.

Mell, J. C., Howard, S. M., & Miller, B. L. (2003). Art and the brain: The influence of frontotemporal dementia on an accomplished artist. *Neurology, 60,* 1707-1710.

Mitra, P. P., & Pesaran, B. (1999). Analysis of dynamic brain imaging data. *Biophysical journal*, *76*(2), 691-708.

Mok, L. W. (2014). The interplay between spontaneous and controlled processing in creative cognition. *Frontiers in human neuroscience*, *8*,663.

Oostenveld, R., Fries, P., Maris, E., Schoffelen, J. M. (2011). FieldTrip: open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. *Computational Intelligence and Neuroscience, 2011*, 156869.

Razoumnikova, O. M. (2007). Creativity related cortex activity in the remote associates task. *Brain Research Bulletin, 63*(1-3), 96-102.

Reverberi, C., Toraldo, A., D'agostini, S., & Skrap, M. (2005). Better without (lateral) frontal cortex? Insight problems solved by frontal patients. *Brain*, 128(12), 2882-2890.

Sarnthein, J., Petsche, H., Rappelsberger, P., Shaw, G. L., & Von Stein, A. (1998). Synchronization between prefrontal and posterior association cortex during human working memory. *Proceedings of the National Academy of Sciences*, *95*(12), 7092-7096.

Sauseng, P., Klimesch, W., Freunberger, R., Pecherstorfer, T., Hanslmayr, S., & Doppelmayr, M. (2006). Relevance of EEG alpha and theta oscillations during task switching. *Experimental Brain Research*, *170*(3), 295-301.

Siegel, M., Donner, T. H., & Engel, A. K. (2012). Spectral fingerprints of large-scale neuronal interactions. *Nature Reviews Neuroscience*, *13*(2), 121.

Thagard, P., & Stewart, T. C. (2010). The AHA! Experience: Creativity Through Emergent Binding in Neural Networks. *Cognitive Science, 35,* 1-33.

Torrance, E. P. (1974). *The Torrance Tests of Creative Thinking-Norms Technical Manual Research Edition-Verbal Tests, Forms A and B Figural Tests, Forms A and B.* Princeton, NJ: Personnel Press.

Van de Vijver, I., Ridderinkhof, K. R., & Cohen, M. X. (2011). Frontal oscillatory dynamics predict feedback learning and action adjustment. *Journal of Cognitive Neuroscience*, *23*(12), 4106-4121.

Van Driel, J., Swart, J. C., Egner, T., Ridderinkhof, K. R., & Cohen, M. X. (2015). (No) time for control: frontal theta dynamics reveal the cost of temporally guided conflict anticipation. *Cognitive, Affective, & Behavioral Neuroscience*, *15*(4), 787-807.

Vigário, R. N. (1997). Extraction of ocular artefacts from EEG using independent component analysis. *Electroencephalography and Clinical Neurophysiology, 103*, 395– 404.

Von Stein, A., & Sarnthein, J. (2000). Different frequencies for different scales of cortical integration: from local gamma to long range alpha/theta synchronization. *International journal of psychophysiology*, *38*(3), 301-313.

Wokke, M. E., Cleeremans, A., & Ridderinkhof, K. R. (2017). Sure I'm sure. *The Journal of Neuroscience*, *37*, *781-789.*

Wokke, M. E., Talsma, L. J., & Vissers, M. E. (2015). Biasing neural network dynamics using non-invasive brain stimulation. *Frontiers in systems neuroscience*, *8*, 246.

Wokke, M. E., Scholte, H. S., & Lamme, V. A. (2014). Opposing dorsal/ventral stream dynamics during figure-ground segregation. *Journal of cognitive neuroscience*, *26*(2), 365-379.

Zedelius, C. M., & Schooler, J. W. (2016). The richness of inner experience: relating styles of daydreaming to creative processes. *Frontiers in psychology*, *6*, 2063.