Alpha power over right/mid-frontal regions supports the generation of remote associations in higher creative individuals

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Introduction

The generation of semantically remote concepts is a core aspect of creativity.

However, little is known about the neural correlates of the generation of spontaneous associations, and how they vary in relation to individual differences in creative ability.

Using a free association generation task while recording EEG, we investigated the neural correlates of words with high vs. low semantic proximity.

Methods

Participants

100 participants were recruited from Queen Mary University of London (51 women; mean age = 21.96 y, SD = 2.66 y). Participants generated at least ten responses for each of the four items.

Free association (FA) generation task

Generate as many associations of a word (king, light, mountain, lion) as possible within 2 mins **(Fig. 1).**

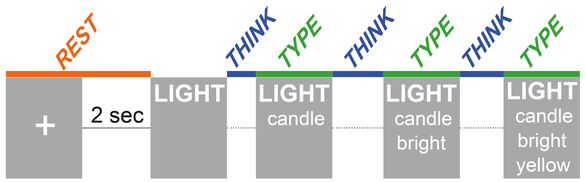

Fig. 1. Trial structure of the free association generation task.

Creativity tasks

Participants' creativity was assessed via the **Alternative Uses Task (AUT).** Generate as many alternative uses of an object (table, shoe, tin-can, umbrella; 2 min); and the **Figure completion task.** Make a drawing to complete an abstract image (1.5 min; **Fig. 2**).

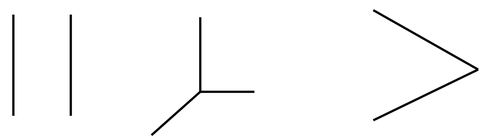

Fig. 2. Examples of images from the figure completion task.

EEG recording & preprocessing

The EEG signals were recorded by eighteen PiStim electrodes placed according to the extended 10-20 electrode placement system. EEG signal was re-referenced to mean earlobes, and filtered via a high-pass at 0.5 Hz and notch filter at 45-55 Hz. Noisy electrodes interpolated & noisy epochs rejected after visual inspection, and eye-blinks were corrected via ICA. Finally, we focus our analysis on the EEG signal during THINK time windows.

Forward Flow (FF): A measure of semantic distance

We first controlled for fluency confounds and standardized across the different items used. Then, for each item we computed the average and item-level FF score, conducted via the forward flow website (www.forwardflow.org). For the average FF analysis, we computed a compiled FF score. This compiled score was computed via principal component analysis. Each item FF score was weighted by its first factor weight. **(Fig. 3).**

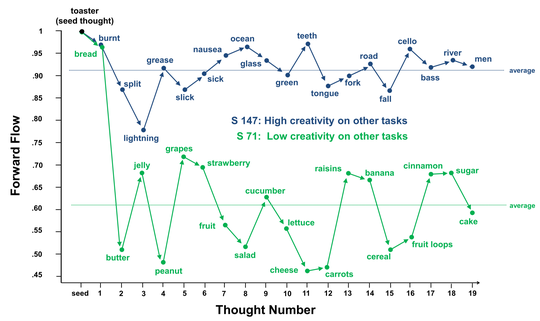

Fig. 3. Examples of word streams of a high and low creative individuals

Behavioral results

A general creativity score was computed by calculating the average creativity performance in the AUT and the Figural task (4 judges, z-scored). Participants were split into 2 groups (median split): higher (N = 50) vs. lower (N = 50) creativity groups. We then measured average RT, semantic distances, FF, and fluency of the FA task across individuals and groups (**Fig. 4**)

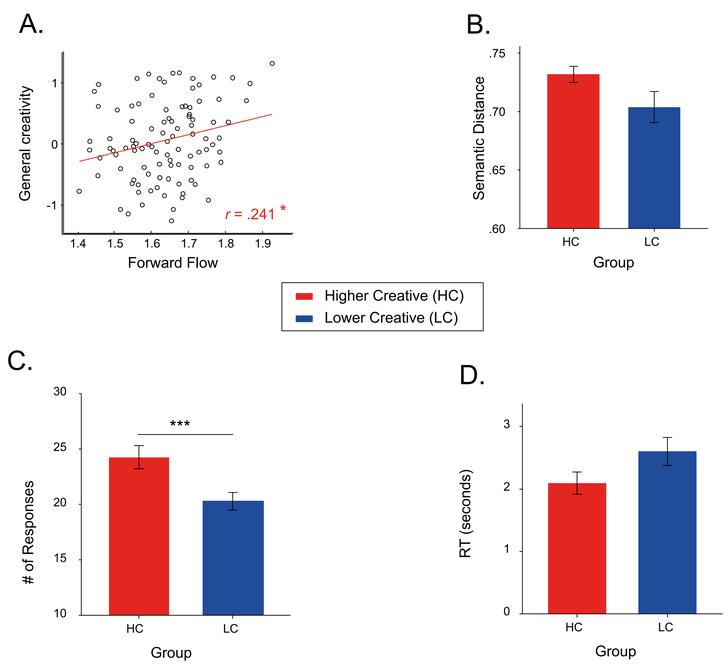

Fig. 4. A) FF is positively correlated with general creativity. B) HC generate averaged more distant, yet not significant, FA than LC. C) HC generate significantly more responses compared to LC. D) HC FA responses are (not significantly) quicker than LC FA responses. Error bars represent ±1 SEM. *** - p < .001; * - p < .05.

EEG Results

The EEG signal (entire duration from the start until the end of the "thinking time" for each response) was convolved with a complex Morlet wavelet on a trial-by-trial basis for Time Frequency Representation (TFR) analysis (**Fig. 5**). The TFR was calculated from 2 to 40 Hz, in steps of 1 Hz, using six-cycle wavelets. The TFR values were transformed to the base 10 logarithm. Each trial was normalized by subtracting a 500 ms baseline from the resting state period (fixation cross before item presentation). The TFR values were averaged over the whole epoch, and for each condition (high vs. low semantic distance responses) for each participant. We analysed the traditional frequency bands: theta (4-8 Hz), alpha (8-12 Hz), beta (13-30 Hz), and gamma (30-40 Hz), as well as the individual alpha frequency (IAF; the frequency with the highest power from 8 to 12 Hz at Pz electrode). The IAF power was calculated as the power of the individual peak frequency averaged over ±1 Hz.

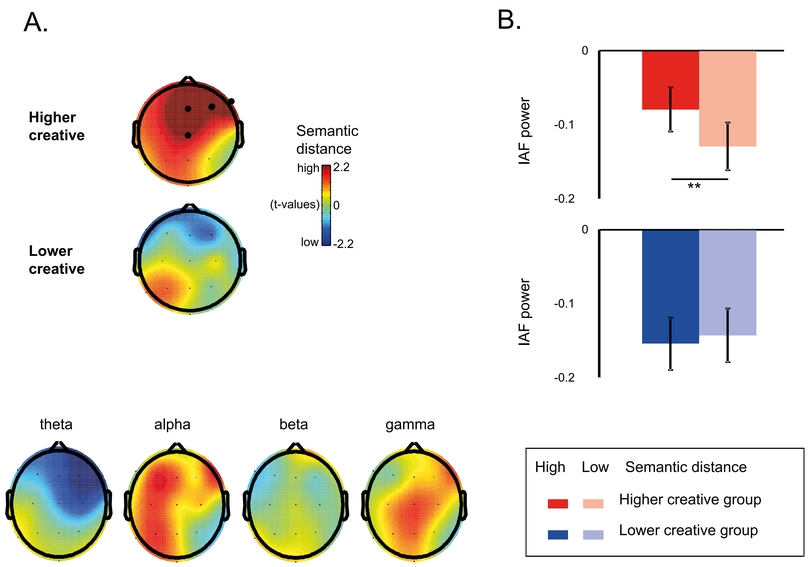

Fig. 5. EEG power differences during production of responses with high vs. low semantic distance in higher vs. lower creativity groups. A) Topographical distributions of t-values representing individual alpha frequency (IAF) differences during FA task. B) The generation of semantically distant concepts is associated with higher alpha frequency activation over right and mid frontal areas, but only for HC. C) No effect is found in the other frequency bands. Error bars represent ±1 SEM. ** - p < .01.

Conclusions

We suggest that enhanced alpha oscillations at right/mid-frontal areas relate to the spontaneous generation of semantically remote concepts, uniquely in higher creative individuals.

Increased alpha power in the prefrontal cortex during free associations in higher creative individuals could indicate that they tend to suppress cognitive control regions as they generate semantic associations or represent an active inhibition process in which alpha oscillations regulate the access to knowledge systems within this area.

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