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Supplementary Materials for

Brain connectivity–based prediction of real-life creativity is mediated by semantic memory structure

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SI Supplementary Tables

Table S1. Relationship between individual semantic network metrics, creativity scores, and age, education, IQ and sex. For age, education and IQ factors we ran Spearman correlations. We ran Mann-Whitney U non-parametric tests using sex as a group variable. * - $p < .05$ ** - $p < .010$ *** - $p < .005$. In bold are correlations that reached significance after FDR correction for multiple comparisons.

Variables	age		education		IQ		sex	
	r_s	p	r_s	p	r_s	p	U	p
Creativity scores								
ICAA_Act	-.021	.844	-.188	.070	-.065	.533	1084.5	.906
ICAA_Ach	.064	.541	-.240*	.020	.122	.242	1055	.733
WUN metrics								
ASPL	.054	.608	-.023	.825	-.091	.384	824*	.036
CC	-.058	.580	.086	.408	.157	.130	761*	.010
Q	.020	.846	-.027	.799	-.279**	.006	**687*** **	**.002**
S	-.117	.263	-.197	.057	-.192	.064	886	.105
UUN metrics								
ASPL	.031	.766	-.103	.325	-.113	.279	785*	.017
CC	.027	.796	.159	.125	.066	.528	865	.075
Q	-.050	.635	.027	.798	-.184	.076	**694*** **	**.002**
S	.111	.287	-.016	.878	-.118	.258	854	.062

Table S2. Relationship between individual semantic network metrics and creativity explored in 93 participants. The Spearman correlations between SemNet metrics and creativity scores are reported (r_s for *C-Act* and *C-Ach*) for 93 participants (i.e., excluding the participant who performed the RJT outside the scanner). In bold are the significant predictions of creativity from the SemNet properties after permutation testing. * indicate correlations that reached significance after FDR correction for multiple comparisons.

Creativity scores	*C-Act*		*C-Ach*	
	r_s	*p*	r_s	*p*
WUN metrics				
ASPL	**-.278**	**.007***	-.192	.065
CC	.164	.116	.188	.072
Q	-.179	.086	**-.291**	**.005***
S	.241	.020	-.001	.994
UUN metrics				
ASPL	-.125	.233	-.133	.203
CC	.089	.394	.062	.553
Q	**-.284**	**.006***	**-.290**	**.005***
S	-.155	.137	-.213	.041

Table S3. Descriptive statistics of creativity scores for the eight domains explored by the ICAA questionnaire. Data are shown for real-life creativity activities (*C-Act*) and achievements (*C-Ach*).

ICAA domains	mean	S.D.	Min	Max	Skewness	Kurtosis
C-Act						
Literature	6.979	4.333	0	21	0.508	0.199
Music	5.521	5.900	0	24	1.235	0.691
Arts and crafts	8.872	5.757	0	22	0.449	-0.65
Creative cooking	9.830	5.847	0	24	0.299	-0.541
Sports	3.394	4.266	0	24	1.950	5.160
Visual arts	6.213	5.410	0	24	1.166	0.955
Performing arts	3.277	2.942	0	11	0.867	-0.067
Science and engineering	3.809	3.833	0	15	0.979	0.268
C-Ach						
Literature	7.149	7.844	0	31	1.181	0.784
Music	9.117	9.687	0	49	1.166	1.818
Arts and crafts	8.851	9.880	0	55	2.467	7.398
Creative cooking	7.596	5.138	0	25	1.069	1.928
Sports	12.734	13.231	0	55	0.764	-0.286
Visual arts	9.383	11.526	0	55	2.150	4.454
Performing arts	9.160	10.055	0	47	1.267	1.406
Science and engineering	10.649	11.212	0	46	1.086	0.858

SI Supplementary text

Material and Methods.

S1: RJT motor and task training.

Before the RJT task, participants performed a motor and task training outside the MRI scanner. The motor training was performed for the participants to become familiar with the trackball used as an fMRI response device. The training consisted of 25 trials that had the same structure and timing as in the actual task (**Figure 1A**), but instead of word pairs, a number was presented on the screen. Participants were instructed to locate the proposed number on the visual scale by moving the slider using the trackball. Each training trial began with the display of a random number in the center of the screen along with a visual scale below going from 0 to 100. Numbers could have any of the values of the visual scale, and only the extreme values (0 and 100) were displayed on the visual scale. The stimuli were displayed for 4 seconds in total including a reflection period of 2 seconds, and a response period of 2 seconds. During reflection period, participants could visualize the position of the proposed number on the visual scale, but they couldn't move the slider yet. During the response period, the cursor appeared in the middle of the visual scale and the participants were allowed to move the slider on the visual scale to locate it on the position of the proposed number. Participants were asked to validate their response by clicking the left button of the trackball. After the validation, participants received a feedback on the screen indicating the position of the slider on the visual scale at the moment they validated their response. When participants did not validate their response, they received a feedback indicating that they were unable to complete the trial during the response period. At the end of each trial, an inter trial interval jittered from 0.3 to 0.7 seconds (interval = 0.05) occurred before the next trial.

The task training was performed to familiarize the participants with the actual task. This training followed the same principles and timing than the actual task and only varied from it regarding the words used. Participants performed 15 trials. Each trial included the reflection period, the response period and an inter trial interval. Before starting the fMRI acquisition, the participants performed the motor and the task training inside the scanner. In addition, we ensured that all participants were familiar with the 35 words used in the RJT.

S2: Selection of the verbal material of the RJT task.

We developed a computational method to select the verbal material of the RJT task by controlling for linguistic properties and the semantic distance between all possible pairwise combinations between the selected words (*26*). To this aim, we first built a French semantic network of 1,081 words, based on French verbal association norms (http://dictaverf.nsu.ru/dictlist). Then, we computed the shortest path between all pair of nodes (i.e., 1,081 words) in the network, serving as the theoretical semantic distance between the words (*70*).

Second, we developed a computational method to select words with specific associative and linguistic properties in this French semantic network. The method searched for solutions that included a total of 35 words (more words would increase the duration of the RJT task exponentially, 35 words led to 595 word pairs which took 1 hour to judge in the RJT), that were nouns, with a lexical frequency greater than 20 occurrences per million and a number of syllables lower or equal than 3. In addition, words used in the creativity tasks were excluded from the selection. The selection method searched for solutions that optimally balanced the theoretical semantic distance between word pairs. In other words, we selected the words that optimized the proportion of pairs composed of words separated by 1, 2, 3, 4, or 5 or more steps. The selected verbal material contained a set of 35 nouns which resulted in 595 word pair combinations with semantic distances distributed as follow: 10% of 1 step, 18% of 2 steps, 28% of 3 steps, 26% of 4 steps, 15% of 5 steps and 3% of 6 steps. Some of the were polysemous and also belong to another grammatical category, such as verbs (conjugated form, N = 10), adjectives (N = 3), adjectives and verbs (N = 1), and adjectives and adverbs (N = 1). The resulting selection included an approximately balanced mixture of concrete and abstract words.

S3: Summary of questions of the Inventory of Creative Activities and Achievements (ICAA; https://osf.io/4s9p6/; a full description is given in Diedrich et al. (*29*)**)**

The ICAA assesses creative activities and achievements across eight domains.
Creative activities (*C-Act*):
To explore the engagement of the participants in each creative domain, six activities were proposed for each domain, and participants were asked to indicate how often they have carried out this activity over the past 10 years (*29*). The response options were: Never, 1-2 times, 3-5 times, 6-10 times, more than 10 times. We provide one example of the activities proposed for each domain:

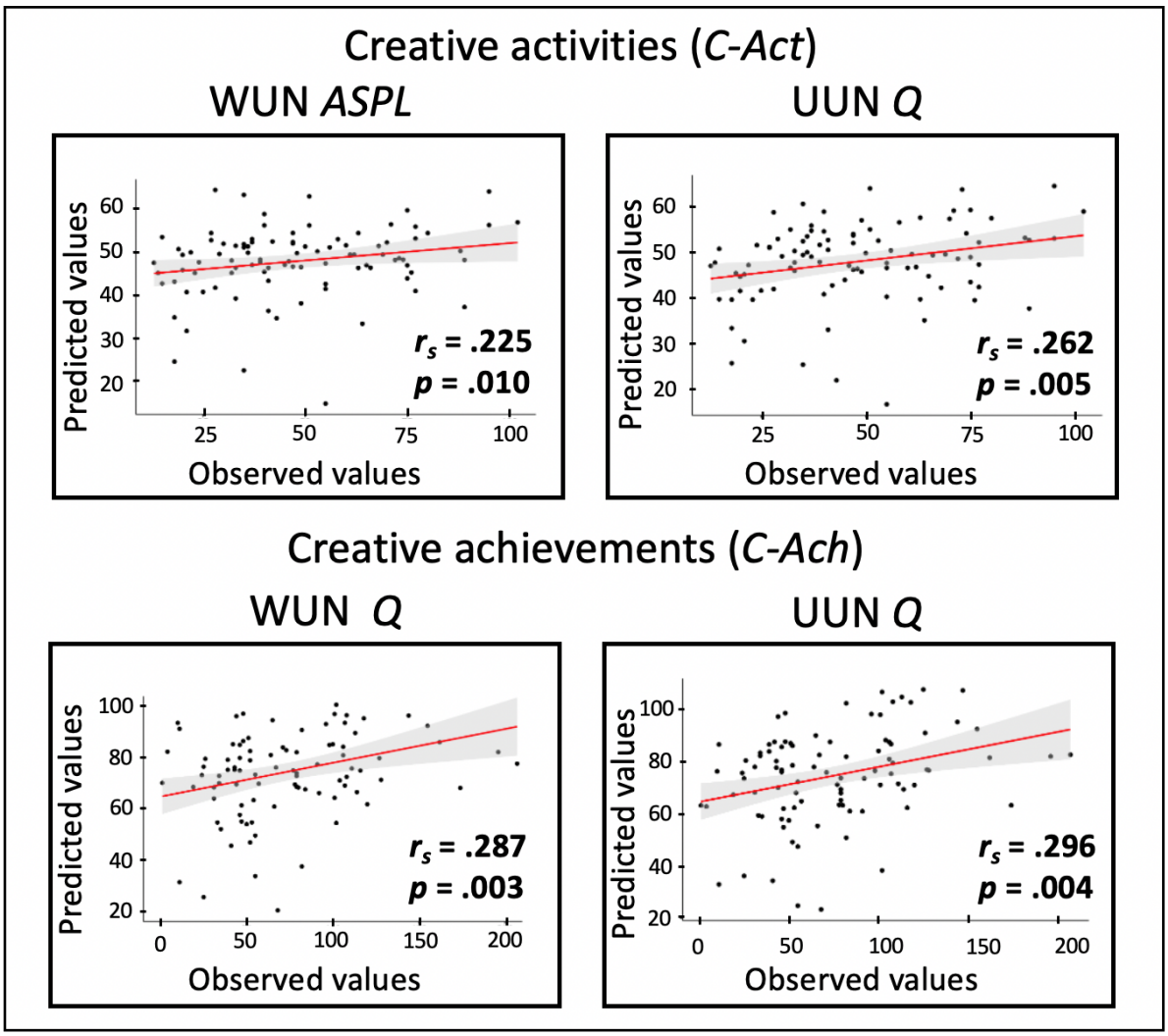
Literature: Wrote a short literary work (e.g., poem, short story).
Music: Wrote a piece of music.
Art and Crafts: Tinkered with a common, everyday object.
Creative cooking: Cooked an original dish.
Sports: Created new tricks/movement sequences requiring dexterity (e.g., juggling).
Visual arts: Created a photomontage or photo collection.
Performing arts: Performed in a play.
Science and Engineering: Wrote a scientific paper.

Creative achievements (*C-Ach*):
To explore the level of achievement in each creative domains, participants answered to these 10 premises, going from a more personal to a more public level of achievement:

(0) I have never been engaged in this domain
(1) I have tried this domain once
(2) I have already created at least one original work in this domain
(3) I have presented my original work in this domain to some friends
(4) I have presented my original work in this domain to strangers
(5) I have already taken classes to improve my skills in this domain
(6) I have already published my original work in this domain
(7) I have already participated in a contest in this domain
(8) I have already won an award or prize for my original work in this domain
(9) Media have already reported about my work in this domain
(10) I have already sold some of my work in this domain.

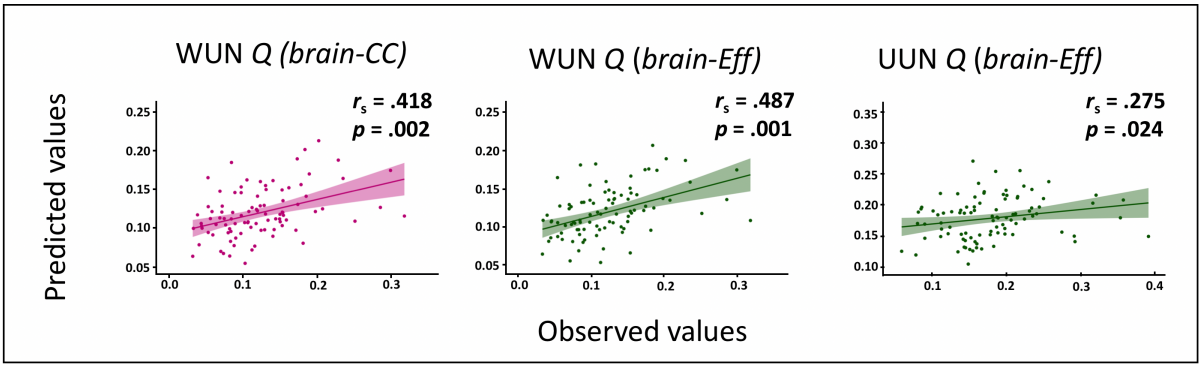
SI Supplementary Figures

Supplementary Figure S1



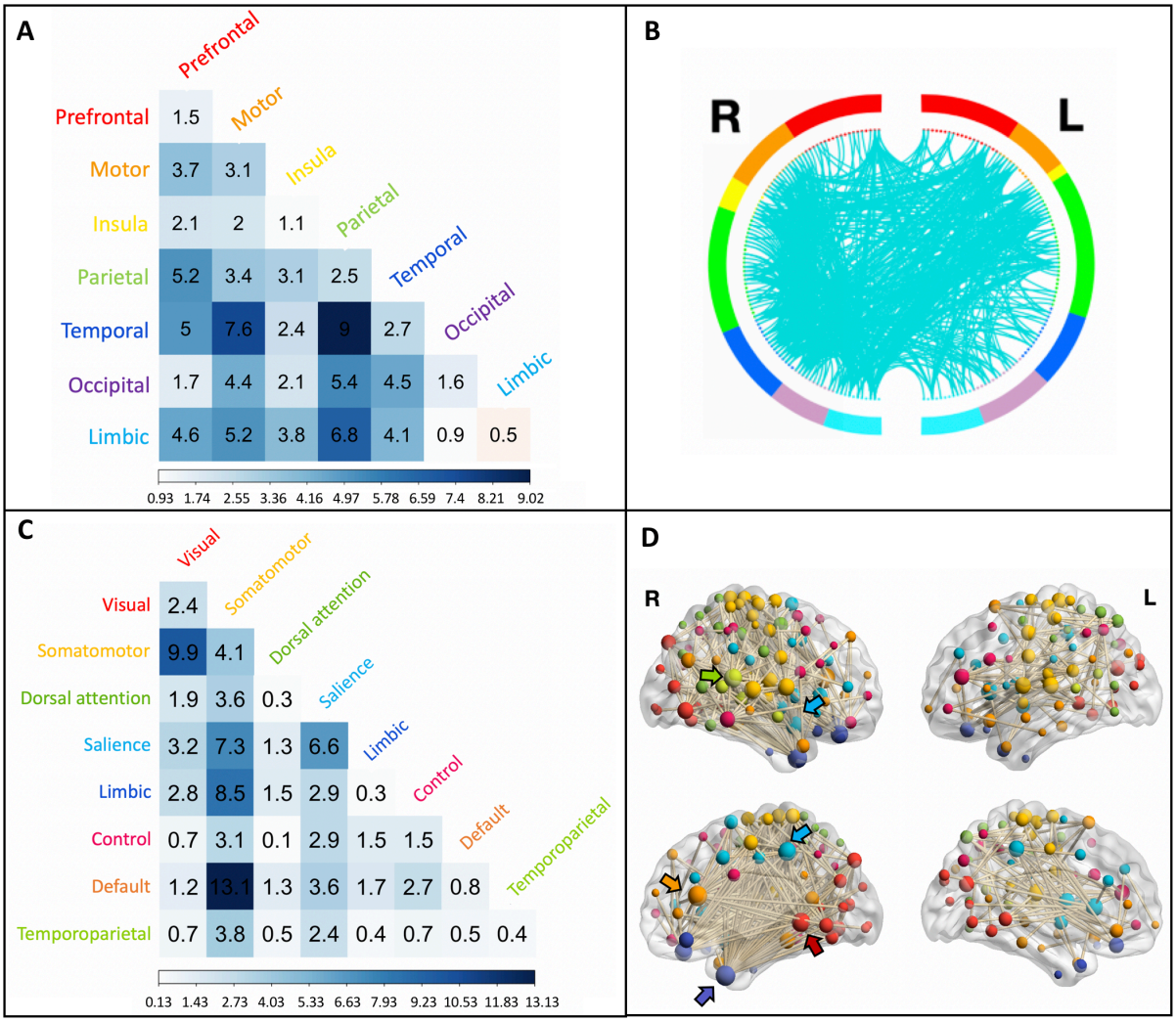
Supplementary Figure S1. Prediction of creativity scores from Semantic network metrics controlling for sex, education and IQ. The plots show the Spearman correlations between the predicted values (y-axis) and observed values (x-axis) of creative activities and achievements based on individual SemNet metrics for the significant predictions controlling for sex, education, and IQ variables. In the bottom-right part of each plot, we present the r_s and the p values, based on permutation testing.

Supplementary Figure S2



Supplementary Figure S2. Predicted and observed SemNet metrics controlling for sex, education and IQ variables. The plots show the Spearman correlations between the predicted values (y-axis) and observed values (x-axis) of SemNet metrics based on brain connectivity for the significant predictions. Green plots are presented for *brain-Eff* and magenta ones for *brain-CC*. In the upper-right side of each plot, we present the r_s and the *p* values, based on permutation testing.

Supplementary Figure S3



Supplementary Figure S3. Functional anatomy of the CPM-predicted SemNet metric WUN *Q*. (**A**) First, we examined the distribution of the links of the model network at the brain location level, specifically into the brain lobes. The correlation matrix represents the percentage of links within the model network connecting seven different brain lobes (total of links = 754). (**B**) A circular graph represents the distribution of links within and between brain regions in the left and right hemispheres. Brain regions are color-coded as in (**A**) and the cyan lines represent the links connecting the ROIs. For visualization purposes, we used a nodal degree threshold of $k = 20$. (**C**) Second, we examined the distribution of the links across intrinsic functional networks based on Schaefer's atlas *(43)*. The matrix represents the percentage of links within the model network occurring within and between eight intrinsic brain networks. (**D**) The nodes and links of the model network are superimposed on a volume rendering of the brain. The color of the nodes represents the functional network they belong to, using a similar color code as in (**B**). The size of the nodes is proportional to their degree, and the highest degree nodes are marked by arrows. Nodes with degree $k = 0$ are not displayed. The highest degree nodes were found in the right hemisphere in the temporal pole (purple arrow, $k = 65$), medial prefrontal cortex (orange arrow, $k = 64$), extra-striate cortex (red arrow, $k = 48$), temporal parietal (green arrow, $k = 44$), parietal medial (light blue arrow, $k = 40$) and insula (light blue arrow, $k = 37$).