# The relationship between creativity and individual semantic network properties

**Marcela OVANDO-TELLEZ,** Matthieu BERNARD, Yoed KENETT, Mathias BENEDEK, Emmanuelle VOLLE

*FrontLab, Institut du Cerveau et de la Moelle Epinière (ICM), Paris*

## INTRODUCTION

Creativity can be defined as the ability to make new connections between elements that were not associated before [1]. The associative theory of creativity suggests that creative abilities rely on the organization of semantic associations in memory. Recent research has demonstrated the importance of semantic memory regions in creative abilities [2,3,4] and several findings showed that more creative individuals have less common word associations or a less constrained organization of semantic associations [5-10]. Recently, computational network science methods (i.e. semantic networks) have allowed exploring the challenging question of the organization of semantic associations in relation to creativity [8,10].

## AIM

The aim of the current study was to investigate the link between creative abilities and the properties of semantic networks at the individual level, and to this purpose:

❖ To **develop a method allowing to build individual semantic networks** based on a word relatedness task (AJT).
❖ To use this method and **relate the graph metrics of the semantic networks to creative abilities.**

## METHODS

### THE ASSOCIATIVE JUDGMENT TASK (AJT) USED FOR SEMANTIC NETWORKS

### CREATION OF A FRENCH SEMANTIC NETWORK



(http://dictaverf.nsu.ru/)

x= Number of participants who gave the answer
y= Total number of participants surveyed
r = Pearson correlation coefficient

French semantic network

### SELECTION OF WORDS



Based on the number of theoretical steps between words
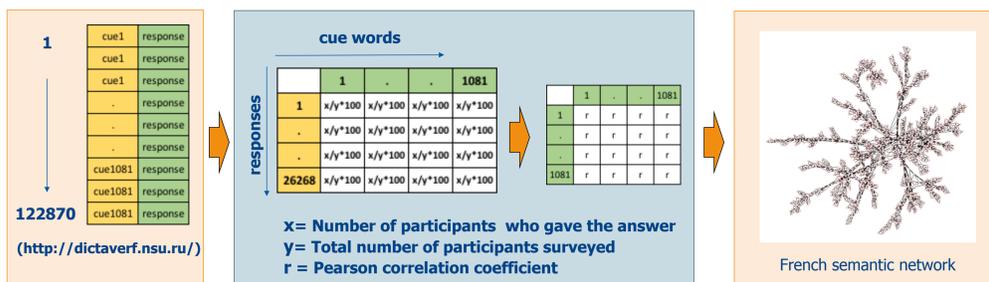
**35** words were selected.
**595** possible combinations.
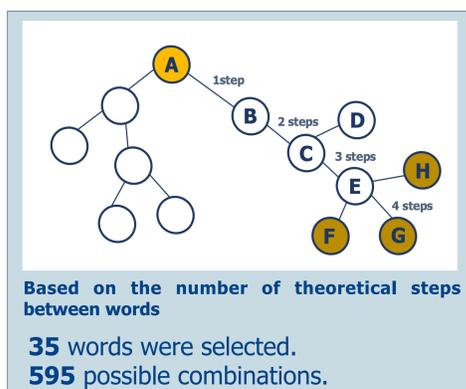
### TASK TRIAL REPRESENTATION



nose    flower

0              100
unrelated    strongly related

**Provides relatedness ratings [10]**

**35** words represent the nodes.
**595** combinations represent the edges.
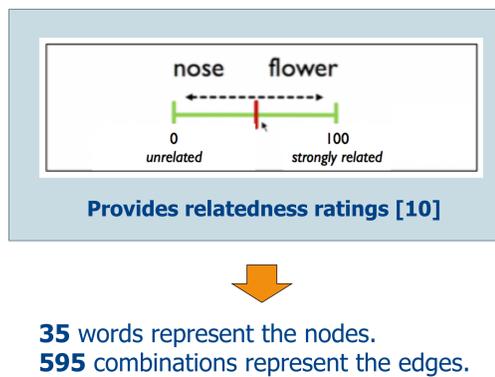
### FROM AJT RATINGS TO INDIVIDUAL SEMANTIC NETWORK MEASUREMENTS

### NETWORK FILTERING

❖ **Weighted Undirected Networks (WUN)** ➔ Edges weighted by the relatedness judgment.

❖ **Unweighted Undirected Networks (UUN)** ➔ Minimum relatedness threshold = 50.

### NETWORK PARAMETERS

Clustering coefficient (CC)      Average shortest path length (ASPL)



Small worldness (S)

Modularity (Q)      Diameter of the graph (D)

### STATISTICAL ANALYSES

**1. VALIDATION OF THE METHOD: correlation ratings – theoretical distance**

**2. CREATIVITY: correlation networks metrics – creativity assessments**

## ASSESSING CREATIVE ABILITIES

### Alternative Uses Task (AUT) [11]
❖ **Fluency:** Number of responses.
❖ **Originality**: Unique response among the top-two rated ideas. [12]



### Combinatorial Association Task (CAT) [9]
❖ **CAT_Total**: Total of correct trials.

WEATHER WATER CLOTHING     ? 1 trial     ARTWORK MOTIONLESS LIBERTY     ? 40 trials

### Inventory of Creative Activities and Achievements (ICAA) [13]
❖ **ICAA**: Creative achievements in 8 different domains.

## RESULTS
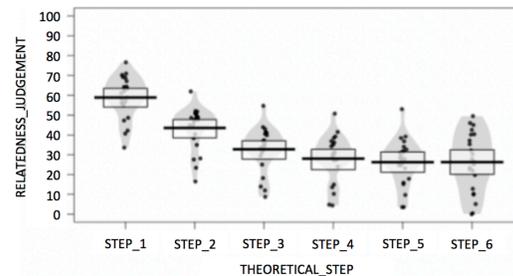


**Figure 1. VALIDATION OF THE METHOD**
**Correlation between the participants' ratings of word pairs and theoretical steps between these pairs according to the French semantic network.**
Correlation between experimental and theoretical semantic distance was significant for all the participants ($p<0.001$) with a correlation coefficient between -0.2 and -0.3.

|  |  | CAT Total | ICAA | AUT Fluency | AUT Originality |
|---|---|---|---|---|---|
| Diameter | UUN | -0,20 | -0,25 | -0,24 | **-0,51**\*\* |
|  | WUN | -0,11 | **-0,35**\* | -0,23 | **-0,45**\*\* |
| ASPL | UUN | -0,09 | -0,22 | -0,05 | **-0,44**\* |
|  | WUN | -0,15 | **-0,34**\* | -0,17 | **-0,41**\* |
| CC | UUN | 0,14 | -0,07 | -0,14 | 0,26 |
|  | WUN | 0,12 | -0,03 | 0,07 | **0,35**\* |
| Q | UUN | 0,03 | -0,27 | -0,15 | **-0,38**\* |
|  | WUN | 0,05 | 0,01 | -0,01 | -0,32 |

**Table 1.**
**LINK WITH CREATIVITY: CORRELATIONS BETWEEN AJT-BASED SEMANTIC NETWORK METRICS AND CREATIVITY SCORES.**
Kendall Tau-b correlations between network metrics and creativity scores.
Bold coefficients reached significance.
(\* $p<0.05$; \*\* $p<0.01$, uncorrected).



**High creative**      **Low creative**
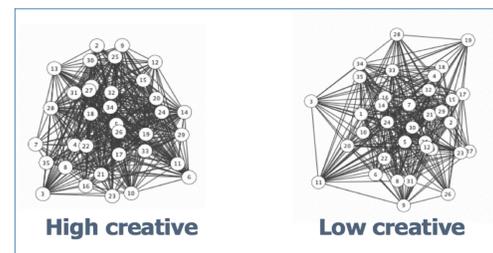
**Figure 2. LINK WITH CREATIVITY: REPRESENTATION OF SEMANTIC NETWORKS OF A HIGH AND A LOW CREATIVE PERSON.**

## CONCLUSION

❖ Close relationship between the organization of semantic associations and creative abilities.
❖ High creative participants presented a more clustered and densely connected semantic network whereas less creative participants had a more spread out and fragmented network with higher path length, replicating and extending the results of previous studies [1,8,10].
❖ The use of individual semantic networks is a promising approach to understand the mechanisms of the creative cognition.
❖ Our findings also provide a new method and tool based on the French semantic network that will be useful in future studies for measuring semantic distance between words in semantic tasks or for building new task material in which semantic distance needs to be controlled.

## PERSPECTIVES

To use graph theory to explore the brain networks which functional connectivity varies with the ability to connect distant concepts as measured by semantic graph metrics.



**Creativity scores**

**Brain connectivity graph metrics**      **Semantic networks**

## REFERENCES

[1] Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review*, 69, 220-232.
[2] Gonen-Yaacovi G., et al. (2013) Rostral and caudal prefrontal contribution to creativity: a meta-analysis of functional imaging data. *Front Hum Neurosci*, 7:465.
[3] Bendetowicz, D., et al. (2018) Two critical brain networks for generation and combination of remote associations. *Brain*, 141, 217-233.
[4] Volle E. (2018) Associative and Controlled Cognition in Divergent Thinking:Theoretical, Experimental,Neuroimaging Evidence, and New Directions. R.Jung & O.Vartanian (Eds.).*The Cambridge Handbook of the Neuroscience of Creativity.*
[5] Rossmann, E. & Fink, A. (2010). Do creative people use shorter associative pathways? *Personality and Individual Differences*, 49, 891-895.
[6] Benedek, M., et al. (2012). Associative abilities underlying creativity. *Psychology of Aesthetics, Creativity, and the Arts,* 6(3), 273-281.
[7] Beaty R. E., et al. (2014). The roles of associative and executive processes in creative cognition. *Memory & Cognition.* 42: 1186–1197.
[8] Kenett, Y. N., Anaki, D., & Faust, M. (2014). Investigating the structure of semantic networks in low and high creative persons. *Frontiers in Human Neuroscience, 8,* 407.
[9] Bendetowicz, D., et al. (2017). Brain morphometry predicts individual creative potential and the ability to combine remote ideas. *Cortex,* 86, 216-229.
[10] Benedek,M., Kenett, Y.N., & Umdasch,C. (2017). How semantic memory structure and intelligence contribute to creative thought: a network science approach. *Thinking & Reasoning*, 23(2), 158-183.
[11] Guilford, J. P. (1967) Creativity: Yesterday, Today and Tomorrow. *The Journal of Creative Behavior* 1, 3-14.
[12] Benedek M., et al. (2013) Assessment of Divergent Thinking by means of the Subjective Top-Scoring Method: Effects of the Number of Top-Ideas and Time-on-Task on Reliability and Validity. *Psychol Aesthet Creat Arts*, 7(04),341-349.
[13] Diedrich, J., et al. (2018). Assessment of real-life creativity: The Inventory of Creative Activities and Achievements (ICAA). *Psychology of Aesthetics, Creativity, and the Arts*, 12(3), 304–316