Investigating the effect of distance entropy on semantic priming

Cynthia S. Q. Siew

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Twitter: @csqsiew
Email: cynthia@nus.edu.sg
Web: http://hello.csqsiew.xyz

Sensitivity to large-scale structure

Recent studies have found that people are sensitive to *large-scale* structure of the mental lexicon

- Semantic networks: word pairs separated by a longer path are rated as less related than word pairs separated by a shorter path [1,2]

The present work aims to conduct a stronger test of people's sensitivity to more nuanced aspects of semantic network structure.

Aim of current study: Examine the influence of *distance entropy* on semantic priming through

1. Simulations using *spreadr*
2. Re-analysis of data from the Semantic Priming Project

[1] Kumar, A. A., Balota, D. A., & Steyvers, M. (2020). Distant connectivity and multiple-step priming in large-scale semantic networks. Journal of Experimental Psychology: Learning, Memory, and Cognition, 46(12), 2261.
[2] Kenett, Y. N., Levi, E., Anaki, D., & Faust, M. (2017). The semantic distance task: Quantifying semantic distance with semantic network path length. Journal of Experimental Psychology: Learning, Memory, and Cognition, 43(9), 1470-1489.

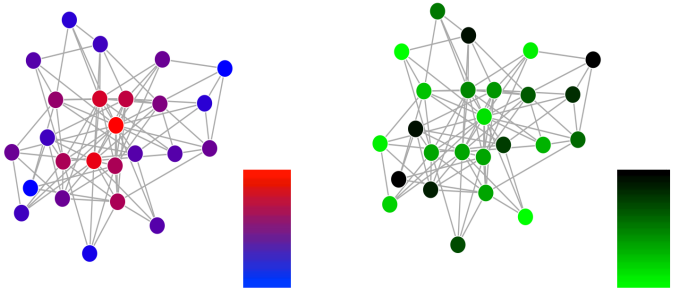
Distance entropy

Distance entropy refers to the information entropy of the set of the shortest paths from a target node *i* to all other nodes in the network [3].

- Higher (lower) DE = more (less) heterogeneous distribution of shortest path lengths

Stella & De Domenico (2018) found that words with lower DEs tend to be acquired earlier in life [3].

- They suggested that learning lower DE words earlier is related to cognitive advantages associated with a more “even” spread of activation throughout the lexicon.



Distance entropy provides additional information beyond closeness centrality

[3] Stella, M., & De Domenico, M. (2018). Distance Entropy Cartography Characterises Centrality in Complex Networks. Entropy, 20(4), 268.

Simulations: Method

Semantic network

- English free associations from the Small World of Words [4]
- Unweighted, undirected links are placed between cue words and their associations
- DE computed for all prime words in the SPP based on this network

Stimuli

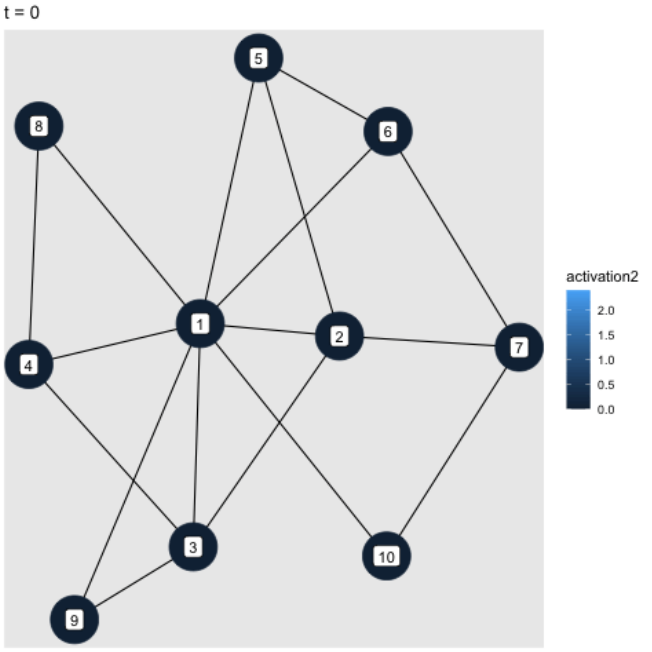
- 200 words selected from the SPP cue words with varying DE values

[4] De Deyne, S., Navarro, D. J., Perfors, A., Brysbaert, M., & Storms, G. (2019). The “Small World of Words” English word association norms for over 12,000 cue words. Behavior Research Methods, 51(3), 987-1006.

Simulations: Method

Procedure

- Each word received an arbitrary amount of activation at t=0
- Amount of activation each node at time *t* = initial amount of (retained) activation at *t-1* + sum of activation received from its neighbors
- Amount of activation each node sends out = amount of unretained activation / number of neighbors
- Repeated for 5 time steps
- Implemented on the SWOW-EN network with the *spreadr* R package [5]



[5] Siew, C. S. Q. (2019). spreadr: A R package to simulate spreading activation in a network. Behavior Research Methods, 51(2), 910-929.

Simulations: Results

Summary: Lower distance entropy is associated with higher median, lower SD, and higher H of nodes' activation levels in the network.

	Dependent variable:		
	median	sd	h
	(1)	(2)	(3)
scale(degree)	-0.00003*** (0.00000)	0.0002* (0.0001)	-0.131*** (0.025)
scale(closeness)	0.0001*** (0.00000)	-0.001*** (0.0001)	0.351*** (0.025)
scale(distance_entropy)	-0.00003*** (0.00000)	0.0003*** (0.0001)	-0.094*** (0.020)
Constant	0.0003*** (0.00000)	0.005*** (0.0001)	11.792*** (0.019)
Observations	200	200	200
R^2	0.682	0.405	0.535
Adjusted R^2	0.677	0.396	0.528
Residual Std. Error (df = 196)	0.00004	0.001	0.271
F Statistic (df = 3; 196)	140.088***	44.444***	75.180***
Note:			*p<0.05; **p<0.01; ***p<0.001

Regression models with distance entropy predicting different characterizations of the network's activation patterns at t=5.

Semantic Priming Project[6]: Results

Summary: No effect of distance entropy (of the prime) on the processing of target words.

	LD.RT	N.RT
Predictors	Estimates	Estimates
(Intercept)	660.417 ***	543.534 ***
ISI	23.349 ***	-8.703 ***
relatedness	19.819 ***	7.119 ***
word length (prime)	0.991	-0.01
OLD20 (prime)	-1.44	1.254
frequency (prime)	0.262	-1.769 **
concreteness (prime)	-1.359 **	-0.714
semantic neighborhood size (prime)	0.456	-0.075
word length (target)	9.379 ***	8.268 ***
OLD20 (target)	4.269 *	1.242
frequency (target)	-18.573 ***	-6.574 ***
concreteness (target)	-6.489 ***	-3.580 ***
semantic neighborhood size (target)	-11.486 ***	-1.665
distance entropy	-0.272	-0.42

Linear mixed effects model with distance entropy predicting RTs on lexical decision and speeded naming. Random effects not shown.

[6] Hutchison, K. A., Balota, D. A., Neely, J. H., Cortese, M. J., Cohen-Shikora, E. R., Tse, C. S., ... & Buchanan, E. (2013). The semantic priming project. Behavior Research Methods, 45(4), 1099-1114.

Summary

- *spreadr* simulations supported the idea that lower DE leads to a more even spread of activation in the lexicon
    - Activating lower DE words led to a more "even" spread of activation across words in the network, even after controlling for other network measures
    - This suggests that low DE words may be especially effective prime words
- Archival re-analysis of SPP data did not provide converging support
    - No effect of prime DE affecting RTs in lexical decision or naming
    - However, each prime only associated with 1 related and 1 unrelated target
    - May not provide the most sensitive test of distance entropy effects
- A pre-registered experiment is currently underway to provide a stronger empirical test of DE on semantic priming

Thank you for listening! :)