Item-based Prediction of Reaction Times in Priming: an Evaluation of Distributional Semantic Models

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Models

Distributional Semantic Models (DSMs) represent word meaning in terms of **patterns of co-occurrence** encoded in **distributional vectors.**

shared contexts ⟷ shared meaning

distance between vectors ⟷ semantic similarity/ relatedness

Depending on the choices of specific parameters, different DSMs are sensitive to different relations (Sahlgren, 1996). This study is a **large scale evaluation** of a number of DSMs parameters (38800 combinations).

Parameter	Value
Type of DSM	Term-term (cfr. HAL)
Corpus (5)	BNC, Wp500, WaCkypedia_EN, UkWac, Joint (BNC+WaCkypedia_EN, UkWac)
Window (3)	2, 5, 15 words (left and right)
Part-of-Speech Information (3)	no pos, pos on target, pos on targets and features
Score (6)	frequency, Mutual Information, Simple-LL, Dice coefficient, z-score, t-score
Transformation (3)	no transformation, root, logarithmic, sigmoid transformation
Distance Measure (3)	cosine, euclidean, manhattan
Dimensionality Reduction (3)	no reduction, singular value decomposition (300 dimensions), random indexing (1000 dimensions)
Relatedness Index (4)	distance, rank of target in prime's neighbors (forward rank), rank of prime in target's neighbors (backward rank), average rank

Data

Materials from a number of priming studies (Ferretti et al., 2001; McRae et al. 2005; Hare et al. 2005)

404 word triples composed by a target, a consistent prime and an inconsistent prime.

For every triple, the following information is available:
- Decison or naming latencies for congruent and incongruent conditions;
- Semantic relation holding between target and prime (16 relations over the 3 datasets);

Dataset	Relation	N	Effect
V-N (Ferretti et al. 2001)	Agent	28	27 *
	Patient	18	32 *
	Patient Feature	20	33 *
	Instrument	26	32 *
	Location	24	-5
N-V (McRae et al. 2005)	Agent	30	18 *
	Patient	30	22 *
	Instrument	32	16 *
	Location	24	18 *
N-N (Hare et al. 2005)	Event-People	18	32 *
	Event-Thing	26	33 *
	Location-Living	24	37 *
	Location-Thing	30	29 *
	People-Instrument	24	45 *
	Instrument-People	24	-10
	Instrument-Thing	24	58 *

How to interpret modeling results when so many combinations of parameters are involved? Analysis of mean/range of performance and/or identification of "best model" are not fully satisfactory (see Lapesa & Evert, 2013)

Method

Task 1: Pearson correlation between semantic distance and RTs *(congruent)*

Q: Which parameters have a significant effect on model performance? Are there differences among datasets?

Method: We analyze the influence of parameters and interactions using linear models with absolute correlation as a dependent variable and model parameters as independent variables.

Task 2: Item-based prediction of RTs with different corpus-based predictors

Q: Can DSMs predict priming at the item level? Hutchinson et al. (2008): no effect for LSA. How about bag-of-words DSMs?

Method: We conduct linear regression with priming effect in ms as a dependent variable and different types of corpus-based predictors as independent variables.

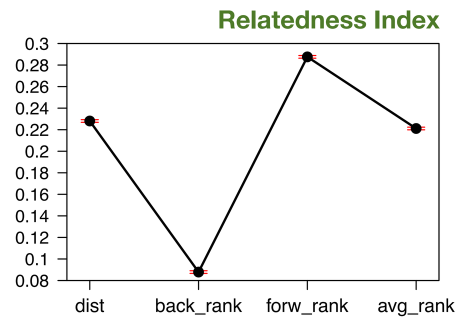
Distributional modeling of priming is usually carried out in terms of significance analysis of the difference of means. Problems:
a) DSMs have been found to overestimate priming effects
b) significance analysis does not take into account RTs

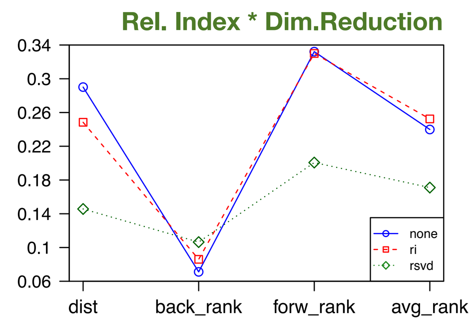
Correlation to RTs

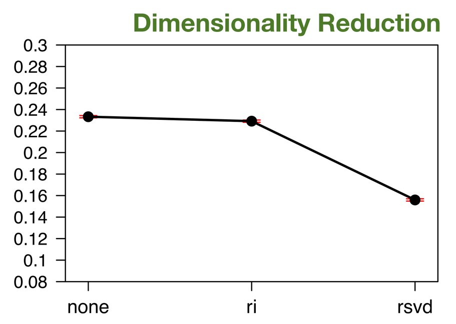
Verb-Noun (Ferretti et al. 2001)

Parameter	Df	R^2(%)	p
corpus	4	0.87	***
window	2	0.30	***
pos	2	1.41	***
score	5	1.63	***
trans	3	3.01	***
distance	2	1.66	***
dim.reduction	2	**8.33**	***
rel.index	3	**35.37**	***
dim.red:rel.index	6	**6.43**	***
distance:rel.index	6	4.47	***

Main effects & interactions, R^2(%): 75





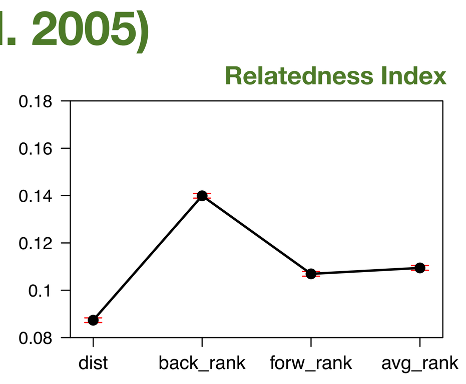


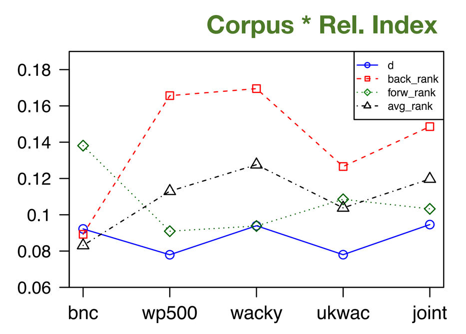
Forward rank performs better than distance, suggesting that VN priming can be interpreted as due to the activation of the neighbors of the prime.

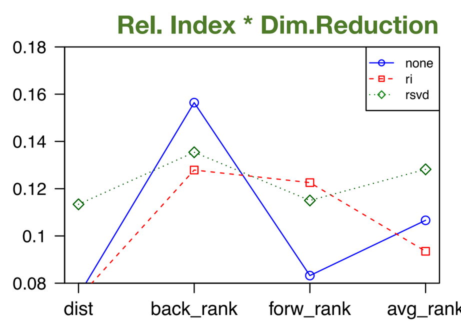
Noun-Verb (McRae et al. 2005)

Parameter	Df	R^2(%)	p
corpus	4	1.35	***
window	2	0.28	***
pos	2	1.34	***
score	5	0.28	***
trans	3	0.17	***
distance	2	0.39	***
dim.red	2	1.71	***
rel.index	3	**8.27**	***
corpus:rel.index	12	**7.12**	***
rel.index:dim.red	6	**4.02**	***

Main effects & interactions, R^2(%): 43





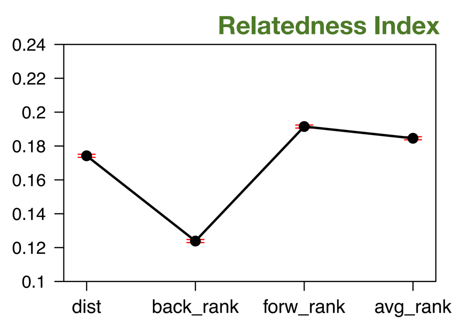


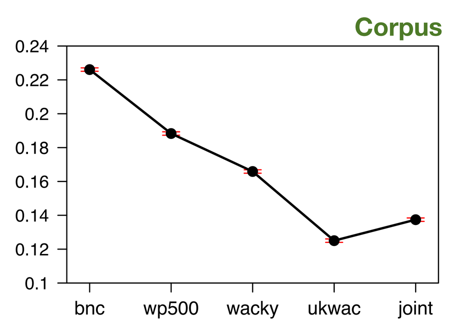
Best value is here **backward rank**, suggesting that NV priming may be strongly influenced by the activation of the neighbors of the target. Counterintuitive, given the experimental setting?

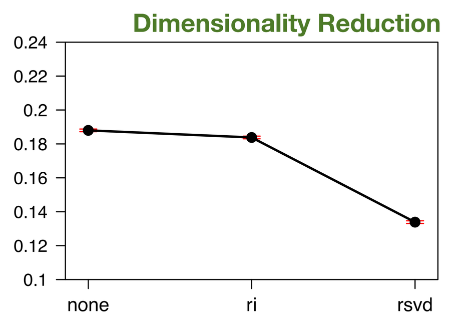
Noun-Noun (Hare et al. 2009)

Parameter	Df	R^2(%)	p
corpus	4	**16.72**	***
window	2	0.39	***
pos	2	0.84	***
score	5	4.67	***
trans	3	6.75	***
distance	2	6.92	***
dim.reduction	2	**7.69**	***
rel.index	3	**8.95**	***
score:transform	6	5.19	***
dim.red:rel.index	15	3.49	***

Main effects & interactions, R^2(%): 74







Similar to VN, forward rank and no dim. reduction are best values. Differences for rel.index are, however, less sharp: average rank is almost as good as **forward**. Bidirectionality?

Item-based Prediction

Predictors

First-order predictors

Co-occurrence frequency, joint corpus, 15 words (left & right):

a. Target-prime co-occurrence frequency (***fo_freq***)
b. Rank of target in prime's collocates (***fo_forw***)
c. Rank of prime in target's collocates (***fo_back***)

DSM predictors

Based on semantic relatedness in 4 DSMs, identified by Lapesa and Evert (2013) as best model and best setting in two tasks (global dataset): *accuracy* in picking up consistent primes (*bow_1*, best model, 96.5%; *bow_2*, best setting: 93.5%); *Pearson correlation* to congruent RTs (*bow_3*, best model, .47 *r; bow_4,* best setting:.43 *r*).

a. Target-prime semantic distance (***dsm_dist***)
b. Rank of target in prime's nearest neighbors (***dsm_forw***)
c. Rank of prime in target's nearest neighbors (***dsm_back***)

Term-document predictors

Based on a LSA-like (term-document, similar parameters, Wp500 corpus):

a. Target-prime semantic distance (***lsa_dist***)
b. Rank of target in prime's nearest neighbors (***lsa_forw***)
c. Rank of prime in target's nearest neighbors (***lsa_back***)

We performed linear regression with **priming effect (ms)** as a dependent variable and **semantic relation, first order, term-document, and DSM predictors** as independent variables.
We tested all two way interactions between corpus parameters, and used *backward stepwise regression* (based on AIC) to select the best model.

Results

V-N

Model	R^2	AIC	p
Bow_1	48	760	**
Bow_2	52	759	**
→ **Bow_3**	51	**742**	***
Bow_4	54	744	***

V-N dataset: DSM evaluation

Parameter	df	R^2	p
relation	3	9	**
dsm_forw	1	4	*
lsa_dist	1	4	*
dsm_dist:lsa_dist	1	**9**	**
lsa_dist:lsa_back	1	**9**	**
fo_freq:dsm_back	1	8	**
fo_freq:fo_back	1	4	*
fo_back	1	2	.

V-N: item-based prediction (R^2:51)

N-V

Model	R^2	AIC	p
Bow_1	33	847	*
Bow_2	27	844	**
→ **Bow_3**	41	**839**	**
Bow_4	25	846	*

N-V dataset: DSM evaluation

Parameter	df	R^2	p
lsa_dist	1	5.2	**
dsm_back	1	4.2	*
dsm_dist:lsa_dist	1	**6.9**	**
dsm_dist:lsa_back	1	4.4	**
lsa_dist:lsa_forw	1	4.2	*
lsa_dist:lsa_back	1	3.8	*
fo_freq:fo_forw	1	1.8	
dsm_back:lsa_dist	1	1.7	
dsm_dist:lsa_forw	1	1.4	
lsa_back:lsa_forw	1	1.1	

N-V: item-based prediction (R^2:41)

N-N

Model	R^2	AIC	p
Bow_1	23	1537	*
Bow_2	23	1541	*
Bow_3	15	1536	*
→ **Bow_4**	23	**1536**	*

N-N dataset: DSM evaluation

Parameter	df	R^2	p
relation	6	4	*
dsm_forw	1	2	.
dsm_back	1	2	.
fo_forw:dsm_back	1	4	**
fo_freq:lsa_back	1	4	*
dsm_dist:lsa_back	1	2	*
lsa_dist:lsa_forw	1	2	.

N-N: item-based prediction (R^2:23)

Discussion

- **Corpus-based predictors do have an effect in item-based prediction.**
- Lot of variation by changing DSM: importance of **evaluation** (possible improvement: running regression with all models in the study).
- Interactions are powerful, but not always straightforward to interpret (possible improvement: selecting "meaningful" interaction before regression).
- Ongoing analyses show that explained variance improves significantly with z-scores (e.g., Bow_4,N-N, R^2:42;AIC: 229).

References & Acknowledgements

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