

# Inhibitory Interference in Reflexives: Evidence for Cue Confusability



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Current assumptions about cue-based memory retrieval mechanisms in sentence processing explain only a subset of interference effects from structurally inaccessible distractors observed in reflexive anaphors.

We propose two independently motivated principles that account for previously unexplained patterns in the literature: **activation-dependent fan sensitivity** and **dynamic cue similarity**.

## Antecedent match

**Distractor match:** The **surgeon** who treated **Jonathan** had pricked **himself**..  
[+c-com +masc] [-c-com +masc] [+c-com +masc]

**Distractor mismatch:** The **surgeon** who treated **Jennifer** had pricked **himself**..  
[+c-com +masc] [-c-com -masc] [+c-com +masc]

## Antecedent mismatch

**Distractor match:** The **surgeon** who treated **Jennifer** had pricked **herself**..  
[+c-com -fem] [-c-com +fem] [+c-com +fem]

**Distractor mismatch:** The **surgeon** who treated **Jonathan** had pricked **herself**..  
[+c-com -fem] [-c-com -fem] [+c-com +fem]

## Current ACT-R-based model of cue-based retrieval

(e.g., Lewis & Vasishth, 2005; Dillon et al., 2013; Parker & Phillips, 2014; for ACT-R cogn. architecture see Anderson et al., 2004)

- To build a dependency, the respective item is retrieved by associating a set of retrieval cues with the features of available items in content-addressable memory.
- Similarity-based interference ("fan effect"):** If memory items overlap in retrieval-relevant features (e.g., gender), they compete for a limited source activation, i.e., inhibit each other.
- Partial matching:** Due to noise, partially matching distractor items can occasionally be retrieved instead of the target. When no features overlap, this can speed-up retrieval latency in the mean.

## The model predicts:

- Inhibitory interference from distractor when antecedent **matches** cues (fan effect).
- Facilitatory interference when antecedent **mismatches** cues (misretrievals due to partial match).

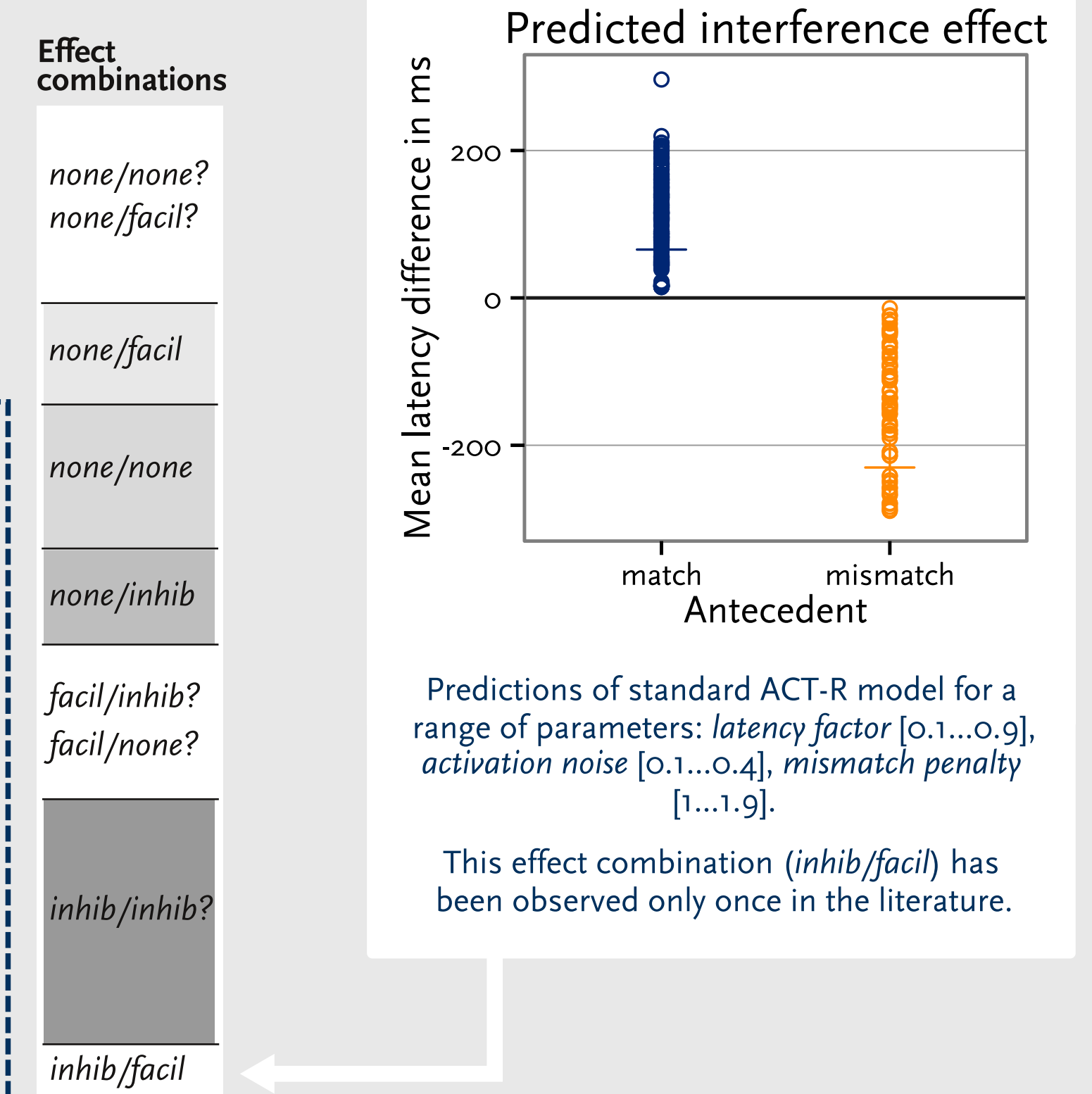
**Because no cue-relevant features overlap between items in the antecedent mismatch / distractor match condition, no inhibitory fan-effect is possible:**

antecedent [+c-com -fem] distractor [-c-com +fem]

Publication	Lang.	Method	Cue	Distractor position	Effect in antecedent match		Effect in antecedent mismatch	
					Interference	AOI, Measure	Interference	AOI, Measure
Xiang et al. '09	EN	EEG	gend	subj.	—	—	—	—
Nicol&Swinney '89	EN	Primg	gend	subj.,obj.	none	—	—	—
Badecker&Straub '02 Exp5	EN	SPR	gend	Gen.	none	—	—	—
Badecker&Straub '02 Exp6	EN	SPR	gend	prep.obj.	none	—	—	—
King et al. '12 non-adjacent	EN	ET	gend	prep.obj.	none	—	facil	n, FPRT
Parker&Phillips '14	EN	ET	nu/ge/an	subj.	none	—	facil	n, TFT
Sturt '03 Exp2	EN	ET	gend	obj.(focus)	none	—	none	—
King et al. '12 adjacent	EN	ET	gend	obj.	none	—	none	—
Dillon et al. '13	EN	ET	numb	obj.	none	—	none	—
Kush&Phillips '14*	Hindi	SPR	numb	prep.obj.	none	—	(inhib)	n+2
Jäger&Vasishth '12 Exp1	CN	ET	anim	subj.	none	—	(inhib IWM)	n+2, FFD/FPRT/RPD
Cummings&Felsler '13 Exp1	EN	ET	gend	subj.(focus)	(facil IWM)	n+2, FPRT	(inhib IWM)	n+2, FFD
Cummings&Felsler '13 Exp2	EN	ET	gend	subj.(focus)	facil IWM	n, FFD/FPRT	(inhib IWM)	(n, FFD)
Sturt '03 Exp1	EN	ET	gend	subj.(focus)	facil	n+2, RRT	none	—
Jäger&Vasishth '12 Exp2	CN	ET	anim	3 memory items	inhib	n, FPRT/RPD/TFT	—	—
Badecker&Straub '02 Exp3	EN	SPR	gend	subj.	inhib	n+1	—	—
Badecker&Straub '02 Exp4*	EN	SPR	numb	subj.	inhib	[n+1-n+4]	—	—
Chen et al. '12	CN	SPR	animacy	subj.	inhib	n+1	—	—
Clackson&Heyer '14	EN	VW	gend	subj.(focus)	inhib	gaze shift	—	—
Patil et al. subm.	EN	ET	gend	subj.	inhib	n, FPRP, (regr.-cont. FFD)	(facil)	(n, regr.-cont. FFD)

\*Kush&Phillips '14 and Badecker&Straub '02 Exp4 used reciprocal "each other".

Marginal effects in brackets. "—" means that the respective condition was not tested.



Literature

## 4 patterns unexplained:

A) 4 studies with an effect in antecedent mismatch but not in match conditions. The opposite appears only once.

B) Presence of effects seems to correlate with prominence of distractors (subj / focused / multiple).

C) Inhibition in antecedent mismatch conditions (Mandarin; low WM; reciprocals).

D) Facilitation in antecedent match conditions (all with distractor in focused subject position).

2 new proposals

## Proposal 1: Activation-dependent fan sensitivity

In standard ACT-R, the fan effect is simply based on the number of overlapping features. We propose that the impact of the fan also depends on an item's activation relative to that of similar items. I.e., if a target is highly activated (fully matching antecedent) compared to distractors, it is less affected by similarity-based interference.

### Predictions:

- Generally less interference in antecedent match conditions due to high activation of fully matching antecedent.
- Stronger inhibitory interference in antecedent match conditions when distractors are highly activated (subject / focused) or when there are multiple distractors.

## Proposal 2: Cue confusion due to dynamic cue similarity

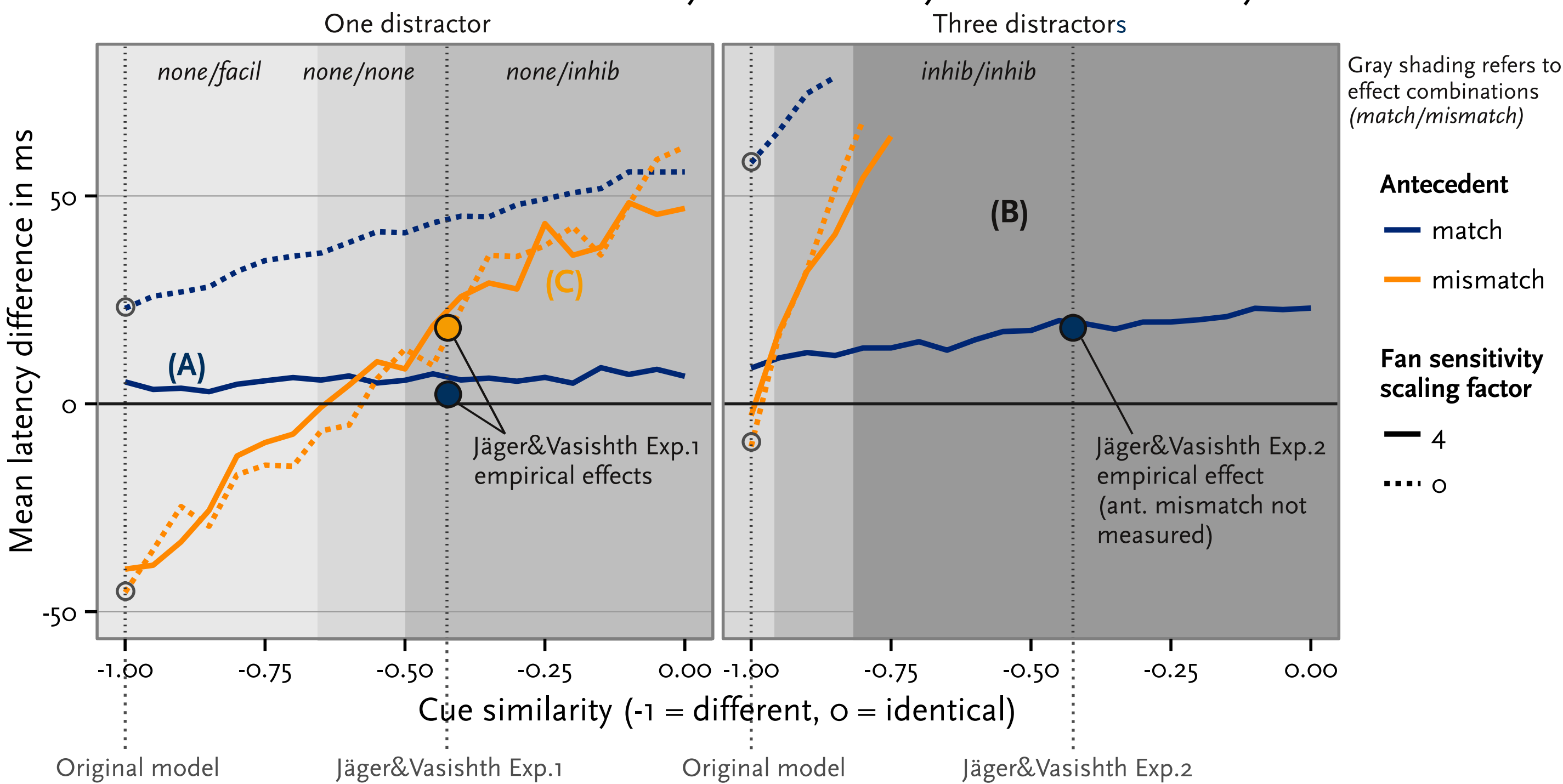
Previous modeling assumed that retrieval cues perfectly distinguish matching features from non-matching ones. But in the general ACT-R framework, features can be similar to each other, like any other memory chunk.

We propose that task requirements (frequent co-occurrence of certain cues in similar retrieval contexts) and individual differences (working-memory limitations) dynamically influence how cues are treated during a retrieval request. Sometimes it is efficient and "good enough" to treat certain cues as similar, i.e., to confuse them.

### Predictions:

- Inhibitory interference in antecedent mismatch conditions when structural and non-structural cues are treated as similar due to their frequent co-occurrence (leads to fan effect despite absence of feature overlap).
- Inhibitory interference in antecedent mismatch conditions for readers with low WM capacity because confusing cues might conserve cognitive resources.

## Predicted interference effect by cue similarity and fan sensitivity



Extended model implemented in R with 1000 simulations per parameter set. Fan sensitivity factor scales the influence of relative activation on the fan effect. Parameters set to values used in previous models: latency factor=1.5, noise=1.5, mismatch penalty=1.2. Gray shading refers to predicted effect combinations (antecedent match / mismatch)

- Predictions of original model correspond to cue similarity = -1.0 and fan sensitivity factor = 0.
- Example prediction:** The effect sizes of Jäger & Vasishth (2012) Exp. 1 and Exp. 2 (both about 19 ms) are predicted by equal parameter values (cue sim. = -0.45; fan sensitivity factor = 4).

## Discussion

The extension of the cue-based retrieval model by activation-dependent fan sensitivity and dynamic cue similarity explains three so far unexplained patterns (A-C).

### Activation-dependent fan sensitivity (scaling factor >3) accounts for:

- Less interference effects in antecedent match conditions.
  - Correlation between presence of effects and prominence of distractors.
- » **Structural priority assumption not necessary?** (Sturt '03; Dillon et al. '13; Parker & Phillips '14; Phillips et al. '11)  
Combinations *inhib/none* and *inhib/facil* are only predictable with lower fan sensitivity factor. However, *inhib/none* is unobserved and *inhib/facil* has only one marginal observation.

### Dynamic cue similarity accounts for:

- Inhibitory interference in Mandarin reflexives (Jäger & Vasishth, 2012) and English reciprocals (Kush & Phillips, 2014): In Mandarin reflexive retrieval, cues [+c-com] and [+anim] always co-occur. The same holds for [+c-com] and [+plural] in the English reciprocal *each other*. In contrast, English reflexives have more alternative forms (*himself/herself/itself/themselves*), where [+c-com] co-occurs with different combinations of [+/-anim], [gen:fem/masc/neutr], and [num:sing/plur].
- Inhibitory interference for low-WM readers (Cummings & Felsler, 2013).

**Facilitatory interference in antecedent match (D):** For exceptionally highly activated single distractors (e.g., focused subject?), facilitation in antecedent match conditions is possible in either model due to misretrievals.

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