Current issues in sentence comprehension: Reading 01 Engelmann, J ager, Vasishth, submitted

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The paper

- This paper is part of the PhD work of Felix Engelmann, and the modeling and literature review were done jointly by Engelmann and Lena Jäger.
- The main issue of interest is: interference effects in antecedent-reflexive and subject verb dependencies.

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Some definitions

I will refer to the syntactically correct element of a dependency as target and to a syntactically unlicensed retrieval candidate as distractor.
Note that distractors can appear between the target and retrieval site (retroactive interference) or before the target (proactive interference):

- Retroactive: Target Distractor RetrievalSite
- Proactive: Distractor Target RetrievalSite

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Inhibitory interference in reflexives and antecedents (target match)

(1) [$_{\text{Distractor}}$ Jane$^{-masc}_{-c\text{-}com}$/John$^{+masc}_{-c\text{-}com}$] thought that [$_{\text{Target}}$ Bill$^{+masc}_{+c\text{-}com}$] owed *himself*$\{^{masc}_{c\text{-}com}\}$ another opportunity to solve the problem.

The increased difficulty in determining the correct antecedent for the reflexive will be called **similarity-based interference**. SBI causes increased retrieval latencies at the reflexive with the distractor John compared to the condition with Jane.

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Inhibitory interference in subject-verb dependencies (target match)

Van Dyke papers

(2) The worker was surprised that the [$_{\text{Target}}$ resident$^{+anim}_{+locSubj}$] who was living near the dangerous [$_{\text{Distractor}}$ warehouse$^{-anim}_{-locSubj}$/neighbor$^{+anim}_{-locSubj}$] *was complaining*$\{^{anim}_{locSubj}\}$ about the investigation.

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Inhibitiory interference: a consequence of competition

- The observation of elevated reading times caused by the mechanism of similarity-based interference is also called inhibitory interference.
- In terms of the [1] model of sentence processing, the inhibitory effect is explained by a competition between the target and the distractor for a limited amount of activation:
  - Since the amount of activation associated with a retrieval cue is shared between all matching items, the presence of competitors in memory will reduce **each item**'s activation, leading to a slowdown no matter whether a target or distractor is retrieved.
  - Since retrieval speed is a function of an item's activation, reduced activation due to a cue-matching distractor results in a longer retrieval latency as compared to a condition without a cue-matching distractor.

Facilitatory interference (target mismatch)

Distinct from SBI, another mechanism called Misretrieval causes incorrectly formed dependencies, affecting comprehension in the respective trials.
An example is number attraction.

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Facilitatory interference (target mismatch)

Example: Number attraction

(3) *The [$_{\text{Target}}$ key$^{-plur}_{+locSubj}$ to the [$_{\text{Distractor}}$ cabinet$^{-plur}_{-locSubj}$/cabinets$^{+plur}_{-locSubj}$] *were*$\{^{plur}_{locSubj}\}$ rusty from many years of disuse.

Facilitatory interference (target mismatch)

Example: Antecedent-reflexive configurations (King et al 2012)

Misretrieval can also play a role in antecedent-reflexive configurations:

(4) The [$_{\text{Target}}$ *mechanic*$^{-fem}_{+c\text{-}com}$] who spoke to [$_{\text{Distractor}}$ John$^{-fem}_{-c\text{-}com}$/Mary$^{+fem}_{-c\text{-}com}$] sent a package to *herself*$\{^{fem}_{c\text{-}com}\}$ ...

[Note: the sentence isn't ungrammatical, but mechanic has stereotypical gender male in English.]

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The mechanisms and predictions of the classical cue-based retrieval model

Table: Mechanisms and predictions of the classical cue-based retrieval model [1] (LV05) compared with observations from the literature review (see paper).

Target	Classical model (LV05)		Empirical findings
	Mechanism	Predictions	
Match	SBI & Misretrievals	(A) Inhibition	(A1) No effect (A2) Inhibition (A3) Facilitation
Mismatch	Misretrievals	(B) Facilitation	(B1) No effect (B2) Facilitation (B3) Inhibition

Note that misretrievals happen in both Target Match and Mismatch conditions, but the effect of SBI is stronger in Target Match with default ACT-R parameters.

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The mechanisms and predictions of the classical cue-based retrieval model

- Notice that the model's predictions are highly restricted whereas the data show all possible outcomes.
- There is a trivial explanation for the variability in the data: Type M and Type S errors (see slides from ESSLLI 2015, lecture 2 slide 37 on). If this explanation is the correct one, then this implies we are running very low power studies and most of the studies are just reporting noise.
- However, some people believe that running repeated measures (within subjects) studies gives us adequate power. I am testing this assumption empirically (will take 5-6 years), but for now we will suspend disbelief and assume that the observed variability is meaningful.

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Distractor prominence

The prominence of distractor can be influenced by several factors, e.g.:

- Linear order: pro- or retroactive interference (Cunnings and Felser 2013)
- Grammatical status: subject distractors may be more prominent than object distractors (Cunnings and Felser 2013, Patil et al 2012)
- Discourse topichood (Cunnings and Felser 2013, Sturt 2003)

Distractor prominence

Claim:
Distractor prominence can cause facilitatory interference in target match conditions, because very prominent distractors might lead to more misretrievals.

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Cue confusion

Claim:
An independently motivated mechanism called *cue confusion* may cause competition for activation even between conceptually different features, resulting in similarity-based interference in target-mismatch conditions, leading to inhibitory interference in target-mismatch conditions.

[Recall that in the classical model, competition only happens when features match between target and distractor]

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The mechanisms and predictions of the extended cue-based retrieval model developed by Engelmann and Jäger

Table: Mechanisms and predictions of the extended cue-based retrieval model.

Target	Extended model		Explanation
	Mechanism	**Predictions**	
Match	SBI & misretrievals **increase with prominence**	(A1) No effect	Low *distractor prominence*
		(A2) Inhibition	Increased *distractor prominence*
		(A3) Facilitation	Very high *distractor prominence*
Mismatch	Misretrievals **& SBI by cue confusion**	(B1) No effect	Very low *distractor prominence*
		(B2) Facilitation	Increased *distractor prominence*
		(B3) Inhibition	High *cue confusion*

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Variability in the data

- See tables 1-3 in paper.
- This variability in publications could in principle have (a) a systematic component, or (b) be entirely due to Type M and S errors (low power), or (c) be a result of p-value hacking, or some combination of (a-c).
- We are incentivized to engage in p-value hacking by the academic system presently in place, which values and rewards volume of publications, therefore (c) is almost certainly part of the reason for the variability. But it may not be the whole story.

In this paper, we are going with the working assumption that the variability has a systematic component.

Discussion of variability in reflexive-antecedent data

- Neither a purely structural search account nor a cue-based account that prioritizes structural cues is able to explain the presence of interference effects observed in several experiments.
- The prominence of the distractor seems to have some effect on causing facilitatory interference in target match conditions (although the evidence is quite limited).

Discussion of variability in subject-verb dependencies

- Agreement attraction research (Bock et al) has been explained in terms of feature percolation—this account works for both grammatical and ungrammatical sentences—see example 11.
- Interference in subject-verb dependencies also uses the feature match-mismatch of the distractor (these studies only look at grammatical sentences).

Since agreement attraction research usually looks for main effects of grammaticality and of feature match between target and distractor (and their interaction), the conditions were re-coded for the literature review.

Original coding for agreement attraction

Grammaticality	Verb	Target-Distractor	Example
Gram	Singular	Match	key . . . cabinet was
Gram	Singular	Mismatch	key . . . cabinets was
Ungram	Plural	Match	key . . . cabinet were
Ungram	Plural	Mismatch	key . . . cabinets were

See Tables 5 and 6 in paper for re-coding.

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Principle 1: Prominence correction

- Note that SBI is only a function of the fan. It is insensitive to the difference in activation between target and distractor.
- The prominence correction factor makes SBI sensitive to the target vs distractor's activations.
  - When the target is highly activated relative to the mean of the distractors' activation, SBI decreases.
  - When the mean of the distractors' activation is high relative to target's activation, then SBI behaves as usual.

See Figure 9 for the effect that the prominence correction factor has.

Principle 2: Associative cues

In the classical model, SBI only happens in target match cases. SBI does not occur in target-mismatch cases because there are no features shared between target and distractor that are needed for retrieval.

(5)
a. *Target-match; distractor-match*
The surgeon$^{+masc}_{+\ c\text{-}com}$ who treated Jonathan$^{+masc}_{-\ c\text{-}com}$ had pricked himself$\{^{masc}_{c\text{-}com}\}$ ...
b. *Target-match; distractor-mismatch*
The surgeon$^{+masc}_{+\ c\text{-}com}$ who treated Jennifer$^{-masc}_{-\ c\text{-}com}$ had pricked himself$\{^{masc}_{c\text{-}com}\}$ ...
c. *Target-mismatch; distractor-match*
The surgeon$^{-fem}_{+\ c\text{-}com}$ who treated Jennifer$^{+fem}_{-\ c\text{-}com}$ had pricked herself$\{^{fem}_{c\text{-}com}\}$ ...
d. *Target-mismatch; distractor-mismatch*
The surgeon$^{-fem}_{+\ c\text{-}com}$ who treated Jonathan$^{-fem}_{-\ c\text{-}com}$ had pricked herself$\{^{fem}_{c\text{-}com}\}$ ...

Principle 2: Associative cues

- What if a cue could be associated with multiple features to varying degrees? That would induce SBI even in target-mismatch cases and lead to inhibitory interference.
- The motivation is frequent co-occurrence of features: "If two features co-occur frequently in target items for a certain type of dependency, it does not matter for the success of completing that dependency whether these two features can be distinguished conceptually."
- Examples: animacy and c-command in Chinese reflexives; plural and c-command in English reciprocals.

Principle 2: Associative cues

- The associative strength of the *c-com* cue could be 100% with the feature +*c-com* and 25% with the feature +*plural*. This means that at retrieval, a +*plural* feature would receive 25% of the amount of activation a +*c-com* feature receives.
- Similarly, the associative strength of the *plural* cue would be 100% with the feature +*plural* and 25% with the feature +*c-com*.
- We call this a *crossed association* between the cues *c-com* and *plural*. In other words, the two cues are being confused.

See Figures 10 and 11.

Results

See Figure 12.

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Concluding remarks

- We should be careful to note that the model constructs are driven by observing the data.
- What is now needed is an evaluation of the predictions of the model.
- "The claims in our paper are falsifiable, and rigorous tests of the extended theory should be aggressively pursued in future work, although of course such an investigation would be more informative if conducted with appropriately powered studies."
- We provide an easy-to-use tool for understanding the behavior of the model and for deriving predictions: https://engelmann.shinyapps.io/ACTRInterference

Bibliography I

[1] Richard L. Lewis and Shravan Vasishth. An activation-based model of sentence processing as skilled memory retrieval. Cognitive Science, 29:1–45, May 2005.

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