Cue Confusion and Distractor Prominence Can Explain Inconsistent Interference Effects

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Current assumptions about cue-based memory retrieval mechanisms in sentence processing (e.g., Lewis & Vasishth, 2005) (LV05) explain only a subset of interference effects from structurally inaccessible distractors observed in dependency resolution. We present (i) a **literature review** that compares observed patterns of effects in **anaphoric and subject-verb dependencies** and (ii) a **cue-based retrieval model extended with Distractor Prominence and Cue Confusion** that offers a principled explanation of hitherto unexplained effects.

For comparability with other dependency types, we relabeled the comparisons of number agreement studies.

a. **Target-match**; *distractor-match*
(Reflexive) The **surgeon**$^{+masc}_{+c\text{-}com}$ who treated *Jonathan*$^{+masc}_{-c\text{-}com}$ had pricked **himself**$^{masc}_{c\text{-}com}$ ...
(Agreement) The **key**$^{+sing}_{+locSubj}$ to the *cabinet*$^{+sing}_{-locSubj}$ **was**$^{sing}_{locSubj}$ rusty from many years of disuse.

b. **Target-match**; *distractor-mismatch*
(Reflexive) The **surgeon**$^{+masc}_{+c\text{-}com}$ who treated *Jennifer*$^{-masc}_{-c\text{-}com}$ had pricked **himself**$^{masc}_{c\text{-}com}$ ...
(Agreement) The **key**$^{+sing}_{+locSubj}$ to the *cabinets*$^{-sing}_{-locSubj}$ **was**$^{sing}_{locSubj}$ rusty from many years of disuse.

Target-Match ○
Partial feature-overlap between target and distractor.
Standard cue-based retrieval (LV05) predicts similarity-based interference.

c. **Target-mismatch**; *distractor-match*
(Reflexive) The **surgeon**$^{-fem}_{+c\text{-}com}$ who treated *Jennifer*$^{+fem}_{-c\text{-}com}$ had pricked **herself**$^{fem}_{c\text{-}com}$ ...
(Agreement) The **keys**$^{-sing}_{+locSubj}$ to the *cabinet*$^{+sing}_{-locSubj}$ **was**$^{sing}_{locSubj}$ rusty from many years of disuse.

d. **Target-mismatch**; *distractor-mismatch*
(Reflexive) The **surgeon**$^{-fem}_{+c\text{-}com}$ who treated *Jonathan*$^{-fem}_{-c\text{-}com}$ had pricked **herself**$^{fem}_{c\text{-}com}$ ...
(Agreement) The **keys**$^{-sing}_{+locSubj}$ to the *cabinets*$^{-sing}_{-locSubj}$ **was**$^{sing}_{locSubj}$ rusty from many years of disuse.

Target-Mismatch △
No feature-overlap between target and distractor.
Standard cue-based retrieval (LV05) predicts facilitatory misretrievals of the distractor.

Anaphoric Dependencies

Publication	Lang.	Method	Cue	Interf. Type	Distractor Position	Target-match ○ Effect	Target-match ○ AOI	Target-mismatch △ Effect	Target-mismatch △ AOI
REFLEXIVES									
Nicol&Swinney '89	EN	Primg	gend	pro	subj.,obj.	*n.s.*			
Badecker&Straub '02 Exp5	EN	SPR	gend	pro	Gen.	*n.s.*			
•Badecker&Straub '02 Exp6	EN	SPR	gend	pro	prep.obj.	*n.s.*			
•Sturt '03 Exp2	EN	ET	gend	retro	obj.(topic)	*n.s.*		*n.s.*	
King et al. '12 adjacent	EN	ET	gend	retro	obj.	*n.s.*		*n.s.*	
•Dillon et al. '13	EN	ET	numb	retro	obj.	*n.s.*		*n.s.*	
•Parker&Phillips '14 Exp1	EN	ET (TFT)	num/gen	pro	subj.	*n.s.*		≈ −250 ms	crit
Exp2		ET (TFT)	num/anim	pro	subj.	*n.s.*		≈ −170 ms	crit
Exp3		ET (TFT)	gen/anim	pro	subj.	*n.s.*		≈ −250 ms	crit
•Cunnings&Felser '13 Exp1	EN	ET (FPRT)	gend	pro	subj.(topic)	*n.s.*		(−25 ms)	post
•Jäger et al. (subm.) Exp1	CN	ET (FPRT)	anim	retro	subj.	*n.s.*		+19 ms	crit
Xiang et al. '09	EN	EEG	gend	retro	subj.			(+1.26 µV)	800-1000 ms
•Sturt '03 Exp1	EN	ET (RRT)	gend	pro	subj.(topic)	−97 ms	post	*n.s.*	
•Cunnings&Felser '13 Exp2 [lwM]	EN	ET (FFD)	gend	retro	subj.(topic)	−24 ms	crit	(+22 ms)	crit
•Jäger et al. (subm.) Exp2	CN	ET (FPRT)	anim	pro	3MemLd	+15 ms	crit		
•Badecker&Straub '02 Exp3	EN	SPR	gend	pro	subj.	+42 ms	post		
•Patil et al. unpublished	EN	ET (FPRP)	gend	retro	subj.	+6.74%	crit	*n.s.*	
PREPOSITIONAL REFLEXIVES									
•King et al. '12 non-adjacent	EN	ET (FPRT)	gend	retro	prep.obj.	*n.s.*		≈ −95	crit
Clackson&Heyer '14	EN	VW (target ident.)	gend	pro	subj.(topic)	*inhib*	200-600 ms		
POSSESSIVE REFLEXIVES									
•Chen et al. '12	CN	SPR	anim	retro	subj.	+9 ms	post		
RECIPROCALS									
•Kush&Phillips '14	HI	SPR	numb	retro	prep.obj.	*n.s.*		(+30 ms)	post
Badecker&Straub '02 Exp4	EN	SPR	numb	pro	subj.	+48 ms	post		

Match/mismatch asymmetry

Facilitation in target-match

Inhibition in target-mismatch

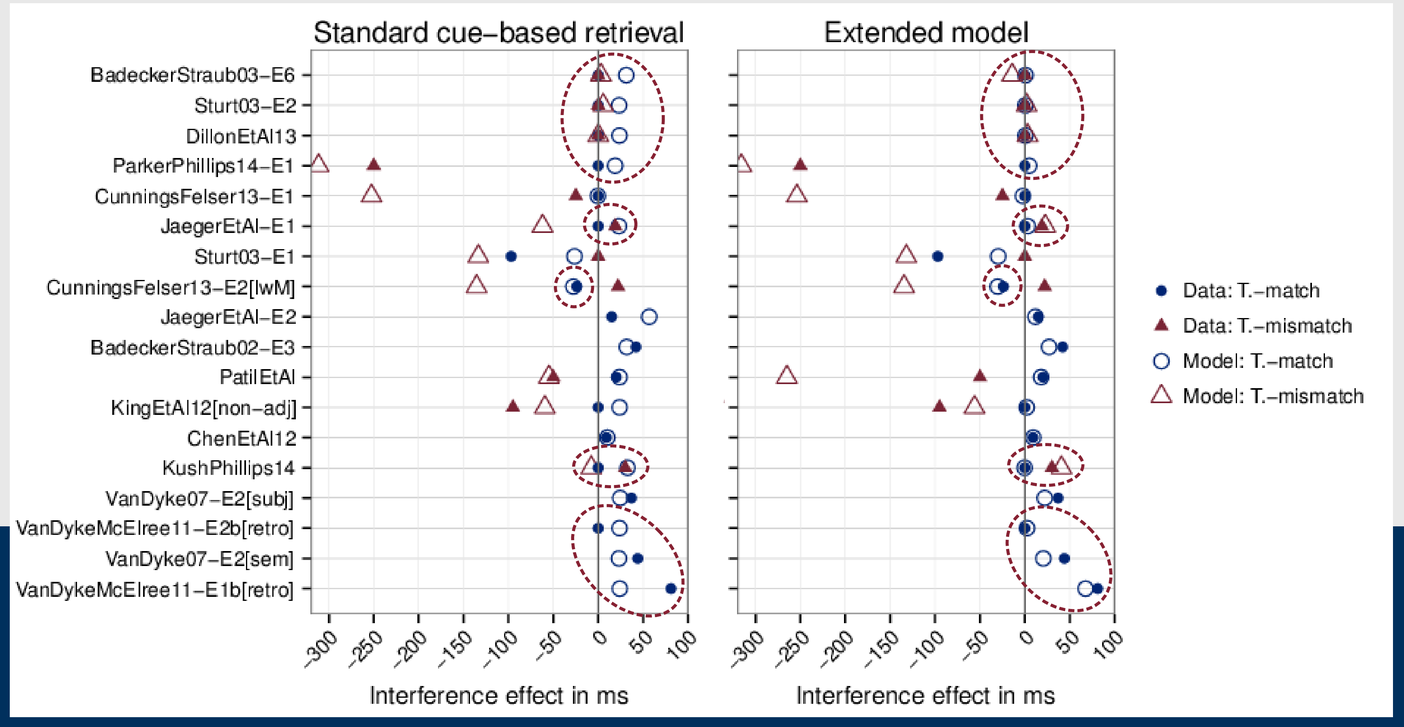
Subject-Verb Dependencies

Publication	Lang.	Method	Interf. Type	Distractor Position	Singular Verb gram ○ Effect	Singular Verb gram ○ AOI	Singular Verb ungram △ Effect	Singular Verb ungram △ AOI	Plural Verb gram ○ Effect	Plural Verb gram ○ AOI	Plural Verb ungram △ Effect	Plural Verb ungram △ AOI
NUMBER AGREEMENT												
Pearlmutter '00 Exp2[1st distr.]	EN	SPR	retro	PP,PP					−19 ms	crit		
Nicol et al. '97 Exp5[*lw-attchmt*]	EN	sent. class.	retro	obj[lwRC]	*n.s.*							
Wagers et al. '09 Exp2	EN	SPR	pro	subj	*n.s.*						−58	post
Wagers et al. '09 Exp3	EN	SPR	pro	subj	*n.s.*		*n.s.*		*n.s.*		(*facil*)	post
Dillon et al. '13 Exp1	EN	ET	retro	obj	*n.s.*						−118 ms	crit
Lago et al. '15 Exp1	SP	SPR	pro	subj	*n.s.*						−39 ms	post
Lago et al. '15 Exp2	EN	SPR	pro	subj	*n.s.*						−36 ms	post
Lago et al. '15 Exp3B	SP	SPR	pro	subj	*n.s.*						−21 ms	post
Nicol et al. '97 Exp1	EN	maze	retro	PP	−70 ms	crit			*n.s.*			
Nicol et al. '97 Exp2	EN	sent. class.	retro	PP	−124 ms	sent			*n.s.*			
Nicol et al. '97 Exp4	EN	sent. class.	retro	PP	−60 ms	sent						
Nicol et al. '97 Exp5[*hg-attchmt*]	EN	sent. class.	retro	obj[hgRC]	−67 ms	sent						
Pearlmutter et al. '99 Exp1	EN	SPR	retro	PP	−35 ms	crit					+19 ms	crit
					−36 ms	post					−26 ms	post
Pearlmutter et al. '99 Exp2	EN	ET(TFT)	retro	PP	−49 ms	post					−106 ms	crit
Pearlmutter et al. '99 Exp3	EN	SPR	retro	PP	−36 ms	crit			+24 ms	post		
Pearlmutter '00 Exp1[2 distractors]	EN	SPR	retro	PP,PP	−23 ms	crit						
Wagers et al. '09 Exp4	EN	SPR	retro	PP	−17 ms	crit					−32 ms	post
Acuña et al. '14	SP	ET(TFT)	retro	PP	−15 ms	crit			−32 ms	crit		
Lago et al. '15 Exp3A	SP	SPR	pro	subj	−12 ms	post					−15 ms	post
STRUCTURAL CUES (SUBJ.)												
Van Dyke & Lewis '03 Exp4	EN	SPR	retro	PP/subj	+56 ms	crit						
VanDyke '07 Exp1[*LoSem*]	EN	SPR	retro	PP/subj	*n.s.*							
•VanDyke '07 Exp2[*LoSem*]	EN	ET(FPRT)	retro	PP/subj	+37 ms	crit						
VanDyke '07 Exp3[*LoSem*]	EN	ET(FPRT)	retro	PP/subj	+20*ms*	crit						
SEMANTIC CUES												
VanDyke & McElree '11 Exp2a[*pro*]	EN	SAT	pro	obj	*n.s.*							
VanDyke & McElree '11 Exp2a[*retro*]	EN	SAT	retro	obj	*n.s.*							
VanDyke & McElree '11 Exp2b[*pro*]	EN	ET(TFT)	pro	obj	*n.s.*							
•VanDyke & McElree '11 Exp2b[*retro*]	EN	ET(TFT)	retro	obj	*n.s.*							
VanDyke & McElree '06	EN	SPR	pro	3MemLd	+38 ms	crit						
VanDyke '07 Exp1[*LoSyn*]	EN	SPR	retro	PP	+54 ms	crit						
•VanDyke '07 Exp2[*LoSyn*]	EN	ET(FPRT)	retro	PP	+44 ms	post						
VanDyke & McElree '11 Exp1a[*pro*]	EN	SAT(d')	pro	subj	*inhib* −0.16	crit						
VanDyke & McElree '11 Exp1a[*retro*]	EN	SAT(d')	retro	subj	*inhib* −0.27	crit						
VanDyke & McElree '11 Exp1b[*pro*]	EN	ET(TFT)	pro	subj	+20 ms	crit						
•VanDyke & McElree '11 Exp1b[*retro*]	EN	ET(TFT)	retro	subj	+81 ms	crit						
VanDyke '07 Exp3[*LoSyn*]	EN	ET(RPD)	retro	PP	(−54 ms)	post						

Distinctive pattern for number agreement

Effect strength correlated with distractor position?

Simulations

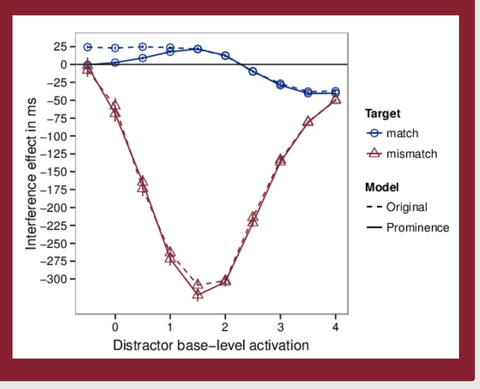


Try out the simulations yourself at https://engelmann.shinyapps.io/ACTRInterference

Principle 1: Distractor Prominence

The strength of similarity-based interference (inhibition) caused by a distractor depends on its activation level in relation to the target (distractor prominence). This predicts:

- Weaker effects in target-match than in target-mismatch ("grammatical asymmetry", Wagers, 2009).
- Effects generally increase with higher **distractor base-level activation**.
- Facilitation in target-match for very high distractor activation.

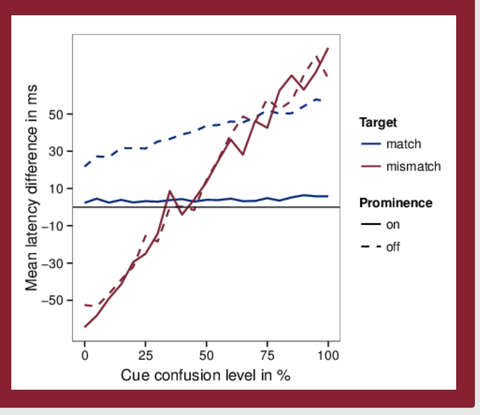


Principle 2: Cue Confusion

A retrieval cue can be associated with multiple features to different degrees. The associative strength between a cue and a feature is learned by experience. If two features co-occur frequently in target items for a certain type of dependency, the parser has no need to treat them separately.

E.g., the correct target for reciprocals (*each other*) invariantly is required to have features +plur and +c-com, while English reflexives (*himself / herself / themselves*) vary in their number and gender requirement.

This leads to a crossed association (an increased **cue confusion level**) between cues and features for +c-com and +plur in reciprocals, which causes similarity-based interference in target-mismatch conditions and, therefore, predicts inhibitory effects.



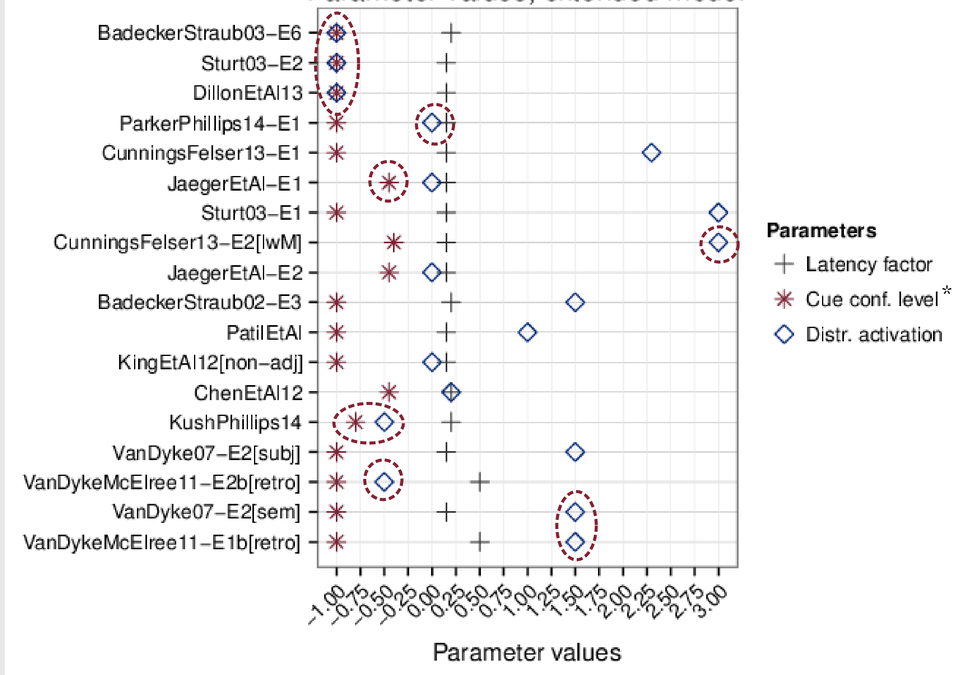
Simulation Parameters

Retrieval latency factor was in both models adjusted for **experimental method**.

Distractor base-level activation was in both models adjusted for **distractor position**: obj. < subj. < discourse-marked subj.

Cue Confusion level in extended model was adjusted for **feature-co-occurrence** (reciprocals and Mandarin reflexive *ziji*).

Selected studies marked with • (Number agreement was not included in simulations.)



*Cue confusion level between -1 (0%) and 0 (100%)

Conclusions

The relabeling of conditions in **number agreement reveals consistent facilitatory interference effects in target-match, contrary to the predictions of cue-based retrieval** (standard or extended). This suggests that number attraction experiments demonstrate a different mechanism than other subject-verb dependencies and anaphoric dependencies.

Distractor base-level activation in the extended model is correlated with distractor position (obj. / subj. / discourse-marked subj.).

Consequently, **Distractor Prominence** can explain the absence of effects, increased effect sizes for prominent distractor positions, and cases of facilitatory interference in target-match conditions (Cunnings & Felser, 2013; Sturt, 2003).

Cue Confusion predicts inhibitory interference in target-mismatch conditions for reciprocals (Kush & Phillips, 2014) and Mandarin reflexives (Jäger et al, subm.).

A high cue confusion level could potentially explain inhibitory interference in target-mismatch conditions for **low-span readers** (Cunnings & Felser, 2013).

Limitations: With increased distractor prominence, the extended model overestimates the magnitude of facilitatory target-mismatch effects.

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