

Computing Dynamic Meanings:
Building Integrated
Competence-Performance Theories for
Semantics

Days 4-5: The semantics and processing of cataphora

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ESLLI 2018, August 9-10 2018

Topic

- ▶ Incremental interpretation of DRSs (and pronoun/presupposition resolution in particular)
- ▶ DRT ACT-R model for pronoun & presupposition resolution

The phenomena: Cataphoric presupposition resolution

Experiment: (mis)match and AND/IF and +/− cataphora

Analysis of incremental interpretation in ACT-R

Conclusion

Discourse representation theory and accessibility

- (1) a. **A delegate** arrives. **She** will register.
b. **A delegate** arrives and **she** will register.

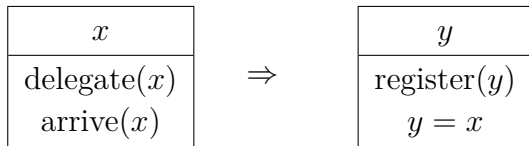
x
delegate(x) arrive(x)

;

y
$y = x$ register(y)

Discourse representation theory and accessibility

(2) If a **delegate** arrives **she** will register.



Discourse representation theory and accessibility

(3) ***A delegate** arrives or **she** will register.

x
delegate(x) arrive(x)

∨

y
register(y) $y = x$

Summary on accessibility

Construction	Accessibility
coordination	Left DRS accessible to the right DRS
disjunction	No DRS accessible
conditional	Antecedent DRS accessible to consequent DRS

Discourse representation theory and accessibility

- (4) a. *John won't eat **it** and **a hamburger** is overcooked.
b. John won't eat **it** if **a hamburger** is overcooked.
Elbourne (2009)

The phenomena

A study of:

- ▶ presupposition resolution and
- ▶ coordinations vs. conditionals
(where conditionals have a sentence-final antecedent)

The phenomena

Tina had coffee with Alex again.

- ▶ *again* - a presupposition trigger
- ▶ presupposition: Tina had coffee with Alex before

The phenomena

Tina had coffee with Alex again.

- ▶ *again* - a presupposition trigger
- ▶ presupposition: Tina had coffee with Alex before

Resolving presupposition:

- ▶ finding a suitable (and accessible) antecedent in discourse

Presupposition resolution

- (5)
 - a. **A delegate** arrives and **she** will register.
 - b. I visited Pompei 2 years ago and last week, I saw that town again.

- (6)
 - a. If **a delegate** arrives **she** will register.
 - b. If you visited Pompei once in your life, you will visit that town again.

- (7) I saw Pompei again after having visited that town a year and a half ago.

The phenomena

1. Tina will have coffee with Alex again AND she had coffee with him at the local café.
2. Tina will have coffee with Alex again IF she had coffee with him at the local café.

- ▶ AND – presupposition resolution is unlikely to come after this point

...since the second conjunct is interpreted relative to the context provided by the first conjunct

- ▶ IF – presupposition resolution is possible

...since the first clause is interpreted relative to the context provided by the second clause

Brasoveanu and Dotlačil (2015)

1. Tina will have coffee with Alex again AND she had coffee with him at the local café.
2. Tina will have coffee with Alex again IF she had coffee with him at the local café.

If the construction of semantic representations is **incremental**, then:

- ▶ presupposition resolution will affect IF but not AND

The phenomena

1. Tina will have coffee with Alex again AND she had coffee with him at the local café.
2. Tina will have coffee with Alex again IF she had coffee with him at the local café.

Note: the expectations triggered by the interaction of

- ▶ the presupposition trigger again, and
- ▶ the operators AND vs. IF

are semantically driven.

The phenomena: Cataphoric presupposition resolution

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Experiment: self-paced reading

- ▶ participants read sentences, one word at a time
- ▶ time spent reading each word measured (down to 1 ms)

Self-paced reading: illustration

— — — — —

Self-paced reading: illustration

The _____.

Self-paced reading: illustration

— boy — — —.

Self-paced reading: illustration

_____ saw _____.

Self-paced reading: illustration

_____ an _____.

Self-paced reading: illustration

— — — — elephant.

Self-paced reading: illustration

- ▶ Question; Next item

$2 \times 2 \times 2$ design: *(mis)match* \times coordination/conditional \times
nothing/presupposition

$2 \times 2 \times 2$ design: *(mis)match* \times coordination/conditional \times nothing/presupposition

- (8) a. *match & and & presupposition:*
Jeffrey will *argue* with Danielle again AND he
argued with her in the courtyard last night.

$2 \times 2 \times 2$ design: *(mis)match* \times coordination/conditional \times nothing/presupposition

- (8) a. **match & *and* & presupposition:**
Jeffrey will *argue* with Danielle again AND he *argued* with her in the courtyard last night.
- b. **match & *if* & presupposition:**
Jeffrey will *argue* with Danielle again IF he *argued* with her in the courtyard last night.

$2 \times 2 \times 2$ design: (*mis*)*match* \times coordination/conditional \times nothing/presupposition

- (8)
- a. **match & *and* & presupposition:**
Jeffrey will *argue* with Danielle again AND he *argued* with her in the courtyard last night.
 - b. **match & *if* & presupposition:**
Jeffrey will *argue* with Danielle again IF he *argued* with her in the courtyard last night.
 - c. **match & *and* & nothing:**
Jeffrey will *argue* with Danielle AND he *argued* with her in the courtyard last night.

$2 \times 2 \times 2$ design: (mis)match \times coordination/conditional \times nothing/presupposition

- (8)
- a. **match & and & presupposition:**
Jeffrey will *argue* with Danielle again AND he *argued* with her in the courtyard last night.
 - b. **match & if & presupposition:**
Jeffrey will *argue* with Danielle again IF he *argued* with her in the courtyard last night.
 - c. **match & and & nothing:**
Jeffrey will *argue* with Danielle AND he *argued* with her in the courtyard last night.
 - d. **match & if & nothing:**
Jeffrey will *argue* with Danielle IF he *argued* with her in the courtyard last night.

- (9) a. **mismatch & *and* & presupposition:**
Jeffrey will *argue* with Danielle again AND he *played* with her in the courtyard last night.
- b. **mismatch & *if* & presupposition:**
Jeffrey will *argue* with Danielle again IF he *played* with her in the courtyard last night.
- c. **mismatch & *and* & nothing:**
Jeffrey will *argue* with Danielle AND he *played* with her in the courtyard last night.
- d. **mismatch & *if* & nothing:**
Jeffrey will *argue* with Danielle IF he *played* with her in the courtyard last night.

Experiment: method

- ▶ self-paced reading
- ▶ 32 items
- ▶ 70 fillers, monoclausal and multiclausal, conditionals, conjunctions, *when*-clauses, relative clauses, quant., adv.
- ▶ 32 native speakers of Eng. participated (UCSC u/g students)

Experiment: predictions

- ▶ IF - slowdown (previous work)
- ▶ IF × CATAPHORA - speed-up
- ▶ but IF × CATAPHORA - slowdown in MISMATCH

Preview: predictions confirmed.

Experiment: regions of interest

- ▶ Jeffrey will argue with Danielle \emptyset /again and/if he argued/played **with her in the** courtyard last night.

Regions of interest (ROIs):

- ▶ the post-verbal ROIs in the second clause:
...with her in the ...

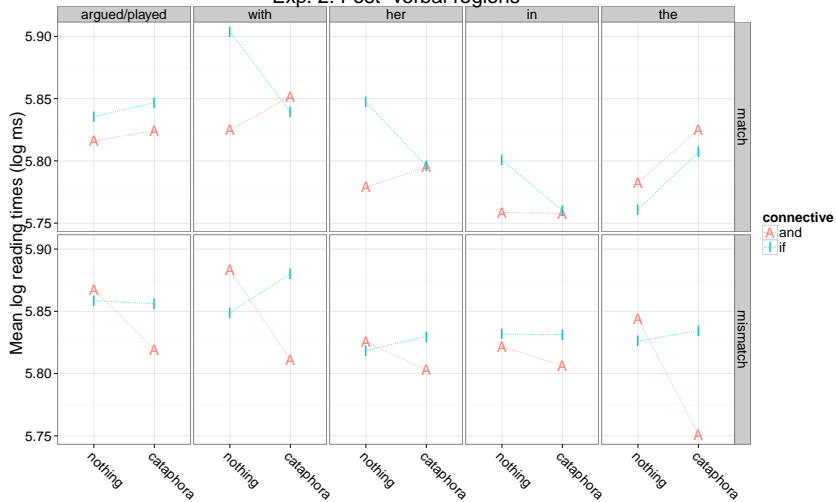
Not more than 4 words because the 5th word was the final one for some items.

Experiment: data analysis

- ▶ linear mixed-effects models
- ▶ response: log RTs
- ▶ predictors (fixed effects): main effects of CONNECTIVE and NOTHING/CATAPHORA, MATCH/MISMATCH and their 2-way and 3-way interactions
- ▶ CONNECTIVE: AND (reference level) vs. IF
- ▶ NOTHING/CATAPHORA: NOTHING (reference level) vs. CATAPHORA
- ▶ MATCH/MISMATCH: MATCH (reference level) vs. MISMATCH
- ▶ crossed random effects for subjects and items
- ▶ maximal random effect structure that converged

	with			her		
	MLE	SE	<i>p</i>	MLE	SE	<i>p</i>
CATA	-	-	-	-	-	-
MISMATCH	-	-	-	-	-	-
IF	0.08	0.04	0.054	0.07	0.04	0.084
CATA × MISMATCH	-0.11	0.06	0.056	-	-	-
CATA × IF	-0.13	0.06	0.026	-0.11	0.06	0.077
MISMATCH × IF	-0.10	0.06	0.083	-	-	-
CATA × MISMATCH × IF	0.20	0.08	0.015	-	-	-
	in			the		
	MLE	SE	<i>p</i>	MLE	SE	<i>p</i>
CATA	-	-	-	-	-	-
MISMATCH	-	-	-	-	-	-
IF	-	-	-	-	-	-
CATA × MISMATCH	-	-	-	-0.14	0.06	0.03
CATA × IF	-	-	-	-	-	-
MISMATCH × IF	-	-	-	-	-	-
CATA × MISMATCH × IF	-	-	-	-	-	-

Exp. 2: Post-verbal regions



Exp: generalizations and their consequences

baseline IF slower (borderline significant)

- ▶ (i.e., IF & NOTHING & MATCH) is more difficult than baseline AND (i.e., AND & NOTHING & MATCH)
- ▶ compatible with the hypothesis that conditionals are harder than conjunctions because
 - we need to maintain two evaluation contexts, and/or
 - the matrix is semantically reanalyzed when *if* is reached
 - Maximize Presupposition

Exp: generalizations and their consequences

CATAPHORA \times IF - speed-up (in the matching condition)

- ▶ that is, IF facilitates the processing of CATAPHORA
- ▶ this supports the hypothesis that the presupposition resolution is incremental

Exp: generalizations and their consequences

MISMATCH \times CATAPHORA - speed-up

- ▶ this interaction effectively cancels the main effects of both MISMATCH and CATAPHORA
- ▶ that is, AND & CATAPHORA & MISMATCH condition is about as difficult as the reference condition AND & NOTHING & MATCH
- ▶ participants do not consider the 2nd conjunct a plausible place for presupposition resolution

Exp: generalizations and their consequences

CATAPHORA × IF × MISMATCH - slowdown (one word after mismatch)

- ▶ the MISMATCH is surprising because readers expect to find a suitable antecedent for the *again* presupposition, and that expectation is not satisfied
- ▶ this expectation is only postulated in IF
- ▶ support for the incremental nature of presupposition resolution and formal semantic representations

Summary

Experiment provides support for the **incremental** nature of presupposition resolution.

The results are also compatible with the competence hypothesis (the parser is fully competent re discourse grammar)

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Analysis of incremental interpretation in ACT-R

Conclusion

An ACT-R based left-corner DRT parser: example

- ▶ A boy sleeps.

A --- - - - - - .

Input

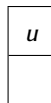
- ▶ Goal: S
- ▶ Found: *a*

Output

- ▶ New goals: N, NP, VP

- ▶ Structure: S
|
NP
|
a

- ▶ Semantics:



An ACT-R based left-corner DRT parser: example

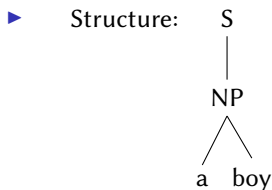
- ▶ A boy sleeps.
- boy ----- .

Input

- ▶ Goal: N
- ▶ Found: *boy*

Output

- ▶ N-goal discarded, NP-goal discarded



- ▶ Semantics:

<i>u</i>
boy(<i>u</i>)

An ACT-R based left-corner DRT parser: example

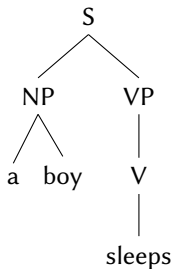
- ▶ A boy sleeps.
- --- sleeps.

Input

- ▶ Goal: VP
- ▶ LexBuffer: *eats*

Output

- ▶ Goal discarded: VP
- ▶ Structure:



- ▶ Semantics:

<i>u</i>
boy(<i>u</i>)
sleep(<i>u</i>)

Details about presupposition resolution

- (10) Jeffrey will argue with Danielle *again*...
- ▶ *again* → retrieval of event (*argue with Danielle*)
 - ▶ mark the retrieved event as unresolved

Details about presupposition resolution

- ▶ each DRS carries the information about the embedding level, EL (needed for accessibility)
- ▶ if $EL_m < EL_n$ then the elements in the DRS_{EL_m} are accessible to DRS_{EL_n}

(11) [Jeffrey will argue with Danielle again]_{EL0} ...

(12) [and he argued with her ...]_{EL1} \Rightarrow pronoun resolution successful, cataphoric presupposition cannot be resolved

Details about presupposition resolution

- ▶ each DRS carries the information about the embedding level, EL (needed for accessibility)
- ▶ if $EL_m < EL_n$ then the elements in the DRS_{EL_m} are accessible to DRS_{EL_n}

(13) [Jeffrey will argue with Danielle again] $_{EL0}$ if ...

- ▶ *if* triggers a reanalysis:
 - ▶ recall DRS with EL_0
 - ▶ change into DRS with EL_2
 - ▶ store the new DRS

(14) [if he argued with her ...] $_{EL1} \Rightarrow$ cataphoric presupposition can be resolved, but pronoun resolution also possible

Details about cataphoric resolution: *and* & match

- (15) [Jeffrey will argue with Danielle again]_{EL0} and [he argued]_{EL1}
- ▶ attempt to resolve cataphoric presupposition resolution
 - ▶ at *argued* – try to recall the unresolved event, after that, check if it matches the currently parsed event
 - ▶ spreading activation from the currently parsed event, *argued*
 - ▶ retrieval failure

Details about cataphoric resolution: *if* & match

(16) [Jeffrey will argue with Danielle again]_{EL2} if [he argued]_{EL1}

- ▶ attempt to resolve cataphoric presupposition resolution
- ▶ at *argued* – try to recall the unresolved event, after that, check if it matches the currently parsed event
- ▶ spreading activation from the currently parsed event, *argued*
- ▶ retrieval success

Details about cataphoric resolution: *and* & mismatch

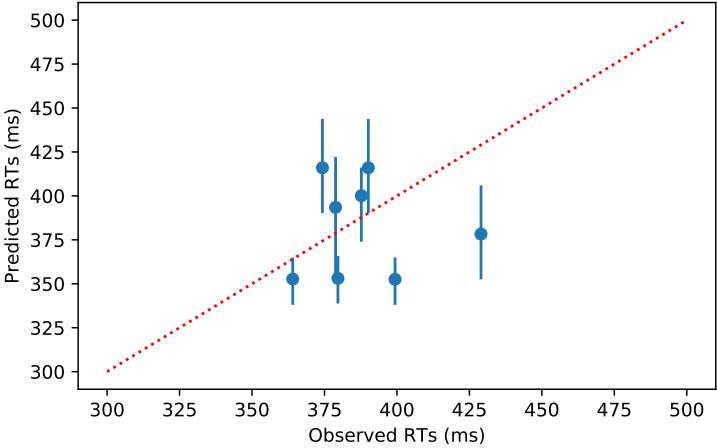
- (17) [Jeffrey will argue with Danielle again]_{EL2} and [he **played**]_{EL1}
- ▶ attempt to resolve cataphoric presupposition resolution
 - ▶ at *played* – try to recall the unresolved event, after that, check if it matches the currently parsed event
 - ▶ no spreading activation from the currently parsed event, *played*
 - ▶ retrieval failure

Details about cataphoric resolution: *if* & mismatch

(18) [Jeffrey will argue with Danielle again]_{EL2} if [he **played**]_{EL1}

- ▶ attempt to resolve cataphoric presupposition resolution
- ▶ at *played* – try to recall the original event, after that, check if it matches the presupposition
- ▶ no spreading activation from the currently parsed event, *played*
- ▶ retrieval success; but mismatching event retrieved

Results



Summary and conclusions

- ▶ Computational and theoretical models of language
- ▶ Psycholinguistics, in particular, processing

Summary and conclusions

- ▶ Computational and theoretical models of language
- ▶ Psycholinguistics, in particular, processing
- ▶ Bridging the domains:
 - ▶ syntax (LC parser with GB-style grammar)
 - ▶ semantics (DRT)
 - ▶ ACT-R as a link between the theory and performance
 - ▶ Bayesian models to make the link possible

Summary and conclusions

- ▶ Computational and theoretical models of language
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Summary and conclusions

- ▶ Computational and theoretical models of language
- ▶ Psycholinguistics, in particular, processing
- ▶ Bridging the domains:
 - ▶ good model fit for the processing of relative clauses
good fit for both lexical recall and syntactic recall
 - ▶ good fit for recall of propositions (the fan experiment)
 - ▶ partially good fit for presupposition resolution

Summary and conclusions

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Summary and conclusions

- ▶ Computational and theoretical models of language
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- ▶ Bridging the domain – extensions:
 - ▶ data-driven linguistic models (for syntax – ACT-R chunker, ACT-R LC parser)
not discussed, but partially done – e-mail us
 - ▶ fit to larger and more varied data sets
not discussed, but see, e.g., Dotlačil (2018) or e-mail us

Summary and conclusions

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 - ▶ other extensions?

Summary and conclusions

**We
Need YOU...**



Summary and conclusions

- ▶ Jakub – a project on presupposition resolution, processing, DRT & computational cognitive modeling
<https://tinyurl.com/yau9k3md>
- ▶ 2 PhD positions open, deadline in September 30
- ▶ Adrian – UCSC, new PhD openings every year

- Brasoveanu, Adrian, and Jakub Dotlačil. 2015. Incremental and predictive interpretation: Experimental evidence and possible accounts. In Proceedings of Semantics and Linguistic Theory (SALT) 25, 57–81.
- Dotlačil, Jakub. 2018. Building an act-r reader for eye-tracking corpus data. Topics in cognitive science 10:144–160.
- Elbourne, Paul. 2009. Bishop sentences and donkey cataphora: A response to barker and shan. Semantics and Pragmatics 2:1–7.