Incrementality, Alignment and Shared Utterances – Revisited

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The Dynamics of Conversational Dialogue (DynDial)
ESRC-RES-062-23-0962
www.kcl.ac.uk/research/groups/ds

December 4, 2009

Outline

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Dialogue and Incrementality

- Plenty of interest in dialogue
  - Formal models of dialogue moves, IS update, fragments
- Plenty of interest in incrementality
  - Incremental processing in psycholinguistics
  - Incremental parsing and generation in computational linguistics
- Increasing interest in incrementality in dialogue
  - e.g. [Schlangen and Skantze, 2009, Schuler et al., 2009]
  - Speeding up dialogue systems
  - Processing human-human dialogue
  - People do it this way ...

The Dynamics of Conversational Dialogue

- An ESRC project, joint between QMUL and KCL
    - formal/computational linguists, logicians, experimental psychologists
- Linguistic modelling using Dynamic Syntax [Kempson et al., 2001]
- Empirical studies using corpora and experiments

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- Empirical studies using corpora and experiments
- Non-sentential utterances
- Clarification requests
- Split utterances
- Priming/alignment

Non-Sentential Utterances

- "Fragments" – utterances without an explicit verbal predicate
- Common in dialogue ($>$ 10% of turns)
- Established formal treatments
  - [Ginzburg, prep, Fernández, 2006, Asher and Lascarides, 2003, Schlangen, 2003]

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- Question-Under-Discussion analysis:

  "Who left?" $\rightarrow$ $\lambda x.leave(x)$ $\rightarrow QUD = \lambda x.leave(x)$
  "John" $\rightarrow$ $QUD(john)$ $\rightarrow leave(john)$
- SDRT analysis:

  "Who left?" $\rightarrow$ $\alpha = \lambda x.leave(x)$
  "John" $\rightarrow$ $\beta = P(john)$ $\rightsquigarrow QAP(\alpha, \beta), \beta = leave(john)$

Clarification Requests

- Requesting clarification or confirmation of a previous utterance
  - Most commonly in the form of NSUs
- Common in dialogue (3-5% of turns)
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  - [Ginzburg and Cooper, 2004, Schlangen, 2004, Purver, 2004]

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- Question-Under-Discussion analysis:

$$\begin{array}{llll} \text{“John left”} \rightarrow & \mathit{leave}(\mathit{john}) & \rightsquigarrow & \mathit{QUD} = \lambda x.?\mathit{assert}(\mathit{leave}(x)) \\ \text{“John?”} \rightarrow & \mathit{QUD}(\mathit{john}) & \rightarrow & ?\mathit{assert}(\mathit{leave}(\mathit{john})) \end{array}$$

- SDRT analysis:

$$\begin{array}{ll} \text{“John left”} \rightarrow & \alpha = \mathit{leave}(\mathit{john}) \\ \text{“John?”} \rightarrow & \beta = P(\mathit{john}) \\ & \rightsquigarrow \mathit{QElab}(\alpha, \beta), \beta = \mathit{clarify}(\mathit{leave}(\mathit{john})) \end{array}$$

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- Utterances containing a change in speaker
  - . . . and therefore a change in hearer

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B: Which is superb. ("expansion")

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A: Before that then if they were ill
G: They get nothing. ("completion")

Split Utterances

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A: Before that then if they were ill
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- Fundamental requirement for incremental processing
  - A good test for syntactic and semantic dependencies
  - A good test of NSU & CR processing
- Treatment for one particular kind [Rieser and Poesio, prep]
  - LTAG grammar and conversational-event-based plan recognition

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Alex: Trecastle,

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(2) A: Have you read ...
B: any of your chapters? Not yet.

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(2) A: Have you read ...
B: any of your chapters? Not yet.

- Splits can occur *before* proposition-intention fixable:

(3) A. They X-rayed me, and took a urine sample, took a blood sample. Er, the doctor
B: Chorlton?
A: Chorlton, mhm, he examined me, erm, he, he said now they were on about a slide [unclear] on my heart.

Priming and/or Alignment

- Tendency to repeat previously used material
  - words
  - syntactic structures
  - multi-word expressions
  - ways of referring
- Both self- and other- effects
- Incremental through a dialogue but also through an utterance
- How should this affect our model of processing?
  - . . . especially in the case of split utterances

Outline

Dynamic Syntax

- An inherently incremental grammatical framework
- Word-by-word incremental construction of semantic interpretation:
  - no autonomous level of syntax
  - "syntax" defined via constraints on incremental semantic structure-building
  - "grammar" is a set of procedures for incremental parsing
  - "trees" are semantic representations defined using LoFT [Blackburn and Meyer-Viol, 1994]
- Monotonic growth with underspecification-plus-enrichment
- Procedural definitions: constraints on *how* interpretations are built

DS Trees as semantic representations

- End product of parsing is a semantic tree
- Nodes decorated with $Ty()$ type and $Fo()$ formula labels

"John likes Mary":

$Ty(t)$, $Fo(like(john, mary))$

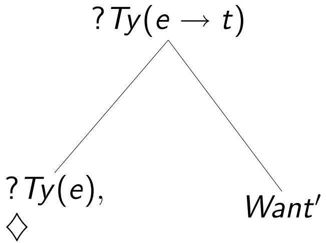
- $Ty(e)$, $Fo(john)$
- $Ty(e \rightarrow t)$, $Fo(\lambda x.like(x, mary))$
  - $Ty(e)$, $Fo(mary)$
  - $Ty(e \rightarrow (e \rightarrow t))$, $Fo(\lambda y \lambda x.like(x, y))$

- Daughter order does not reflect sentence order!
- Nodes interpretable as terms in the λ-calculus
- NPs map onto terms of type e using the ϵ-calculus.

Actions as tree-building procedures

- Words induce sets of actions to be carried out: *"want"*

IF	$\{?Ty(e \rightarrow t)\}$
THEN	make($\langle\downarrow_1\rangle$);go($\langle\downarrow_1\rangle$);
	put($Fo(Want')$,
	$Ty(e \rightarrow (e \rightarrow t)))$
	go($\langle\uparrow_1\rangle$); make($\langle\downarrow_0\rangle$);
	go($\langle\downarrow_0\rangle$); put($?Ty(e)$)
ELSE	ABORT



- General computational actions are also available e.g. requirement fulfillment, beta-reduction

Unfolding then building up the tree

Processing *Someone fainted*

$$?Ty(t), \diamondsuit$$

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$$?Ty(t)$$

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$$
\begin{array}{ccc}
 & ?Ty(t) & \\
 \swarrow & & \searrow \\
\begin{array}{c} Ty(e) \\ \epsilon, x, person(x) \end{array} & & \begin{array}{c} ?Ty(e \rightarrow t), \diamondsuit \\ \lambda y.faint(y) \end{array}
\end{array}
$$

Unfolding then building up the tree

Processing *Someone fainted*

$faint(\epsilon, x, person(x))$

$$\begin{array}{c} faint(\epsilon, x, person(x)) \\ Ty(t), \Diamond \end{array}$$

$$\begin{array}{cc} Ty(e) & Ty(e \rightarrow t) \\ \epsilon, x, person(x) & \lambda y.faint(y) \end{array}$$

Generation

- Speakers go through the same tree-growth actions, except they also have a somewhat richer goal tree.
- Each word licensed must update partial tree towards the goal tree via *subsumption* constraint

* Generating *Someone fainted*

GOAL TREE

$Ty(t), \diamondsuit$
$faint(\epsilon, person(x))$

$Ty(e),$ $\epsilon, x, person(x)$ | $Ty(e \rightarrow t)$ $\lambda y.faint(y)$

TEST TREE

$?Ty(t), \diamondsuit$

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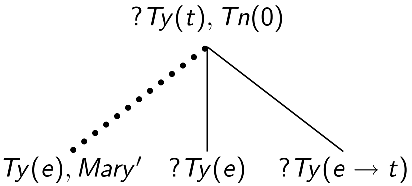
Gen: "Someone fainted"

Underspecification: structural

- “Unfixed” nodes - building underspecified tree relations



- Left-dislocation “Mary, John likes”

Underspecification: content

- Pronouns project META-VARIABLES (**U**)
- Substituted by item from context during construction

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(1) Someone smoked He fainted.

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(1) Someone smoked He fainted.

TREE AS CONTEXT: TREE UNDER CONSTRUCTION:

$smoke(\epsilon, x, person(x))$

$\epsilon, x, person(x)$ $\lambda y.smoke(y)$

SUBSTITUTION

$?Ty(t)$

$\mathbf{U}$, $?\exists x Fo(x)$ $\diamondsuit$ $\lambda y.faint(y)$

Underspecification: ellipsis

- Auxiliaries also project META-VARIABLES (**V**)
  Substituted by item from context in the same way

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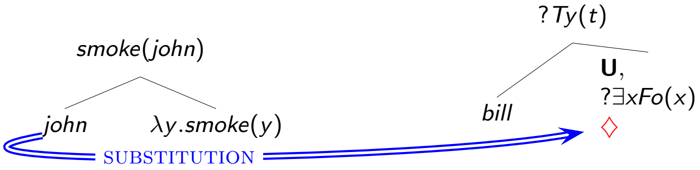

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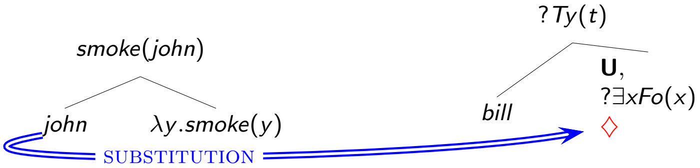
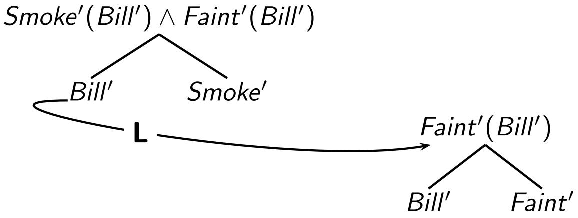


- Alternatively can use *actions* from context (sloppy readings)
- Simple model of *context* containing previous (partial) trees and action sequences

Context-dependence: LINKed tree-pairs

- **Relative clauses**: pairs of LINKed trees evaluated as conjunction

  e.g. Bill, who fainted, smokes.



Appositions as LINKed trees

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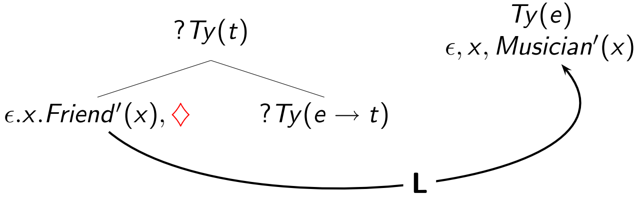
- Partial tree as context with term enriched by LINKed tree of same type
- Parsing *A friend, a musician*



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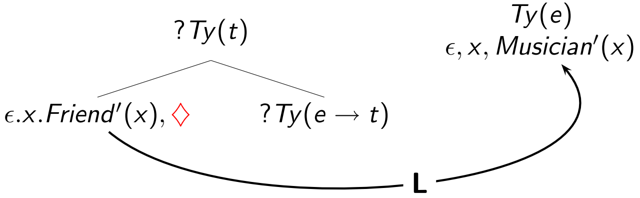

Evaluation of LINKed nodes both of type e yields composite term:

$\epsilon, x, Friend'(x) \wedge Musician'(x)$

Final formula: $Smoke'(\ \ \epsilon, x, Friend'(x) \wedge Musician'(x)\ \ )$

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- Inherent word-by-word incrementality in parsing and generation
- Use of semantic constraints rather than "syntax"
- Use of same actions and partial structures in parsing and generation

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- Use of semantic constraints rather than "syntax"
- Use of same actions and partial structures in parsing and generation
- Is it too general (what are the real constraints)?
- Is it too simplistic (what do split utterances *mean*)?

DS and Non-Sentential Utterances

- DS *seems* well suited for non-sentential utterances
- LINK mechanism for apposition allows general fragment processing
- Semantics very underspecified
- Advantages & disadvantages

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- Is it too simplistic (what do NSUs *mean*)?

DS and Priming/Alignment

- DS *seems* well suited to explain priming/alignment phenomena
- Use of actions at all levels of processing
- Availability of recent action (sequences) for re-use
  - Lexical choice and disambiguation
  - Syntactic phenomena (e.g. DO/PO alternation [Branigan et al., 2000])
  - Semantic/pragmatic phenomena (e.g. routines [Garrod and Anderson, 1987], ellipsis construal [Hardt, 2008])

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    - Semantic/pragmatic phenomena (e.g. routines [Garrod and Anderson, 1987], ellipsis construal [Hardt, 2008])
- Does this really explain general (non-lexical) effects?
- Re-use of specific lexical action sequences should lead to priming
- What about re-use of computational action sequences?

Outline

Empirical Investigations

- What do these phenomena really look like?
- Do split utterances really behave the way we think?
  - How common are they?
  - Where does the split happen?
  - What do they mean?
- What's the deal with lexical and syntactic priming?
  - Do we see them in ordinary dialogue?
  - Can we tell which effect is greater?

BNC Corpus Study

- Take a portion of the BNC (as annotated by [Fernández, 2006])
- Find all the split utterances
  - not just other-person cases [Skuplik, 1999, Szczepek, 2000]
  - or particular CA phenomena [Lerner, 2004, Rühlemann, 2007]
- See how often they occur, for same- and other-person cases
- See how variable the split point is
  - Completeness/constituency of the two halves *completion/expansion*
  - Dependencies across the split
- See what happens in between . . .

Corpus Study: Annotation Schema

- A1: I'll definitely use that

Corpus Study: Annotation Schema

- A1: I'll definitely use that $\longleftarrow$ **END-COMPLETE=Y** —

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- A1: in getting to know

Corpus Study: Annotation Schema

- A1: I'll definitely use that

CONTINUES

- A1: in getting to know

Corpus Study: Annotation Schema

- A1: I'll definitely use that
- A1: in getting to know ← **END-COMPLETE=N**

START-COMPLETE=N

Corpus Study: Annotation Schema

- A1: I'll definitely use that
- A1: in getting to know
- A1: new year seven

Corpus Study: Annotation Schema

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CONTINUES

- A1: new year seven

Corpus Study: Annotation Schema

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- A1: new year seven ← **END-COMPLETE=Y** —

START-COMPLETE=N

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- A1: I'll definitely use that
- UX: *[reading]* Get a headache?
- A1: in getting to know

- A1: new year seven

Corpus Study: Annotation Schema

- A1: I'll definitely use that
- UX: *[reading]* Get a headache?
- A1: [in getting to know]
- A2: [Year seven]
- A1: new year seven

Corpus Study: Annotation Schema

- A1: I'll definitely use that
- UX: *[reading]* Get a headache?
- A1: [in getting to know]
- A2: [Year seven]
- A1: new [year seven]
- A2: [Oh yeah] for year seven

Corpus Study: Observations

- They're common: 19% of all contributions continue something
- 85% of these are same-person cases
- 15% are other-person cases
    - this is about 3% of all dialogue contributions (i.e. about as common as clarification)

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- They're common: 19% of all contributions continue something
- 85% of these are same-person cases
- 15% are other-person cases
  - this is about 3% of all dialogue contributions (i.e. about as common as clarification)
- Many are within-turn (although these are still interesting!)
- Some may be artefacts of the BNC transcription protocol
  - overlapping speech forces a split into two contributions
- But even without all these, 10% of contributions are SUs

Corpus Study: Observations

- They're not always adjacent:
  - Same-person: 35% separated by a backchannel, 20% by 1 or more other turns
  - Other-person: 5% separated by a backchannel, 5% by 1 or more other turns
- Intervening material is often a clarification:

(1) J: If you press N
S: N?
J: N for name, it'll let you type in the docu- document name.

- The antecedent for clarification is often incomplete ...

Corpus Study: Observations

- The first part is often (but not always) incomplete: 26-28% of cases
- Some neat "syntactic" categories exist, as expected
- But these only cover 50-60% of cases
- Splits can apparently happen at any syntactic point, including inside NPs/PPs:

  (2) F: We are going to call you the
  U: Wallering

  (3) A: And they went over just to be fitted with the
  G: just fitted with the brass

- Note the presence of repair: only 5% of cases

Corpus Study: Observations

- Continuations often don't perform the same *function* as the antecedent:

  (4) G: Had their own men
  A: unload the boats?
  G: unload the boats, yes.

  (5) J: How does it generate?
  M: It's generated with a handle and
  J: Wound round?
  M: Yes, wind them round

- Very often a clarification request, but others possible e.g. confirmation, reformulation
- Not quite as simple as just completing a semantic structure …

Corpus Study: Conclusions

- Some conclusions play right into DS's hands ...
  - Splits across syntactic & semantic constraints
  - Not always collaborative as per [Rieser and Poesio, prep]
  - Intervening turns use incomplete antecedents (partial trees)

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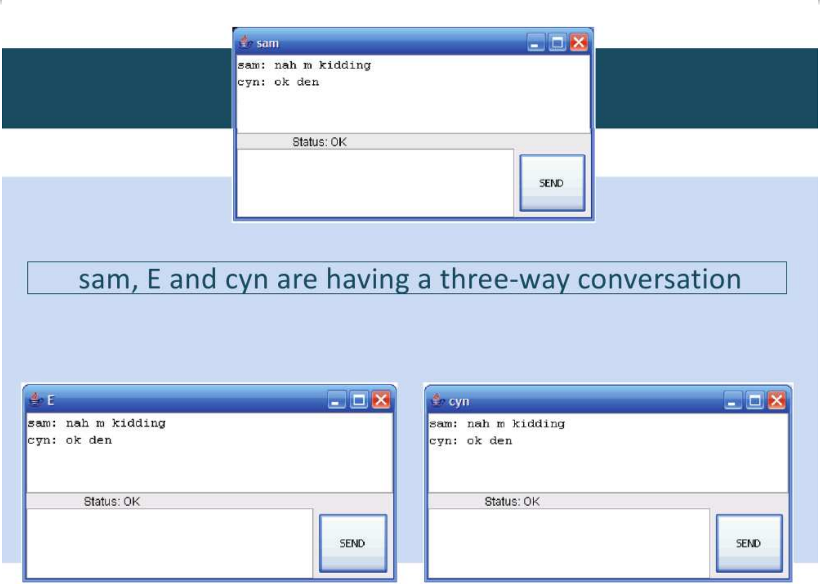
- Some conclusions play right into DS's hands ...
  - Splits across syntactic & semantic constraints
  - Not always collaborative as per [Rieser and Poesio, prep]
  - Intervening turns use incomplete antecedents (partial trees)
- ... but some don't:
  - Repair
  - Clarifications

Experimental Study: the DiET chattool

- Corpora tell us nothing about processing questions
- DiET: a toolbox for experimenting with dialogue [Healey et al., 2003]
- Basic setup: a multi-way chat tool, a bit like MSN Messenger
- Communication is mediated by a server, allowing controlled manipulations
    - transform real turns
    - introduce "fake" turns
- Use this to introduce split utterances, and observe the effects


sam
sam: nah m kidding
cyn: ok den
Status: OK
SEND
sam, E and cyn are having a three-way conversation
E
sam: nah m kidding
cyn: ok den
Status: OK
SEND
cyn
sam: nah m kidding
cyn: ok den
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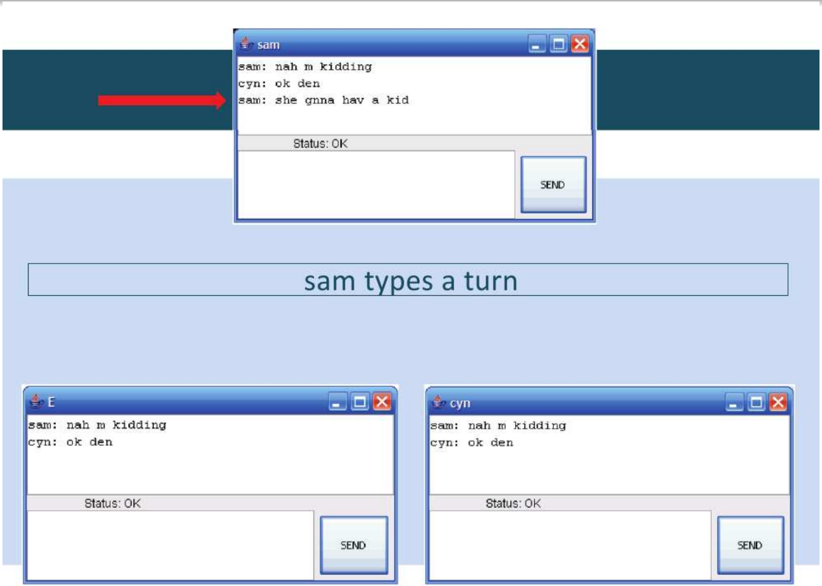
SEND


sam
sam: nah m kidding
cyn: ok den
sam: she gnna hav a kid
Status: OK
SEND
sam types a turn
E
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cyn: ok den
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SEND
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sam: nah m kidding
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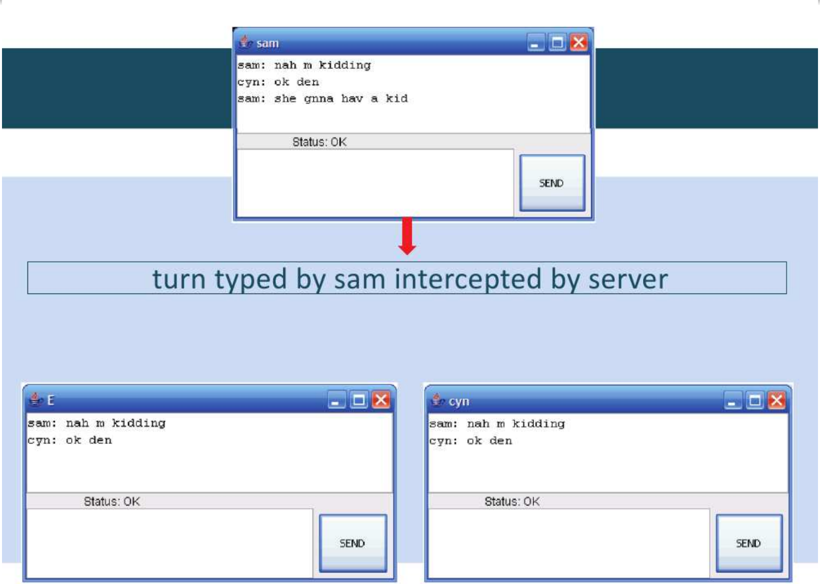
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turn typed by sam intercepted by server
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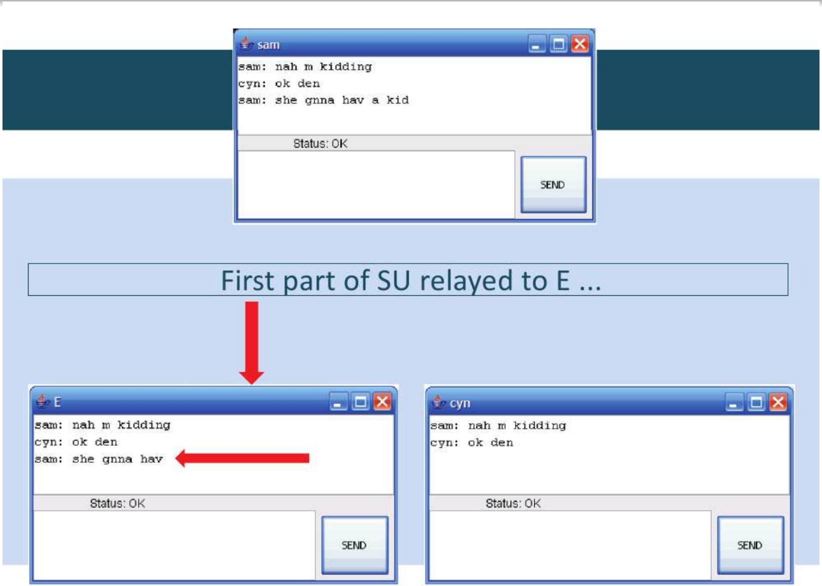
Status: OK
SEND


sam
sam: nah m kidding
cyn: ok den
sam: she gnna hav a kid
Status: OK
SEND
First part of SU relayed to E ...
E
sam: nah m kidding
cyn: ok den
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SEND
cyn
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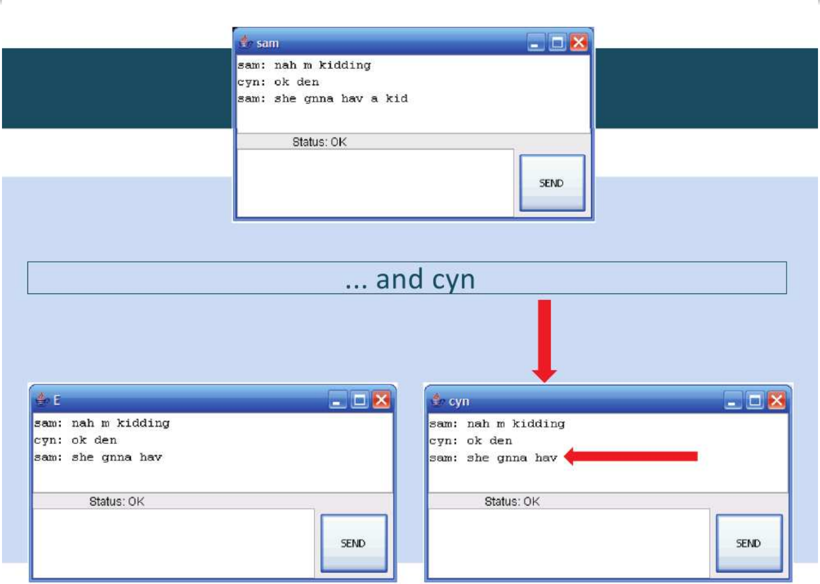
sam
sam: nah m kidding
cyn: ok den
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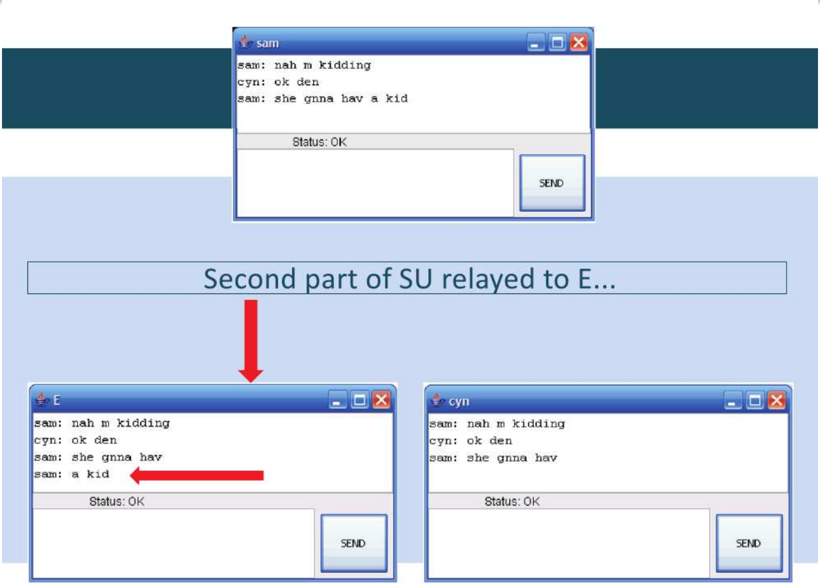
Status: OK
SEND
... and cyn
E
sam: nah m kidding
cyn: ok den
sam: she gnna hav
Status: OK
SEND
cyn
sam: nah m kidding
cyn: ok den
sam: she gnna hav
Status: OK
SEND


sam
sam: nah m kidding
cyn: ok den
sam: she gnna hav a kid
Status: OK
SEND
Second part of SU relayed to E...
E
sam: nah m kidding
cyn: ok den
sam: she gnna hav
sam: a kid
Status: OK
SEND
cyn
sam: nah m kidding
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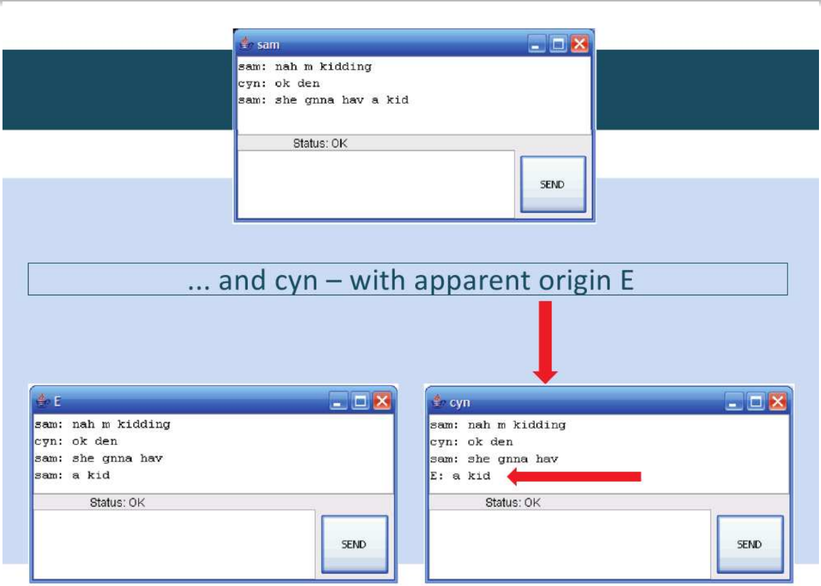
sam
sam: nah m kidding
cyn: ok den
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Status: OK
SEND
... and cyn – with apparent origin E
E
sam: nah m kidding
cyn: ok den
sam: she gnna hav
sam: a kid
Status: OK
SEND
cyn
sam: nah m kidding
cyn: ok den
sam: she gnna hav
E: a kid
Status: OK
SEND

Experimental Study: An example

- 'Bancil' types:

  the only loss here is a pilot and a father which is kinda bad but someones gotta go

- 'Aryan' sees (AA):

  Bancil: the only loss here is a pilot and a father
  Bancil: which is kinda bad but someones gotta go

- 'efparxng' sees (AB):

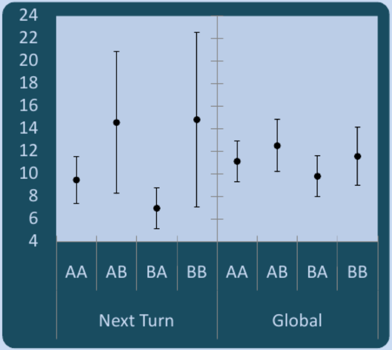
  Bancil: the only loss here is a pilot and a father
  Aryan: which is kinda bad but someones gotta go

Experimental Study: Results

- We can observe: typing time of turn, number of 'deletes' used
  - *next turn* effects: the next participant to type
  - *global* effects: all participants turns until next intervention
- We can compare: speaker switch (AA/BB vs. AB/BA)
- We can compare: floor change (AA/BA vs. BB/AB)
- We can compare: first/second part coherence (Y/N)

Experimental Study: Results

- Main effect of *floor change* on typing time of turn

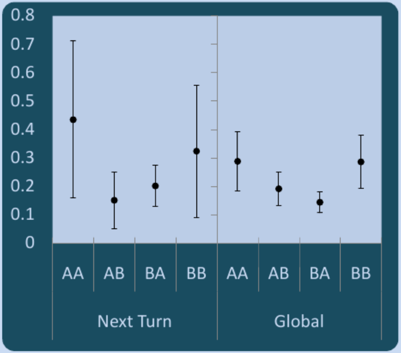


If the second part of the SU is misattributed (AB & BB cases), people take **longer** constructing responses.

Next turns:
$(F(3,249) = 7.13, p < 0.05)$
Globally:
$(F(3,486) = 3.78, p < 0.05)$

Experimental Study: Results

- Main effect of *speaker switch* on number of 'deletes'

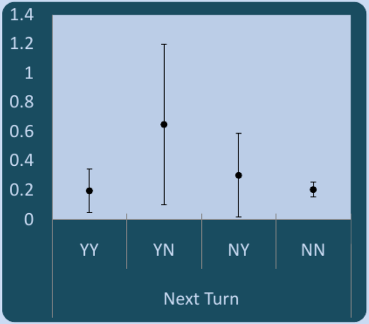


If the SU appears to be a cross-person one (AB & BA cases), people use **fewer** deletes in their responses.

Next turns:
$(F(3,249) = 6.26, p < 0.05)$
Globally:
$(F(3,486) = 9.23, p < 0.05)$

Experimental Study: Results

- Interaction effect of *1st- x 2nd-part coherence* on 'deletes'



If BOTH parts of the split could standalone (YY), or if NEITHER part could (NN), then participants use **fewer** deletes in their first response.

$F(249) = 4.05$, $p < 0.05$

Experimental Study: Conclusions

- Lack of speaker-switch effect on typing time suggests ease of processing
- Effect on deletes may be due to apparent party formation?
- Effect of floor change may be due to interference in turn-taking organisation
- Effect of 1st/2nd-part coherence suggests “garden-path”-style revision
- We’re worried about the robustness of the setup . . .
    - . . . a character-by-character version is almost complete

Priming: Designing a corpus experiment

- DS seems to predict lexical(-syntactic) effects more than general syntactic effects
- Previous dialogue experiments (e.g. [Reitter et al., 2006]) suggest that:
  - general syntactic effects are stronger in task-specific dialogue than in general conversation
  - general syntactic effects are stronger within-person than cross-person
- But no direct control condition:
  - what about dialogue structure effects?
  - how similar would recent turns be by chance?
  - Switchboard corpus is strange

Corpus experiment: Method

- DCPSE corpus, all 2-person dialogues from 3 largest genre samples:
  - face-to-face formal (60 dialogues, 90,000 words)
  - face-to-face informal (91 dialogues, 403,000 words)
  - telephone conversations (89 dialogues, 77,000 words)
- For each dialogue D, create a "fake" control dialogue:
  - keep all turns from first speaker $S1_D$
  - choose a different dialogue D', matching by length and within genre
  - interleave the turns from $S1_D$ with those from $S2_{D'}$
- Compare average turn similarity between real and control dialogues

Corpus experiment: Method

A:	Hello	A':	Hi
B:	Hi	B':	Hello
A:	How are you?	A':	What's up?
B:	Fine - you?	B':	Not much
A:	Yeah fine thanks	A':	Me neither
B:	Uh-huh	B':	Uh-huh

Corpus experiment: Method

A:	Hello		
		B':	Hello
A:	How are you?		
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Corpus experiment: Lexical results

- Lexical similarity expressed via word pair kernel:
  - number of matching word pairs between turns A and $B = N_{AB}$
  - similarity $S_{lex} = \frac{N_{AB}}{\sqrt{N_{AA}.N_{BB}}}$

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  - number of matching word pairs between turns A and $B = N_{AB}$
  - similarity $S_{lex} = \frac{N_{AB}}{\sqrt{N_{AA}.N_{BB}}}$
- ANOVA for real vs. control shows a reliable difference:
  $F_{(1,253)} = 106.55, \; p = 0.00$
- Real dialogues mean other-person similarity
  $S_{lex} = 0.094 \; (SD = 0.04)$
- Control dialogues mean other-person similarity
  $S_{lex} = 0.059 \; (SD = 0.03)$

Corpus experiment: Syntactic results

- Syntactic similarity via tree kernel (variant of [Moschitti, 2006]):
    - number of matching non-terminal syntactic rule pairs between turns A and $B = N_{AB}$
    - similarity $S_{syn} = \frac{N_{AB}}{\sqrt{N_{AA}.N_{BB}}}$

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- ANOVA for real vs. control shows *no* reliable difference

  $F_{(1,253)} = 1.32, \ p = 0.25$
- Real dialogues mean other-person similarity

  $S_{syn} = 0.19 \ (SD = 0.06)$
- Control dialogues mean other-person similarity

  $S_{syn} = 0.18 \ (SD = 0.06)$

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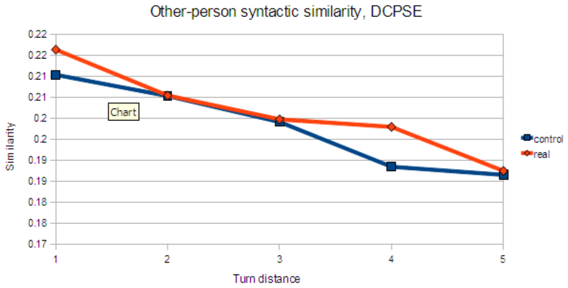
  $S_{syn} = 0.19 \; (SD = 0.06)$
- Control dialogues mean other-person similarity

  $S_{syn} = 0.18 \; (SD = 0.06)$
- But: a reliable effect of genre ($F_{(2,237)} = 20.13, p = 0.00$):

	formal	informal	telephone
real	0.21	0.19	0.17
control	0.21	0.18	0.16

Corpus experiment: Results over distance

- Following [Reitter et al., 2006], we can examine average similarity to recent turns
- Syntactic self-similarity shows a significant linear trend ($p = 0.00$)
- Syntactic other-similarity not reliable ($p = 0.15$)
- Plotting real and control dialogues is interesting though



- Are we just seeing the effect of dialogue structure?

Corpus experiment: Conclusions

- We can measure the effect of lexical priming
- We can't measure the effect of syntactic priming
    - We don't have enough statistical power here to say there's *no* effect
    - But it must be quite small (relative to the lexical effect)
- We can measure the effect of genre on syntactic similarity
    - This seems to agree with (some of) [Reitter et al., 2006]'s results
- We'd like more (parsed) data – working on the BNC now ...

Outline

DS and TTR: Motivation

- So far, we're happy that we're going in roughly the right direction:
  - Split utterances seem to fit the DS approach
  - Priming results fit with prediction (so far as we can tell)

DS and TTR: Motivation

- So far, we're happy that we're going in roughly the right direction:
  - Split utterances seem to fit the DS approach
  - Priming results fit with prediction (so far as we can tell)
- For a proper treatment of NSUs and SUs, DS needs more structured representations
  - Responsibility for a (sub-)utterance (speaker, hearer?)
  - Utterance function (speech acts?)
- Want to avoid *forcing* this into all representations . . .
  - What should really be in the grammar?

Type Theory With Records

- See [Betarte and Tasistro, 1998], following Martin-Löf
- *Records* are sequences of label/value pairs:
$$\begin{bmatrix} l_1 & = & v_1 \\ l_2 & = & v_2 \\ l_3 & = & v_3 \end{bmatrix}$$
- *Record types* are sequences of label/type pairs:
$$\begin{bmatrix} l_1 & : & T_1 \\ l_2 & : & T_2 \\ l_3 & : & T_3 \end{bmatrix}$$
- Record types are true iff they are *inhabited/witnessed*
  - = there exists at least one record of that type
  - = successful type judgements for each label/value pair:
$$v_1 : T_1, \quad v_2 : T_2, \quad v_3 : T_3$$

Type Theory With Records

- Types can be *dependent* on earlier (higher-up) types:

$$\begin{bmatrix} l_1 & : & T_1 \\ l_2 & : & T_2(l_1) \\ l_3 & : & T_3(l_1, l_2) \end{bmatrix}$$

- We can have *nested* records and record types:

$$\begin{bmatrix} l_1 & : & T_1 \\ l_2 & : & \begin{bmatrix} l'_1 & : & T'_1 \\ l'_2 & : & T'_2 \end{bmatrix} \\ l_3 & : & T_3(l_1, l_2.l'_1, l_2.l'_2) \end{bmatrix}$$

Type Theory With Records

- We can have *functional* record types:
$$\lambda r : \left[\begin{array}{lll} l_1 & : & T_1 \\ l_2 & : & T_2 \end{array}\right] \left(\left[\begin{array}{lll} l_3 & : & T_3 \\ l_4 & : & T_4(r.l_1, r.l_2) \end{array}\right] \right)$$
- Given a record $r = \left[\begin{array}{lll} l_1 & = & v_1 \\ l_2 & = & v_2 \end{array}\right]$ of type $\left[\begin{array}{lll} l_1 & : & T_1 \\ l_2 & : & T_2 \end{array}\right]$,

Type Theory With Records

- Used for sentential semantics, e.g. [Cooper, 2005, Ginzburg, 2005]
- "A man left":

$$\begin{bmatrix} x & : & man \\ p & : & leave(x) \end{bmatrix}$$

- for truth: x must be a man, p a proof that x left
- Similarities to DRT representation:

$$\begin{array}{|c|} \hline x \\ \hline \text{man(x)} \\ \text{leave(x)} \\ \hline \end{array}$$

- "Every man left":

$$\lambda r : \begin{bmatrix} x & : & man \end{bmatrix} (\begin{bmatrix} p & : & leave(r.x) \end{bmatrix})$$

Type Theory With Records

- Used for dialogue modelling in the information-state-based tradition
  - [Cooper and Ginzburg, 2002, Ranta and Cooper, 2004, Fernández, 2006, Ginzburg, prep]

The best of both worlds?

- TTR gives us a type-theoretic framework, applicable to dialogue phenomena
- DS gives us an incremental framework using type theory as an underlying mechanism
- Can we combine the two?

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$john$, $Ty(e)$

$\lambda x.leave(x)$, $Ty(e \rightarrow t)$

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$$\begin{bmatrix} x & : & \mathit{john} \end{bmatrix} \qquad \lambda [x] . \begin{bmatrix} p & : & \mathit{leave}(x) \end{bmatrix}$$

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$$\begin{array}{c} \diamondsuit, ?Ty(t) \\ \swarrow \qquad \searrow \\ Ty(e), \qquad\qquad Ty(e \rightarrow t), \\ john \qquad\qquad \lambda x.leave(x) \end{array}$$

IF	$?Ty(e)$
THEN	$\texttt{put}(Ty(e))$
	$\texttt{put}(Fo(john))$
ELSE	$\texttt{abort}$

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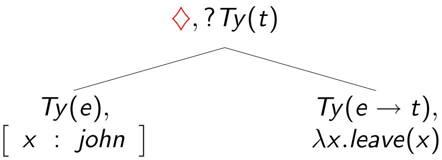

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A simple version

- Replace $Fo()$ epsilon-calculus labels with TTR record types
- Interpret $Ty()$ simple type labels as referring to *final* TTR field type
- Function application as before for DS `elimination` process

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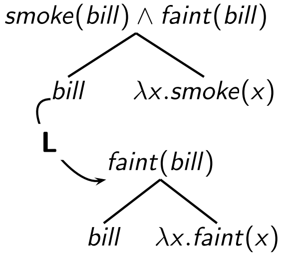
Adding in LINK relations

- For LINKed trees, we need conjunction

"Bill, who fainted, smokes."



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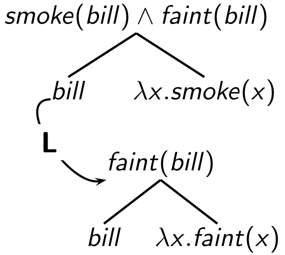

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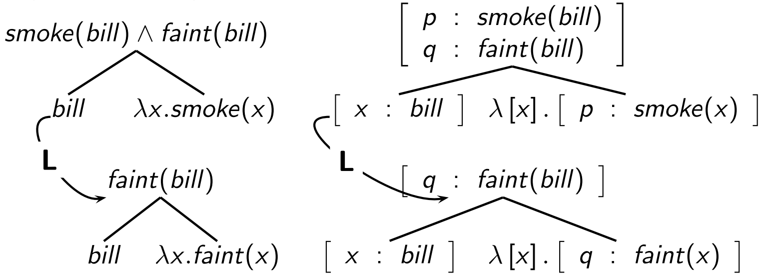

Can we do better?

- From an implementational point of view, this is OK
- But we're in danger of losing something
  - DS trees as they stand have a direct correspondence with semantics
  - Nodes are terms in the lambda-calculus
  - (Unreduced terms at daughter nodes)
  - What exactly are they now?
- Would prefer tree definitions via TTR(-compatible) logic
  - Type dependencies rather than abstraction (via [Kopylov, 2003] dependent intersection)
  - Initial versions for basic framework; LINK more complicated
  - (Meyer-Viol/White, forthcoming)

LINK as optional enrichment process

- Add utterance-event information
- Add speaker (or rather "responsible party") information

"John left"

$$\diamondsuit, Ty(t), \left[\begin{array}{lcl} & & \\ x & : & john \\ p & : & leave(x) \end{array}\right]$$

$$Ty(e), \quad Ty(e \rightarrow t),$$

$$\left[\ x \ : \ john\ \right] \qquad \lambda[x].\left[\ p \ : \ leave(x)\ \right]$$

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$$Ty(e), \left[\begin{array}{lcl} x & : & john \end{array}\right] \qquad Ty(e \rightarrow t), \lambda[x].\left[\begin{array}{lcl} p & : & leave(x) \end{array}\right]$$

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LINK as optional enrichment process

- Speech act inferences conditional on syntax/semantics

"Did John leave?"

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- Similarities with [Ginzburg et al., 2003]

An example: a “clausal” clarification request

A: “Did John leave?”

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B: "John?"

$$\left[\begin{array}{lll} u_1 & : & utt-event \\ b & : & spkr(u_1) \\ x & : & john \end{array}\right]$$

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A: "Did John leave?"

$$+Q, \left[\begin{array}{lcl} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ p & : & leave(x) \end{array}\right]$$

$$\left[\begin{array}{lcl} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ p & : & leave(x) \\ q_0 & : & ask(u_0, a, ?p) \end{array}\right]$$

$$\left[\begin{array}{lcl} x & : & john \end{array}\right] \qquad \lambda[x] . \left[\begin{array}{lcl} p & : & leave(x) \end{array}\right]$$

B: "John?"

$$\left[\begin{array}{lcl} u_1 & : & utt-event \\ b & : & spkr(u_1) \\ x & : & john \end{array}\right]$$

$$\left[\begin{array}{lcl} u_0 & : & utt-event \\ \ldots & : & \ldots \\ u_1 & : & utt-event \\ b & : & spkr(u_1) \\ q_1 & : & ask(u_1, b, ?ask(u_0, a, ?p)) \end{array}\right]$$

An example: a “constituent” clarification request

- Add [Poesio and Traum, 1997]'s *micro-conversational events*

  A: “Did John ...”

$$?Ty(t), +Q$$

$$\left[\begin{array}{lll} u_{01} & : & utt-event \\ a & : & spkr(u_{01}) \\ x & : & john \end{array}\right] \qquad ?Ty(e \rightarrow t)$$

An example: a "constituent" clarification request

- Add [Poesio and Traum, 1997]'s *micro-conversational events*

  A: "Did John ..."

$$?Ty(t), +Q$$

$$\begin{bmatrix} u_{01} & : & utt-event \\ a & : & spkr(u_{01}) \\ x & : & john \end{bmatrix} \qquad ?Ty(e \rightarrow t)$$

B: "John?"

$$\begin{bmatrix} u_1 & : & utt-event \\ b & : & spkr(u_1) \\ x & : & john \end{bmatrix}$$

An example: a "constituent" clarification request

- Add [Poesio and Traum, 1997]'s *micro-conversational events*

  A: "Did John . . ."

$$?Ty(t), +Q$$

$$\begin{bmatrix} u_{01} & : & utt-event \\ a & : & spkr(u_{01}) \\ x & : & john \end{bmatrix} \qquad ?Ty(e \rightarrow t)$$

B: "John?"

$$\begin{bmatrix} u_{1} & : & utt-event \\ b & : & spkr(u_{1}) \\ x & : & john \end{bmatrix} \qquad \begin{bmatrix} u_{01} & : & utt-event \\ \ldots & : & \ldots \\ u_{1} & : & utt-event \\ b & : & spkr(u_1) \\ q_1 & : & ask(u_1, b, ?content(u_{01}, a, x)) \end{bmatrix}$$

An example: a clarificational split utterance

A: "John ..."

$$+Q, \begin{bmatrix} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ \mathbf{P} & : & META(x) \end{bmatrix}$$

$$\begin{bmatrix} x & : & john \end{bmatrix} \qquad ?Ty(e \rightarrow t)$$

An example: a clarificational split utterance

A: "John ..."

$$+Q, \left[\begin{array}{lcl} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ \mathbf{P} & : & META(x) \end{array}\right] \qquad \left[\begin{array}{lcl} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ \mathbf{P} & : & META(x) \\ q_0 & : & ask(u_0, a, ?\mathbf{P}) \end{array}\right]$$

$$\left[\ x \ : \ john \ \right] \qquad ?Ty(e \rightarrow t)$$

An example: a clarificational split utterance

A: "John ..." B: "left?"

$$+Q, \begin{bmatrix} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ \mathbf{P} & : & META(x) \end{bmatrix} \qquad \begin{bmatrix} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ \mathbf{P} & : & META(x) \\ q_0 & : & ask(u_0, a, ?\mathbf{P}) \end{bmatrix}$$

$$\begin{bmatrix} x & : & john \end{bmatrix} \qquad ?Ty(e \rightarrow t)$$

An example: a clarificational split utterance

A: "John ..." B: "left?"

$$+Q, \begin{bmatrix} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ p & : & leave(x) \end{bmatrix} \qquad \begin{bmatrix} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ p & : & leave(x) \\ q_0 & : & ask(u_0, a, ?p) \end{bmatrix}$$

$$\begin{bmatrix} x & : & john \end{bmatrix} \qquad \lambda[x].\begin{bmatrix} p & : & leave(x) \end{bmatrix}$$

An example: a clarificational split utterance

A: "John ..." B: "left?"

$$+Q, \left[\begin{array}{lcl} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ p & : & leave(x) \end{array}\right] \qquad \left[\begin{array}{lcl} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ p & : & leave(x) \\ q_0 & : & ask(u_0, a, ?p) \end{array}\right]$$

$$\left[\; x \;:\; john \;\right] \qquad \lambda[x].\left[\; p \;:\; leave(x) \;\right]$$

$$\left[\begin{array}{lcl} u_0 & : & utt-event \\ \ldots & : & \ldots \\ u_1 & : & utt-event \\ b & : & spkr(u_1) \\ q_1 & : & ask(u_1, b, ?ask(u_0, a, p)) \end{array}\right]$$

(Eventual) Conclusions

- Incrementality of DS with the flexibility of TTR
- Core grammar essentially as before
- Optional enrichment processes for speech act information
  - similarities to [Ginzburg and Cooper, 2004] et al.
  - similarities to [Asher and Lascarides, 2003] et al.
- A proper treatment of split utterances . . . ?
  - capturing insights of [Rieser and Poesio, prep]
  - more fundamentally incremental

Thanks!

And thanks to:

Pat Healey, Christine Howes, Graham White, Arash Eshghi, Greg Mills at QMUL

Ruth Kempson, Eleni Gregoromichelaki, Wilfried Meyer-Viol at KCL

Andrew Gargett in Saarbrücken, Yo Sato in Herts

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