Incrementality, Alignment and Split Utterances

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The Dynamics of Conversational Dialogue (DynDial)
ESRC-RES-062-23-0962
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Outline

1. Dialogue and Incrementality
    - Split Utterances and Alignment
2. Dynamic Syntax (DS)
    - A Quick Introduction to DS
    - DS and Dialogue Modelling
3. Empirical Investigations
    - Priming - Corpus Study
    - Split Utterances - Corpus Study
    - Split Utterances - Experiments
4. Dynamic Syntax & Type Theory with Records (TTR)
    - Adding TTR to DS
    - Fragments & Split Utterances in DS/TTR

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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]
  - inherently incremental grammar formalism
- Empirical studies using corpora and experiments

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    - formal/computational linguists, logicians, experimental psychologists
- Linguistic modelling using Dynamic Syntax [Kempson et al., 2001]
    - inherently incremental grammar formalism
- Empirical studies using corpora and experiments
    - Non-sentential utterances
    - Clarification requests
    - Split utterances
    - Priming/alignment

Split Utterances

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

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A: The profit for the group is 190,000.
B: Which is superb. (“expansion”)

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

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  - . . . and therefore a change in hearer

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B: Which is superb. ("expansion")

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

- Fundamental requirement for incremental processing
  - A good test for syntactic and semantic dependencies
- Treatment for one particular kind [Poesio and Rieser, 2010]
  - LTAG grammar and conversational-event-based plan recognition

Split Utterances

- Particularly interesting from an incrementality point of view

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- Where can splits occur? Within constituents?

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Alex: Trecastle,

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B: any of your chapters? Not yet.

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B: any of your chapters? Not yet.

- Not just a case of splitting a *string*
- How common are these really?
- Where do splits really occur (how incremental must we be)?

Priming and/or Alignment

- Tendency to repeat previously used material
    - words
    - syntactic structures [Branigan et al., 2000]
    - multi-word expressions
    - ways of referring [Garrod and Anderson, 1987]
- Both self- and other- effects [Pickering and Ferreira, 2008]
- Interesting for models of incremental processing
    - (. . . especially in the case of split utterances . . .)
    - what phenomena are primed/aligned? (and therefore represented)?
    - evidence for independence of lexicon/syntax/semantics?
- Most data from controlled experimental settings
- What does this tell us about real dialogue?

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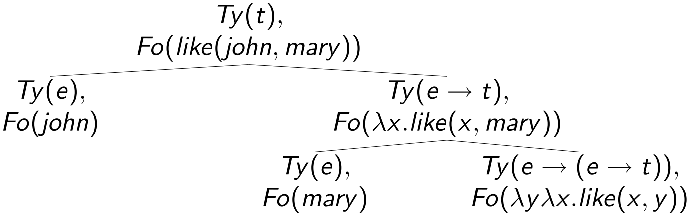
Dynamic Syntax

- 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”:



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

$Ty(e)$, $Fo(john)$

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

$Ty(e)$, $Fo(mary)$

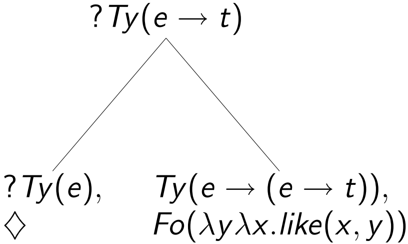
$Ty(e \rightarrow (e \rightarrow t))$, $Fo(\lambda y \lambda x.like(x, y))$

- 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

- Incremental tree growth driven by *requirements* e.g. $?Ty(t)$
- Node under development marked by *pointer* $\diamondsuit$
- Words induce sets of *lexical* actions: *"like"*

IF $?Ty(e \rightarrow t)$
THEN make($\langle\downarrow_1\rangle$);go($\langle\downarrow_1\rangle$);
put($Fo(\lambda y \lambda x.like(x,y))$);
put($Ty(e \rightarrow (e \rightarrow t))$)
go($\langle\uparrow_1\rangle$); make($\langle\downarrow_0\rangle$);
go($\langle\downarrow_0\rangle$); put($?Ty(e)$)
ELSE ABORT



$?Ty(e \rightarrow t)$

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

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

- 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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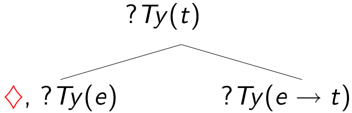

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$\diamondsuit, ?Ty(e)$

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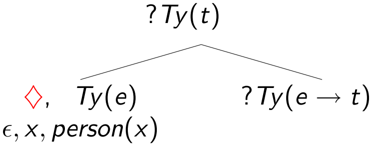

$?Ty(t)$

$\diamondsuit, \quad Ty(e)$

$\epsilon, x, person(x)$

$?Ty(e \rightarrow t)$

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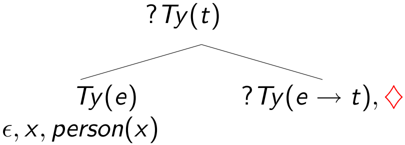

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$?Ty(e \rightarrow t), \Diamond$

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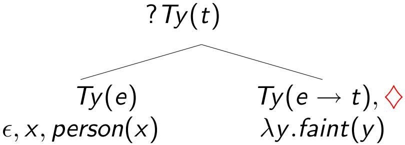

$?Ty(t)$

$Ty(e)$
$\epsilon, x, person(x)$

$Ty(e \rightarrow t), \diamondsuit$
$\lambda y.faint(y)$

Unfolding then building up the tree

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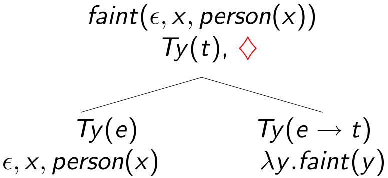

$faint(\epsilon, x, person(x))$
$Ty(t), \diamondsuit$

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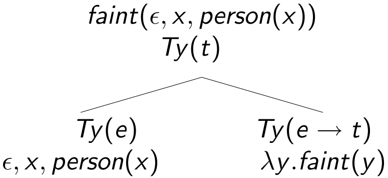
$\rightsquigarrow faint(\epsilon, x, person(x))$



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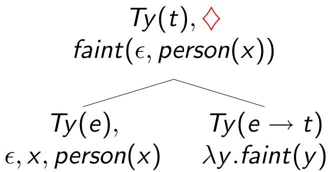
Generation

- 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



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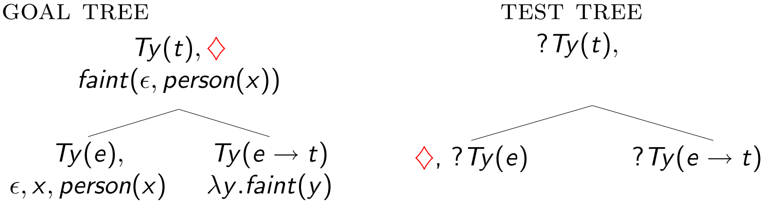

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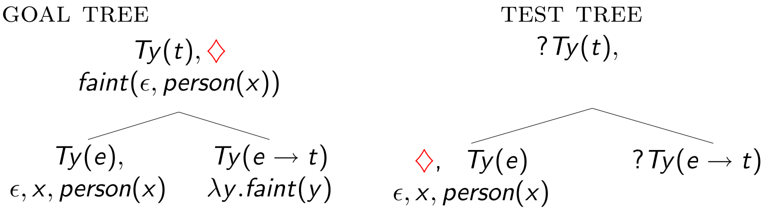

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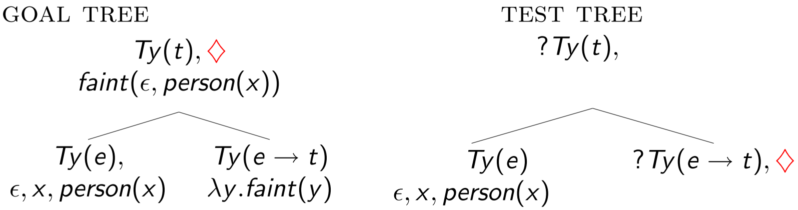

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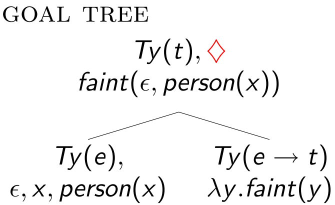
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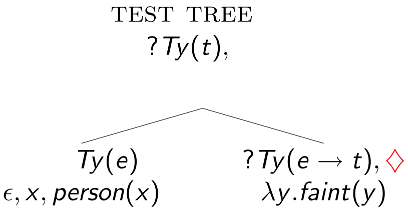
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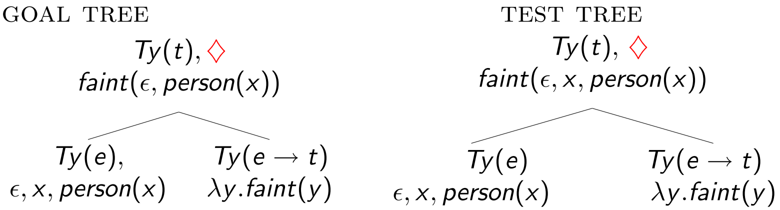

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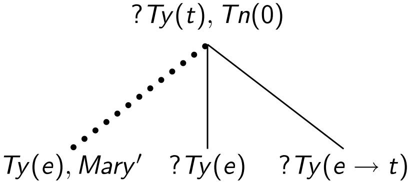
Underspecification: structural

- “Unfixed” nodes - building underspecified tree relations



$?Ty(t), Tn(0)$

$Ty(e), Mary'$ $\quad ?Ty(e)$ $\quad ?Ty(e \rightarrow t)$

- Left-dislocation “Mary, John likes”

Underspecification: content

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

Underspecification: content

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(1) Someone smoked He fainted.

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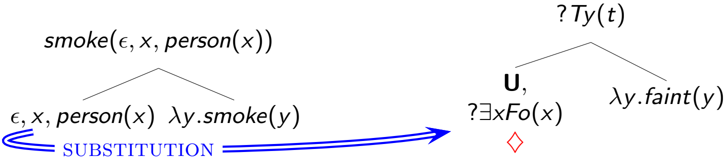
(1) Someone smoked He fainted.

TREE AS CONTEXT: TREE UNDER CONSTRUCTION:



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

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

SUBSTITUTION

$?Ty(t)$

$\mathbf{U}$, $?\exists x Fo(x)$ ◇

$\lambda y.faint(y)$

Underspecification: ellipsis

- Auxiliaries also project META-VARIABLES (**V**)

  Substituted by item from context in the same way

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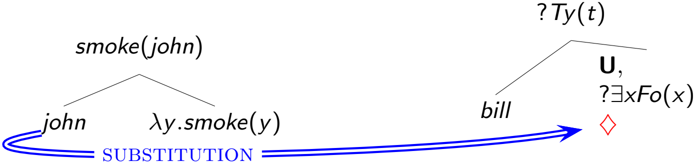

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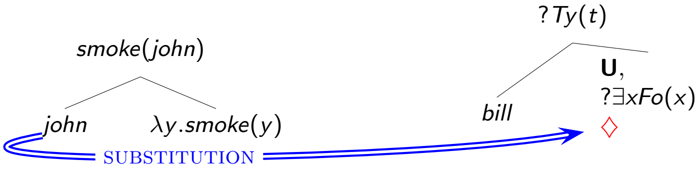
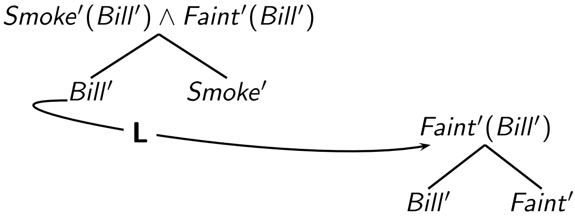


- Alternatively can use *actions* from context (sloppy readings)
- Simple model of *context* containing previous (partial) trees and action sequences

Context-dependence: LINKed tree-pairs

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

  e.g. Bill, who fainted, smokes.



Appositions as LINKed trees

e.g. A friend, a musician, smokes.

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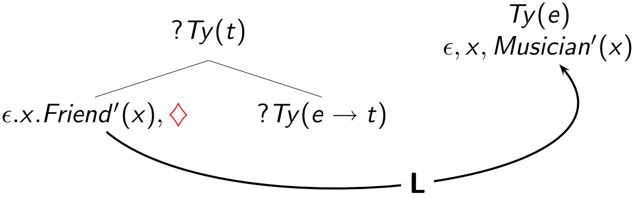
- Partial tree as context with term enriched by LINKed tree of same type
- Parsing *A friend, a musician*



$?Ty(t)$

$\epsilon.x.Friend'(x), \Diamond$

$?Ty(e \rightarrow t)$

$Ty(e)$

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

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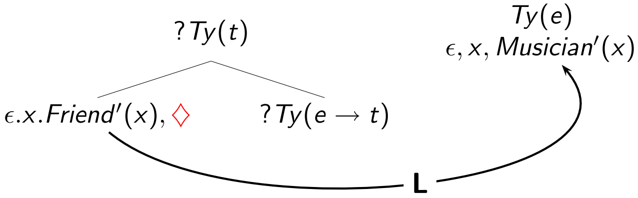

$?Ty(t)$

$\epsilon.x.Friend'(x), \Diamond$ $\quad ?Ty(e \rightarrow t)$

$Ty(e)$
$\epsilon, x, Musician'(x)$

L

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

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

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

DS and Split Utterances

- DS *seems* well suited for split utterances
- Inherent word-by-word incrementality
- Well-defined partial structures at each point
- Same actions and partial structures in parsing and generation
- Grammatical constraints via semantics rather than "syntax"
    - Not licensing a string
    - Splits should be possible anywhere

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$?Ty(t)$

$john$ $\quad ?Ty(e \rightarrow t), \Diamond$

$smoke(john), \Diamond$

$john$ $\quad \lambda y.smoke(y)$

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- Is it too general (what are the real constraints)?
- Is it too simplistic (what do split utterances *mean*)?

DS and Priming/Alignment

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- 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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        put($Ty(e \rightarrow (e \rightarrow t))$)
        go($\langle\uparrow_1\rangle$); make($\langle\downarrow_0\rangle$);
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ELSE    ABORT
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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?
    - Branigan et al found weaker cross-verb effects
    - (re-use of *computational* action sequences?)
- Do we see them in real dialogue?

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   - Priming - Corpus Study
   - Split Utterances - Corpus Study
   - Split Utterances - Experiments
4. Dynamic Syntax & Type Theory with Records (TTR)
   - Adding TTR to DS
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    - Do we see them in ordinary dialogue?
    - Can we tell which effect is greater?
- Do split utterances really behave the way we think?
    - How common are they?
    - Where does the split happen?
    - What do they mean?

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?

B': Not much

A: Yeah fine thanks

B': Uh-huh

Corpus experiment: Method

A:	Hello
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Corpus experiment: Lexical results

- Lexical similarity expressed via word pair kernel:
    - number of matching word pairs between turns A and $B = N_{AB}$
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  $S_{lex} = 0.094\ (SD = 0.04)$
- Control dialogues mean other-person similarity

  $S_{lex} = 0.059\ (SD = 0.03)$

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- Control dialogues mean other-person similarity
  $S_{syn} = 0.18$ $(SD = 0.06)$
- ANOVA for real vs. control shows difference *not* reliable:
  $F_{(1,253)} = 1.32, \;\; p = 0.25$
- 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: Syntactic results (2)

- What's the influence of lexical similarity on syntactic similarity?
- Linear Mixed Model analysis can tell us:
  - subject, dialogue as random factors
  - real/control type as fixed factor
  - lexical similarity as covariate

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- Parameter estimate for S_{syn} negative
- Marginal ("corrected") means: $S_{syn} = 0.184$ real, $S_{syn} = 0.211$ control
- Reliable difference: $p = 0.01$
- i.e. S_{syn} is *lower* than chance when S_{lex} taken into account

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- Reliable difference: $p = 0.01$
- i.e. S_{syn} is *lower* than chance when S_{lex} taken into account
- Checked on BNC spoken portion (bigger but not parsed)
    - parsed using C&C CCG parser, Stanford CFG parser
    - results the same

Corpus experiment: Conclusions

- We can measure the effect of lexical priming
- We can't measure the effect of syntactic priming
  - It appears to be negative when lexical effect taken into account
  - Even if it exists, it must be 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

Corpus experiment: Conclusions

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  - Even if it exists, it must be 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
- A grammar which associates syntactic effects with lexical entries might be on the right track . . .
- We'd like to know more about individual phenomena . . .

Split Utterances: 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

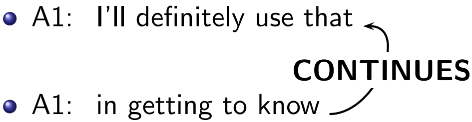
Corpus Study: Annotation Schema

- A1: I'll definitely use that ⟵ **END-COMPLETE=Y** —

Corpus Study: Annotation Schema

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

Corpus Study: Annotation Schema



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CONTINUES

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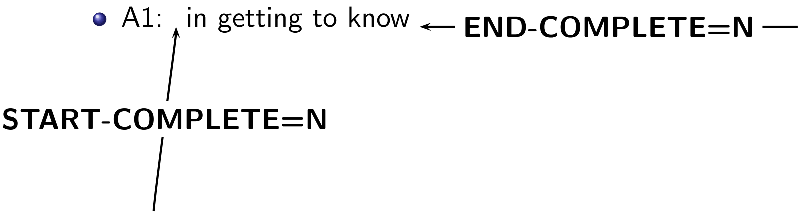


- A1: I'll definitely use that
- A1: in getting to know ← **END-COMPLETE=N** —

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

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

CONTINUES

Corpus Study: Annotation Schema

- A1: I'll definitely use that
- A1: in getting to know
- A1: new year seven ⟵ **END-COMPLETE=Y** —

START-COMPLETE=N

Corpus Study: Annotation Schema

- 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)

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)
- 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

- 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:

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

  (2) 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

- 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:

(3) 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 . . .
  - (hard to establish propositional content/intention of antecedent)

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

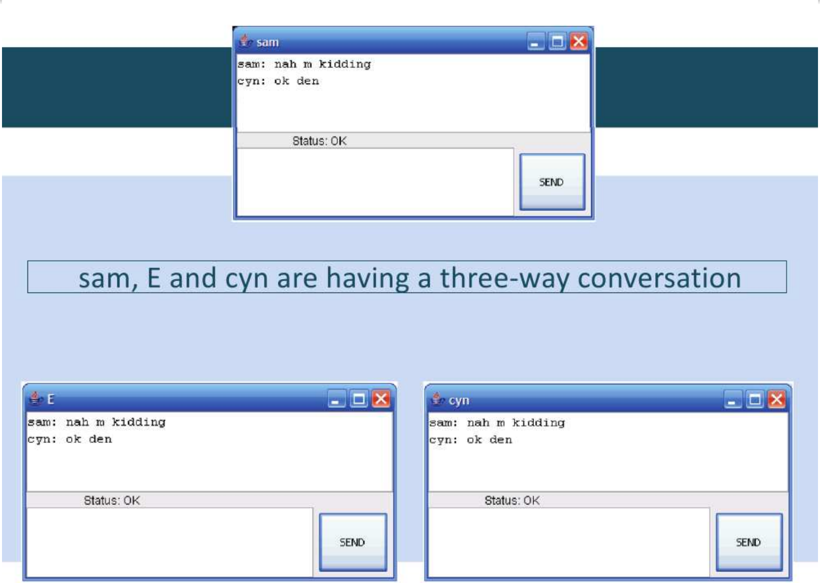
- Some conclusions play right into DS's hands ...
  - Splits happen within syntactic/semantic "constituents"
  - Not always collaborative as per [Poesio and Rieser, 2010]
  - Intervening turns use incomplete antecedents (partial trees)

Corpus Study: Conclusions

- Some conclusions play right into DS's hands . . .
  - Splits happen within syntactic/semantic "constituents"
  - Not always collaborative as per [Poesio and Rieser, 2010]
  - 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
    - SUs may be common, but are they easy/hard to process?
- 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: nah m kidding
cyn: ok den
```

sam, E and cyn are having a three-way conversation

```
sam: nah m kidding
cyn: ok den
```

```
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```
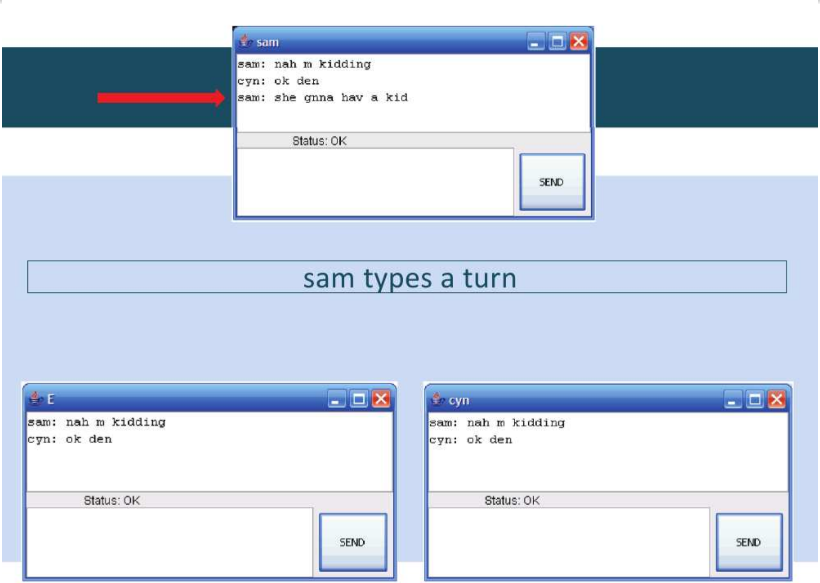
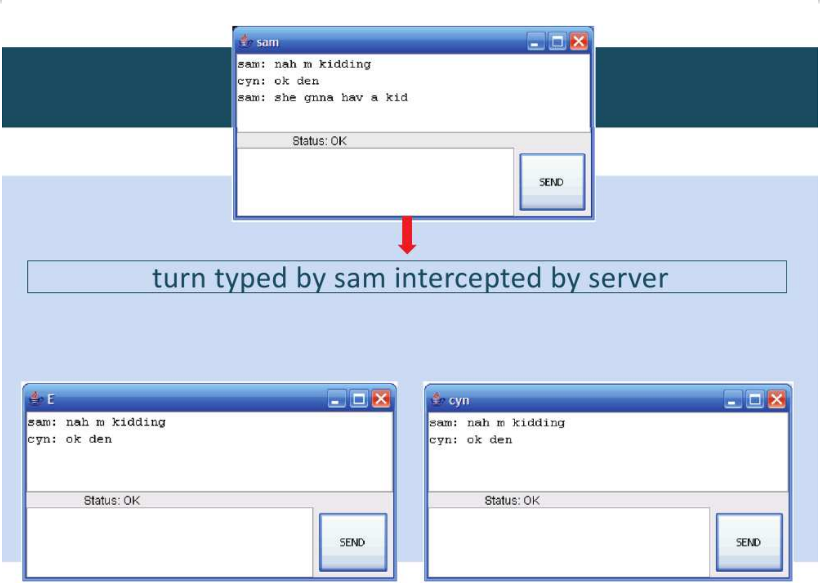



sam: nah m kidding
cyn: ok den
sam: she gnna hav a kid

sam types a turn

sam: nah m kidding
cyn: ok den

sam: nah m kidding
cyn: ok den

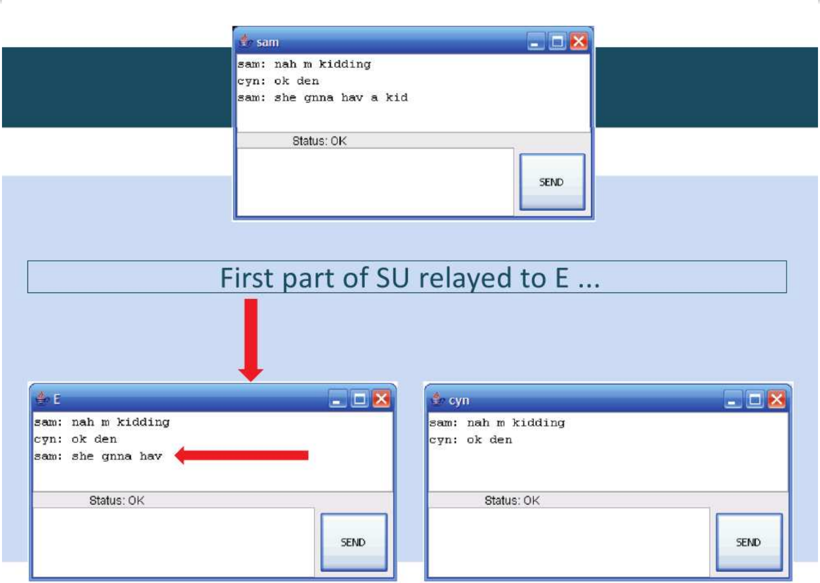


```
sam: nah m kidding
cyn: ok den
sam: she gnna hav a kid
```

turn typed by sam intercepted by server

```
sam: nah m kidding
cyn: ok den
```

```
sam: nah m kidding
cyn: ok den
```



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First part of SU relayed to E ...

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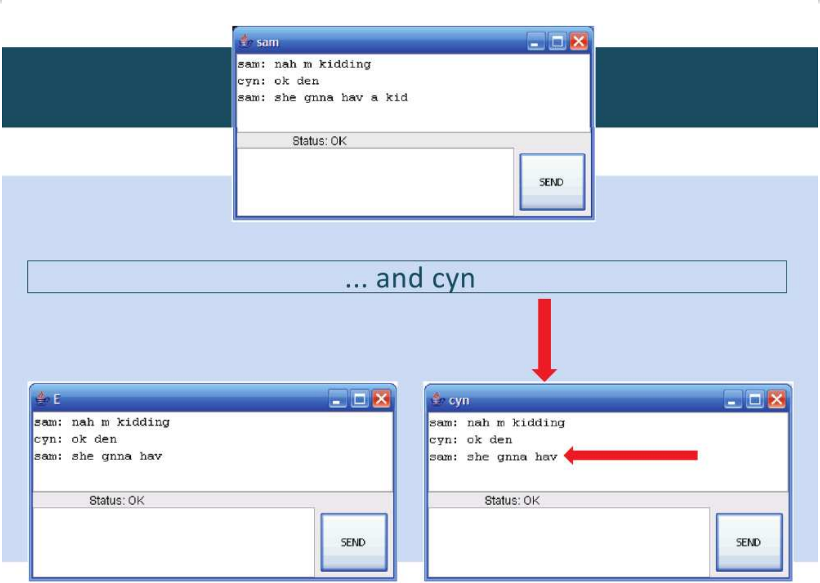

sam: nah m kidding
cyn: ok den
sam: she gnna hav a kid

... and cyn

sam: nah m kidding
cyn: ok den
sam: she gnna hav

sam: nah m kidding
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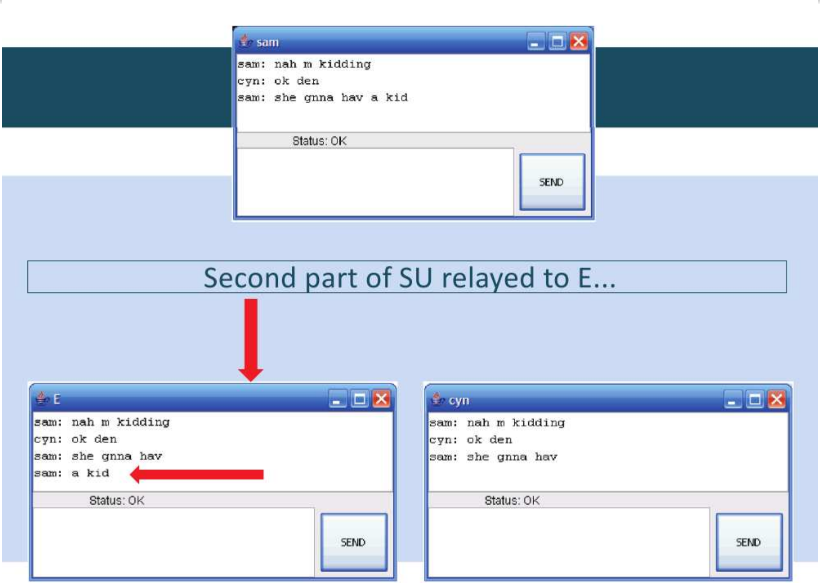
sam: she gnna hav

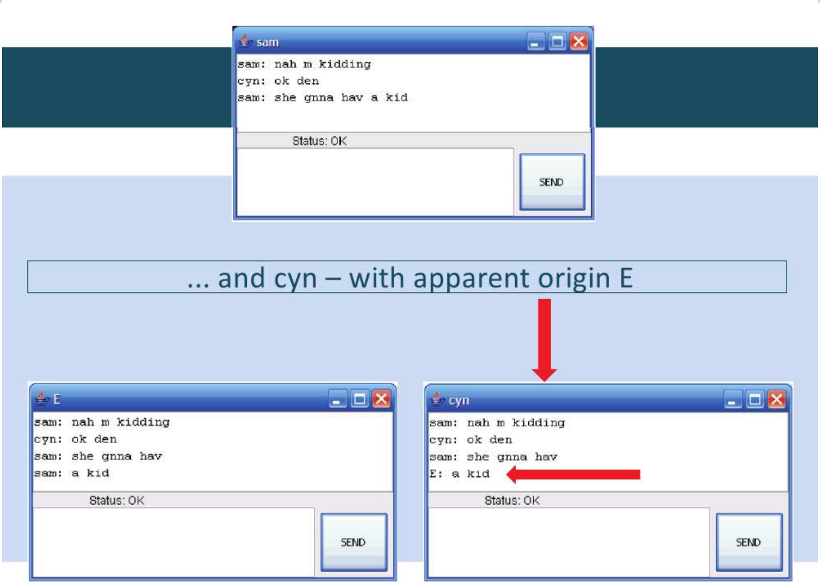


```
sam: nah m kidding
cyn: ok den
sam: she gnna hav a kid
```

Second part of SU relayed to E...

```
sam: nah m kidding
cyn: ok den
sam: she gnna hav
sam: a kid
```

```
sam: nah m kidding
cyn: ok den
sam: she gnna hav
```



```
sam: nah m kidding
cyn: ok den
sam: she gnna hav a kid
```

... and cyn – with apparent origin E

```
sam: nah m kidding
cyn: ok den
sam: she gnna hav
sam: a kid
```

```
sam: nah m kidding
cyn: ok den
sam: she gnna hav
E: a kid
```

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’t* observe time to start typing)

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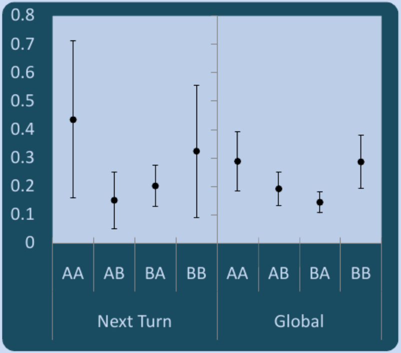
    - *next turn* effects: the next participant to type
    - *global* effects: all participants turns until next intervention
- (We *can't* observe time to start typing)
- We can compare: speaker switch (AA/BB vs. AB/BA)
- We can compare: floor change (AA/BA vs. BB/AB)
- We can compare: first/second part coherence (Y/N)

Experimental Study: Results

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

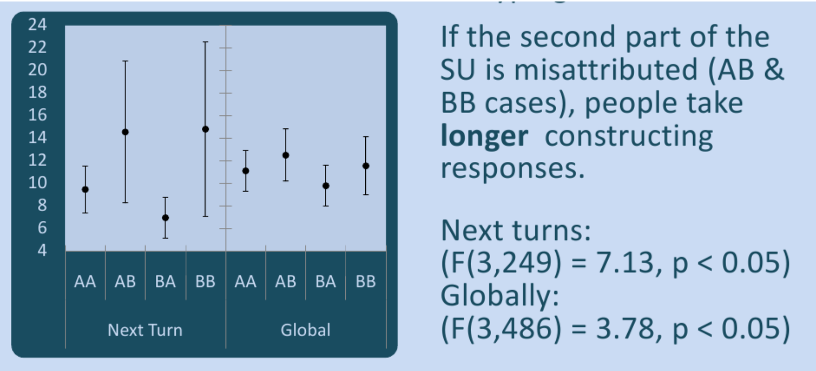


If the SU appears to be a cross-person one (AB & BA cases), people use **fewer** deletes in their responses.

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

Experimental Study: Results

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

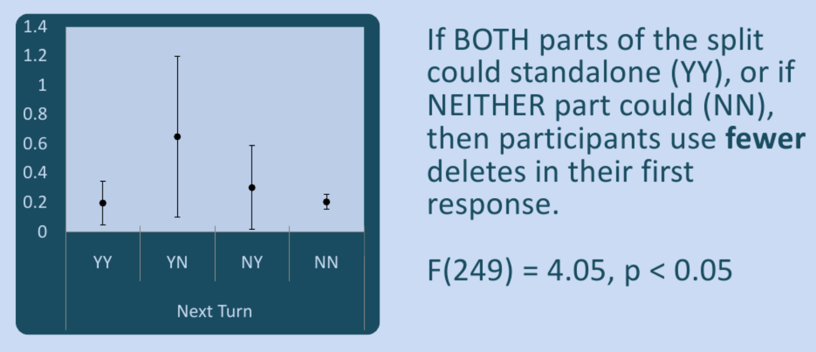


If the second part of the SU is misattributed (AB & BB cases), people take **longer** constructing responses.

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

Experimental Study: Results

- 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 . . .
    - . . . and we'd really like to know about onset delay . . .
    - . . . a character-by-character version is almost complete

Outline

1. Dialogue and Incrementality
   - Split Utterances and Alignment
2. Dynamic Syntax (DS)
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DS and TTR: Motivation

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  - Split utterances seem to fit the DS approach (mostly)
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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 (mostly)
    - Priming results fit with prediction (so far as we can tell)
- For a proper treatment of NSUs and SUs, DS needs:
    - Utterance function (speech acts?)
    - Responsibility for a (sub-)utterance (speaker, hearer?)
    - So we need more structured representations
- 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:

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

- We can have *functional* record types:

$$\lambda r : \begin{bmatrix} l_1 & : & T_1 \\ l_2 & : & T_2 \end{bmatrix} (\begin{bmatrix} l_3 & : & T_3 \\ l_4 & : & T_4(r.l_1, r.l_2) \end{bmatrix})$$

Type Theory With Records

- Used for sentential semantics, e.g. [Cooper, 2005]
  - “A man left”: $\begin{bmatrix} x & : & \mathit{man} \\ p & : & \mathit{leave}(x) \end{bmatrix}$
  - for truth: x must be a man, p a proof that x left
  - “Every man left”: $\lambda r : \begin{bmatrix} x & : & \mathit{man} \end{bmatrix} (\begin{bmatrix} p & : & \mathit{leave}(r.x) \end{bmatrix})$
- Similarities to DRT representation: $\begin{array}{|c|}\hline x \\ \hline \mathrm{man}(x) \\ \mathrm{leave}(x) \\ \hline \end{array}$
- Used for dialogue modelling in the information-state-based tradition
  - [Cooper and Ginzburg, 2002, Ranta and Cooper, 2004, Fernández, 2006, Ginzburg, ming]

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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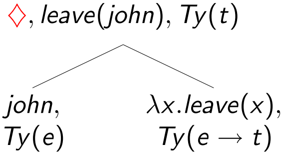

$\diamondsuit$, $leave(john)$, $Ty(t)$

$john$, $Ty(e)$

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

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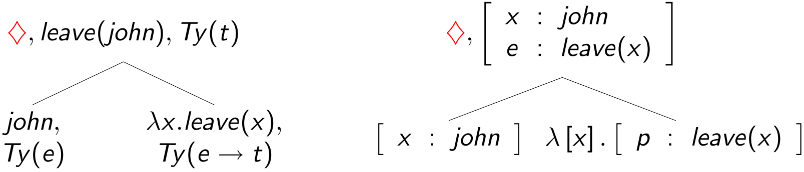

$\Diamond, \mathit{leave}(\mathit{john}), \mathit{Ty}(t)$

$\mathit{john}, \mathit{Ty}(e)$

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

$\Diamond, \left[\begin{array}{lcl} x & : & \mathit{john} \\ e & : & \mathit{leave}(x) \end{array}\right]$

$\left[\begin{array}{lcl} x & : & \mathit{john} \end{array}\right]$

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

A simple version

- Replace *Fo*() epsilon-calculus labels with TTR record types

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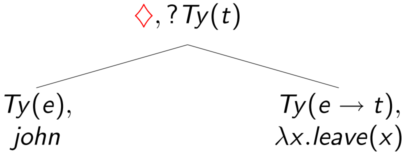

$\Diamond, ?Ty(t)$

$Ty(e),$
$john$

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

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

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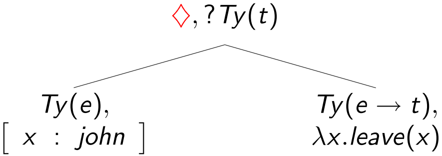

$\Diamond, ?Ty(t)$

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IF $?Ty(e)$
THEN $\mathtt{put}(Ty(e))$
$\mathtt{put}(\left[\ x \ : \ john\ \right])$
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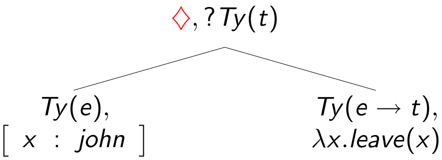
A simple version

- Replace *Fo*() epsilon-calculus labels with TTR record types
- Interpret *Ty*() simple type labels as referring to *final* TTR field type



$\Diamond, ?Ty(t)$

$Ty(e)$, $\left[\ x \ : \ john \ \right]$

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

```
IF      $?Ty(e)$
THEN    put($Ty(e)$)
        put($\left[\ x \ : \ john \ \right]$)
ELSE    abort
```

A simple version

- Replace *Fo*() epsilon-calculus labels with TTR record types
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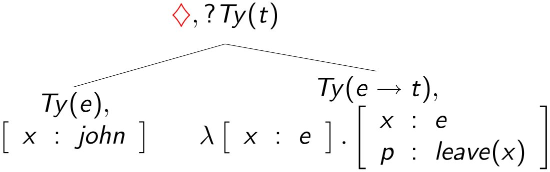


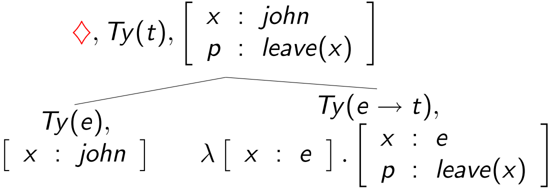
$$\Diamond, ?Ty(t)$$

$$Ty(e), \quad \left[\ x \ : \ john \ \right]$$

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

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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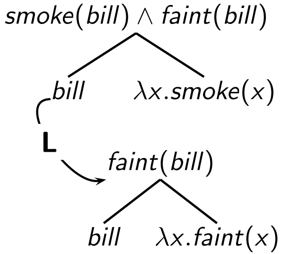
Adding in LINK relations

- For LINKed trees, we need conjunction

“Bill, who fainted, smokes.”



Adding in LINK relations

- For LINKed trees, we need conjunction
- Use *extension*: $\oplus$ where $r_1 \oplus r_2$ adds r_2 to the end of r_1
    - (for distinct labels; identical fields collapse [Cooper, 1998])

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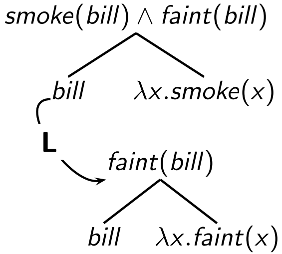

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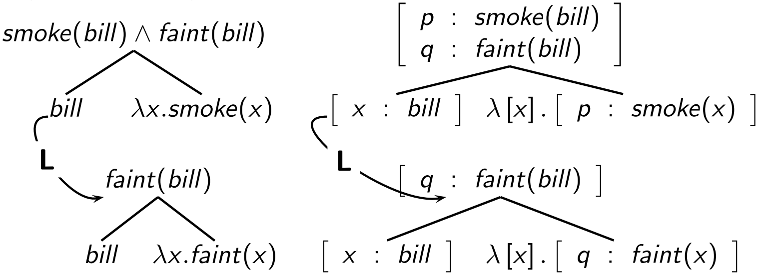


$smoke(bill) \wedge faint(bill)$

$bill$ $\lambda x.smoke(x)$

L

$faint(bill)$

$bill$ $\lambda x.faint(x)$

$\begin{bmatrix} p & : & smoke(bill) \\ q & : & faint(bill) \end{bmatrix}$

$\begin{bmatrix} x & : & bill \end{bmatrix}$ $\lambda[x].\begin{bmatrix} p & : & smoke(x) \end{bmatrix}$

L

$\begin{bmatrix} q & : & faint(bill) \end{bmatrix}$

$\begin{bmatrix} x & : & bill \end{bmatrix}$ $\lambda[x].\begin{bmatrix} q & : & faint(x) \end{bmatrix}$

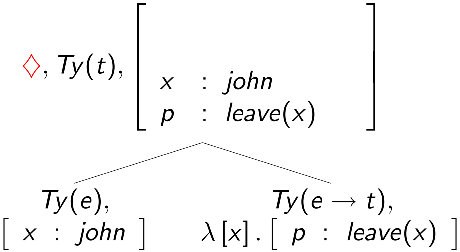
Can we do better?

- 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"



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

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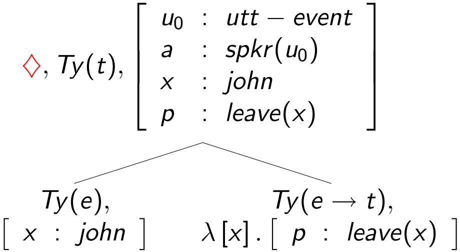

$$\diamondsuit, Ty(t), \begin{bmatrix} u_0 & : & utt - event \\ a & : & spkr(u_0) \\ x & : & john \\ p & : & leave(x) \end{bmatrix}$$

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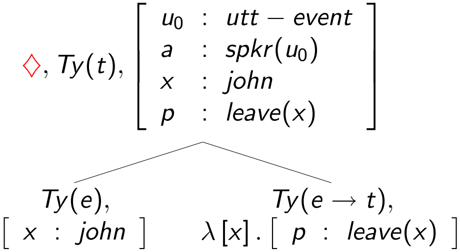

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- Allow *optional* inferences about speech acts

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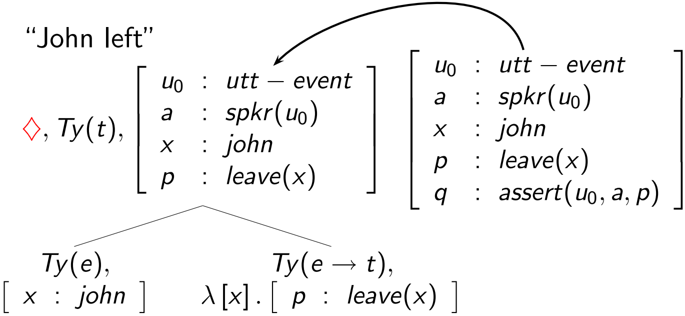

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$$\diamondsuit, Ty(t), \begin{bmatrix} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ p & : & leave(x) \end{bmatrix} \quad \begin{bmatrix} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ p & : & leave(x) \\ q & : & assert(u_0, a, p) \end{bmatrix}$$

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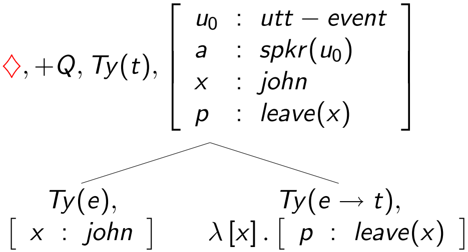
- Allow *optional* inferences about speech acts

LINK as optional enrichment process

- Speech act inferences conditional on syntax/semantics

"Did John leave?"



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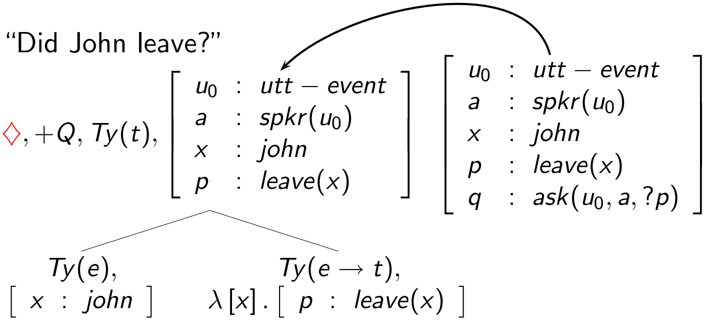

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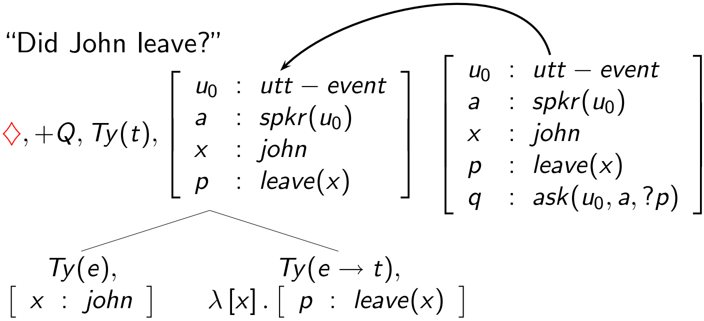

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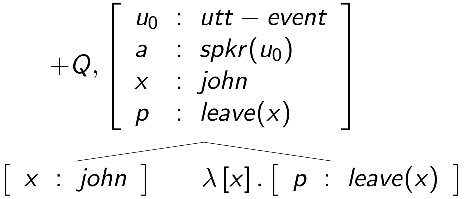
- Similarities with [Ginzburg et al., 2003]

An example: a "clausal" clarification request

A: "Did John leave?"



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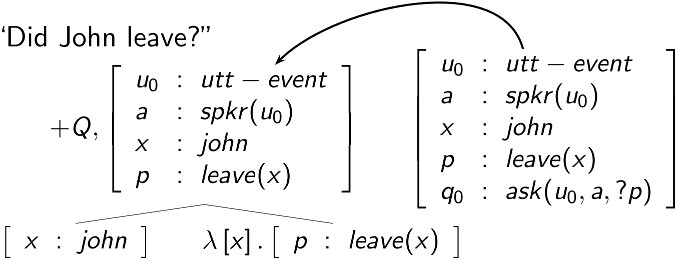

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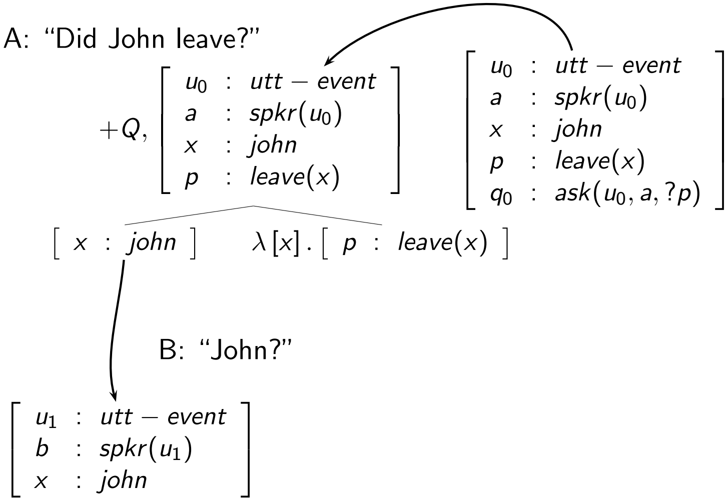

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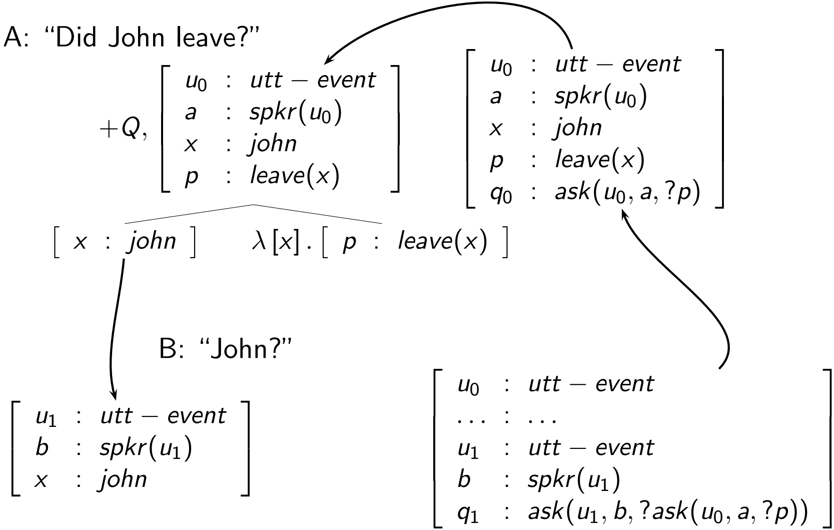
B: “John?”

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

An example: a "clausal" clarification request



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

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An example: a “constituent” clarification request

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

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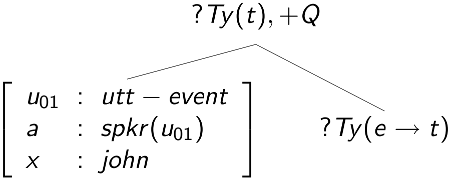

$?Ty(t), +Q$

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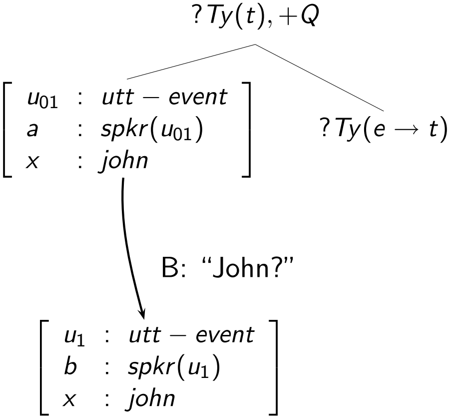

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$?Ty(e \rightarrow t)$

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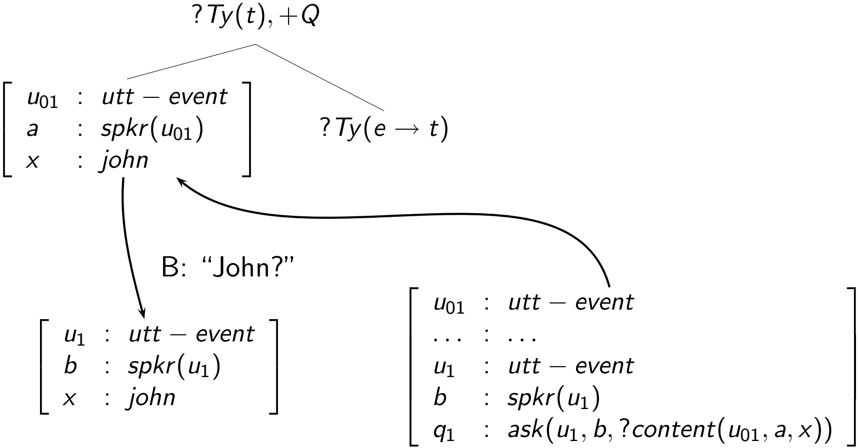

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An example: a clarificational split utterance

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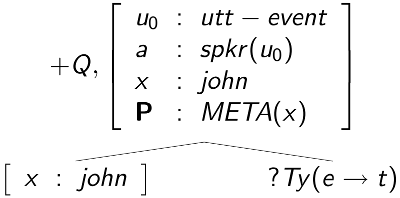

$$+Q, \begin{bmatrix} u_0 & : & utt-event \\ a & : & spkr(u_0) \\ x & : & john \\ \mathbf{P} & : & META(x) \end{bmatrix}$$

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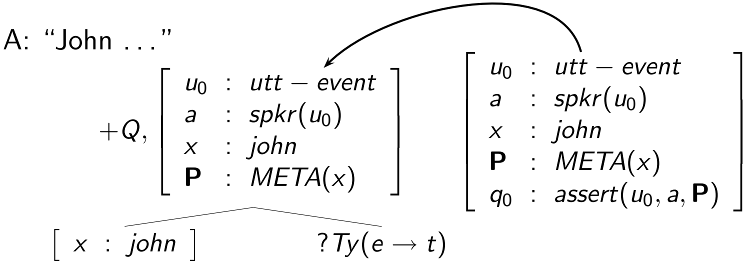

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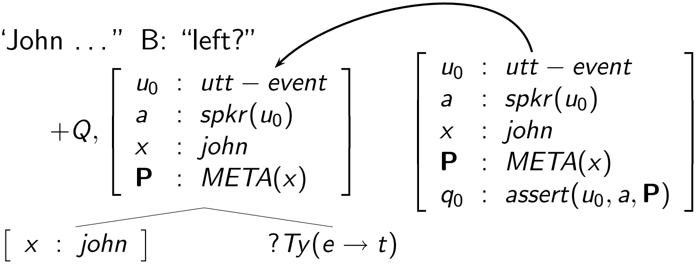
$$?Ty(e \rightarrow t)$$

An example: a clarificational split utterance

A: “John . . . ” B: “left?”



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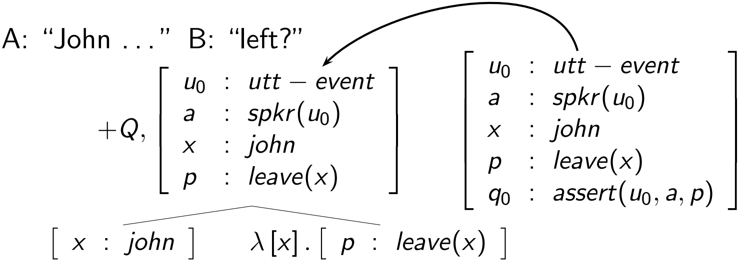

A: “John . . . ” B: “left?”

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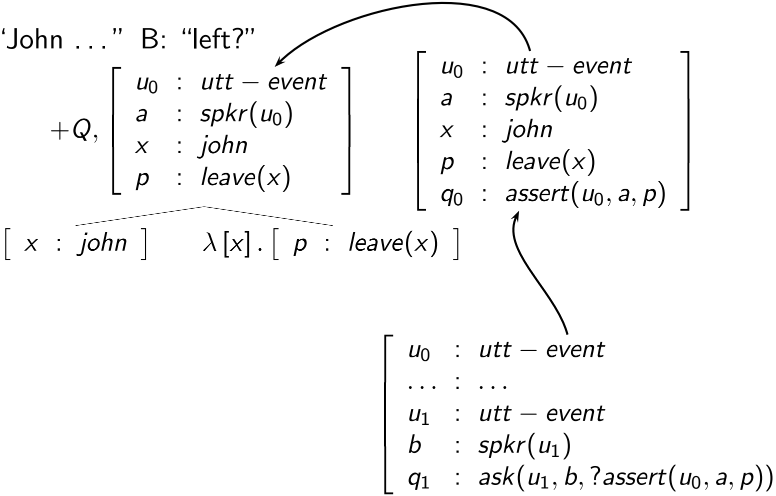

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(Eventual) Conclusions

- 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 [Poesio and Rieser, 2010]
    - 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, Ronnie Cann in Edinburgh, Yo Sato in Herts

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