



# Formal modelling of dialogue: how words interact (not only in the dictionary!)

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# **Formal modelling of dialogue: how words interact (not only in the dictionary!)**

EMLex lecture series/Séminaire de l'ATILF

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Maxime Amblard

March, 30th 2018



# Plan

Introduction

First Order Logic

Semantic Calculus

From Montague to Dynamic Semantics

A dynamic example

Summary

SLAM

Toward a formal treatment

Perspectives

## **Introduction**

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- Phonology, morphology, syntax, semantics, pragmatic

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- Phonology, morphology, syntax, **semantics**, pragmatic

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- Distributionnal / Lexical / Logic

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## **First Order Logic**

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# Leibniz



“The only way to rectify our reasonings is to make them **as tangible as those of the Mathematicians**, so that we can find our error at a glance, and when there are disputes among persons, we can simply say : Let us calculate, without further ado, to see who is right.”

The Art of Discovery, 1685

## Frege, Peano, Russell, ...



- mathematical inspiration thanks to precise calculus
- the ideal view of Leibniz is partially realized from the end of 19<sup>ieme</sup> with the works of Frege, Peano, Russell, etc.
- formal notations + rules of manipulation = formal logic
- use of First Order Logic(FOL)

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- Many other formalisms are contained in FOL or diverging on FOL’s notation.
- Many computer tools (theorem provers, model builders, model checkers) exist to work with the LPO.
- But more importantly, the FOL allows you to talk about anything.  
(temps, modalités, pluriel, événements,...)

# First Order Logic

1. vocabulary symbols (the **non-logical** symbols of the language).
2. **variables**  $x, y, z, w, \dots$
3. boolean operators  $\neg$  (**negation**),  $\rightarrow$  (**implication**),  $\vee$  (**disjunction**), et  $\wedge$  (**conjunction**).
4. quantifiers  $\forall$  (**universal**) and  $\exists$  (**existential**).
5. the **equal** symbol  $=$
6. **parenthesis** ')' and '(' and point ''

## The semantic turn

Around the 1930s, the syntactic vision was extended with the development of model theory.



Tarski (Polish logician): introduction of the famous definition of **satisfaction** and **model theory**

A theory is valid if there exists a model in which it is true

⇒ introduction to the concept of **truth**

[tarski1944] [tarski1956]

## Objectives

- represent the meaning of the statements using logical formulas (proposition, first order, classical, intuitionist, etc.)

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- develop algorithms to produce logical representations and use these representations
- fundamental techniques to construct semantic representations:  
 $\lambda$ -calculus

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- why use representations? Why not use natural language directly?
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- if these approaches have practical advantages, do they have a philosophical, cognitive or conceptual reality? Does that define what we understand? Or is it just a way to play with symbols?
- and indeed, is it so practical? Logical reasoning is mathematically difficult.

## First step towards semantic construction



Frege's principle of compositionality:

*The meaning of the whole is a function of the meaning of the parts.*

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Frege's principle of **compositionality**:

*The meaning of the whole is a function of the meaning of the parts.*

- lexical items = logical representation
- semantics in parallel with syntax

## Language and Logic link

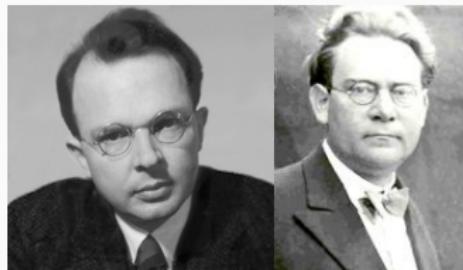
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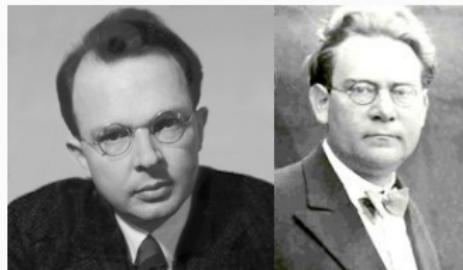


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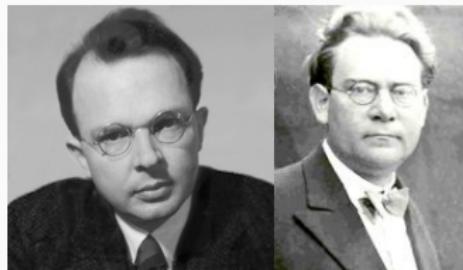
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30's-50's: some logicians took this link seriously : Carnap (modalities) and Reichenbach (time)

But with an abstract view, without calculus (algorithmic).

50's - 60's: many philosophers have argued against a shared approach to logic and natural language

## Richard Montague (1930–1971)



In 3 articles (end of 60's) Montague opens the modern semantics of natural languages:

- English as a Formal Language
- The Proper Treatment of Quantification in Ordinary English
- Universal Grammar

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He replaces analogy with algorithmic

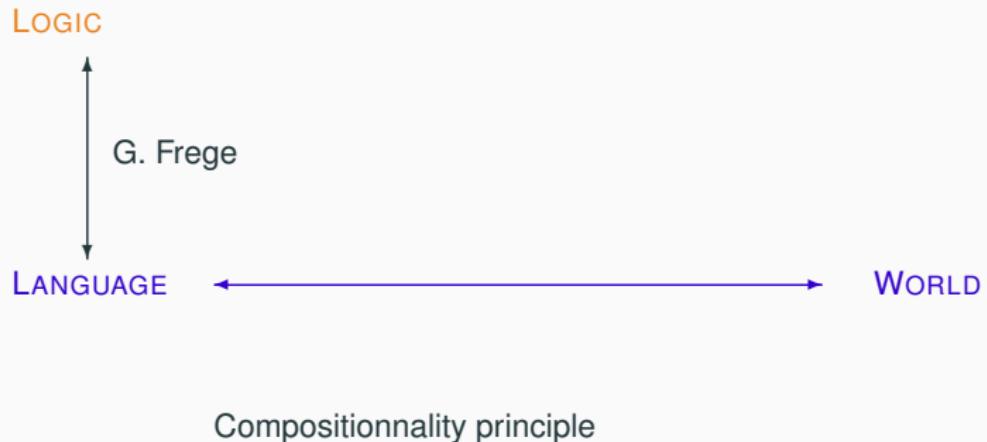
## Semantic Calculus

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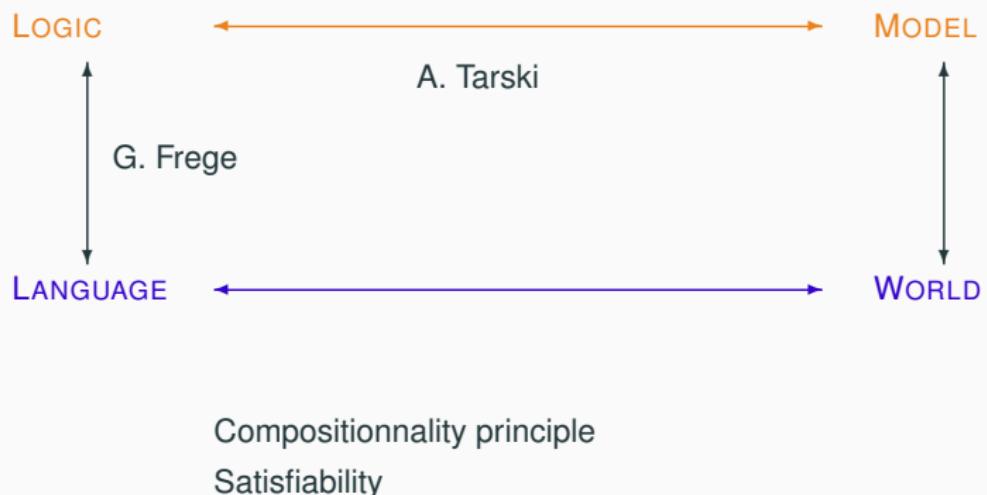
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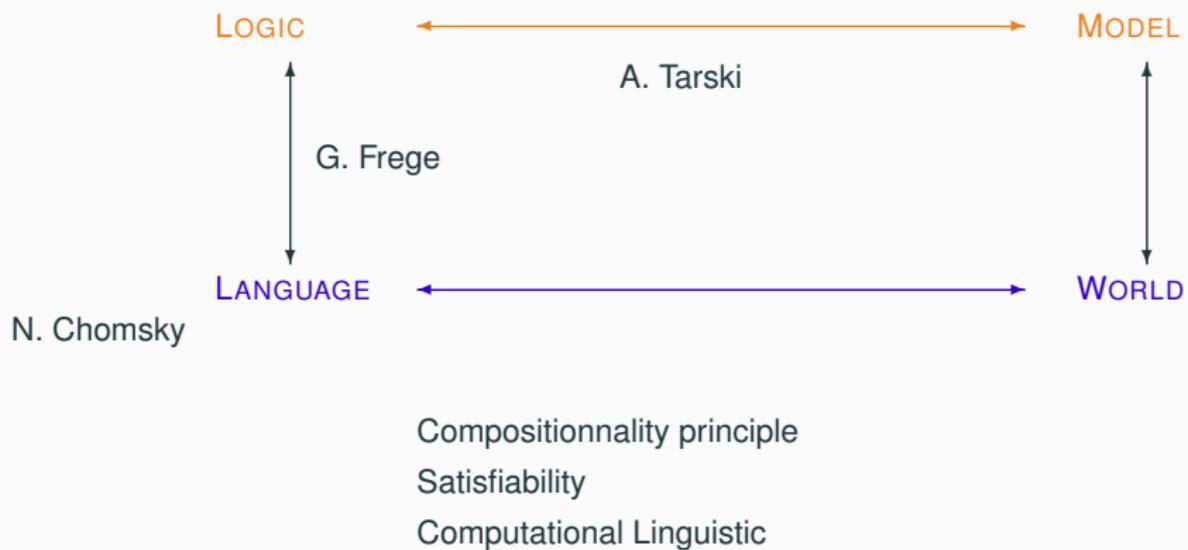
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# Semantic Calculus



Compositionnality principle  
Satisfiability  
Computational Linguistic  
Computational Semantic

## Montague perspective

- intentional logic
- generalized quantifiers (most, few, three, ...)
- first model of the scope ambiguity of quantifiers
- definition of a rigorous syntax semantics interface

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- intentional logic
  - generalized quantifiers (most, few, three, ...)
  - first model of the scope ambiguity of quantifiers
  - definition of a rigorous syntax semantics interface
- 
- task1 definition of a fragment of English [with categorical grammars]
  - task2 specification of the meaning of lexical items [with  $\lambda$ -calculi]
  - task3 exhibit how to build semantics representations [with functional application and  $\beta$ -réduction]

## [Task1] Categorial Grammars

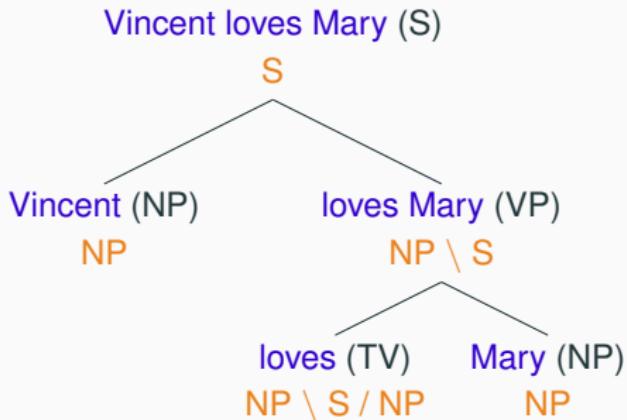
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## [Task1] Categorial Grammars

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## [Task2] $\lambda$ -calcul

Functional view of the computation:

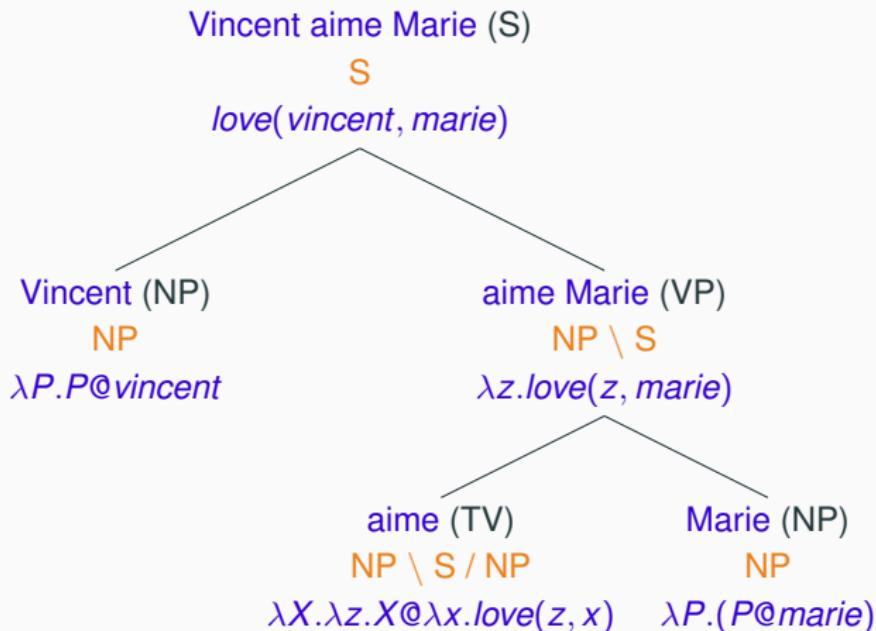
- variables are linked by the  $\lambda$

$$\lambda \textcolor{brown}{x}. \textit{man}(\textcolor{brown}{x})$$

- they are markers in formulas
- two terms are composed by the functional application
- $\beta$ -conversion,  $\alpha$ -conversion and  $\eta$ -expansion perform the calculus

$$((\lambda x. \textit{man}(x)) @ (\textit{vincent})) \rightsquigarrow \textit{man}(\textit{Vincent})$$

## [Task3] Curry-Howard Isomorphism



## But there is still much to do

- Proper name

Vincent vs  $\lambda P.P @ Vincent$

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- ...

## And on the other side of the diagram: LANGUAGE-WORLD

We add information:

- time, tense and aspect: Allen logic, Reichenbach, van Benthem
- event, Davidson
- plural
- modalities
- ...

# Limits of montegeovian approaches

- Donkey sentences

Every farmer who owns a donkey beats it

$$(\exists x \exists y. (\text{farmer } x \wedge \text{donkey } y \wedge \text{own } x \ y)) \rightarrow \text{beat } x \ y$$

- inter-sentencial anaphora

A man walks in the park. He whistle.

$$\exists x. (\text{man } x \wedge \text{walk\_in\_the\_park } x) \wedge (\text{whistle } x)$$

## **From Montague to Dynamic Semantics**

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- Context Change Potential (CCP) [Heim1983]

The interpretation is done **in context** and the context is modified by the interpretation.

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- **Discourse Representation Theory (DRT)** [Kamp1981]/**File Change Semantics (FCS)** [Heim1982]

intermediate levels between representation and truth values

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- **Discourse Representation Theory (DRT)** [Kamp1981]/**File Change Semantics (FCS)** [Heim1982]  
**intermediate levels between representation and truth values**
- **Dynamic Predicate Logic (DPL)** [Groenendijk1991]

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- Primitive types
  - $\iota$ : individual / entity
  - $\sigma$ : proposition / truth value
  - $\gamma$ : left context

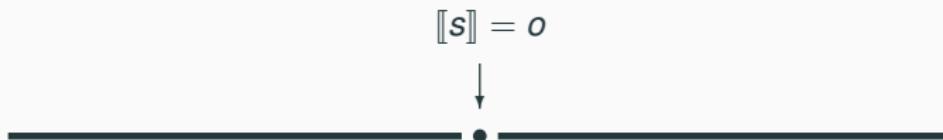
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$$[\![s]\!] = \sigma$$

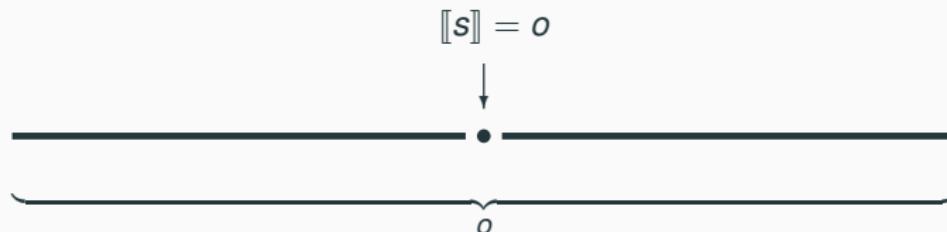
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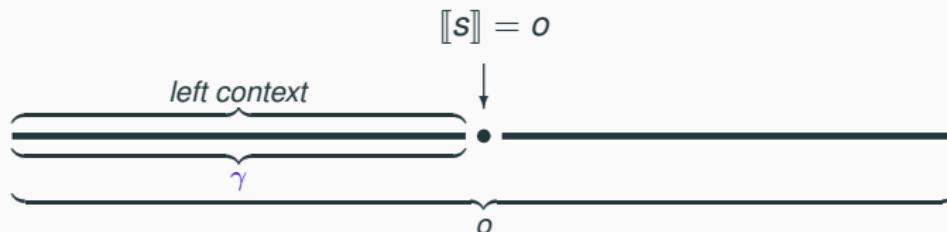
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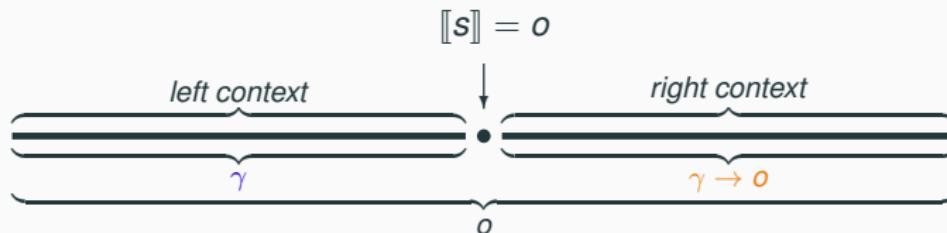
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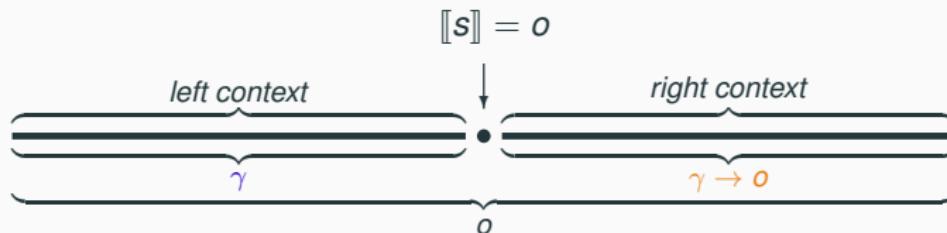
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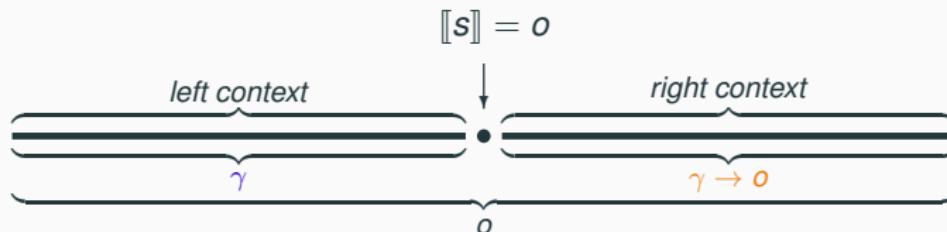
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$$\llbracket s \rrbracket = \gamma \rightarrow (\gamma \rightarrow o) \rightarrow o$$

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$$\llbracket s \rrbracket = \gamma \rightarrow (\gamma \rightarrow o) \rightarrow o$$

$$\lambda e \phi. \exists x. \text{candidate}(x) \wedge \phi(x :: e)$$

## Type and sentences combinaison

- types :

	$\text{MG}$	$\text{TTDL}$
$\llbracket s \rrbracket, \llbracket d \rrbracket : \quad o$		$\Omega \triangleq \gamma \rightarrow (\gamma \rightarrow o) \rightarrow o$

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- context manipulation (variable list):
  - “::” context update
  - “sel” pick a variable from a left-context

$$\iota \rightarrow \gamma \rightarrow \gamma$$

$$\gamma \rightarrow \iota$$

# Connecteurs dynamiques en TTDL

$$\overline{\wedge} \triangleq \mathbf{update}_{TTDL} = \lambda A B e \phi. A e (\lambda e'. B e' \phi)$$

$$\overline{\exists} \triangleq \lambda P e \phi. \exists x. P x (x :: e) \phi$$

$$\mathbf{stop} \triangleq \lambda e. \top$$

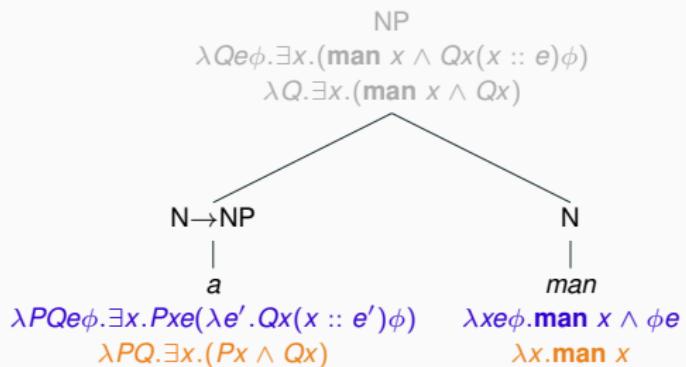
$$\overline{\neg} \triangleq \lambda A e \phi. \neg(A e \mathbf{stop}) \wedge \phi e$$

## A dynamic example

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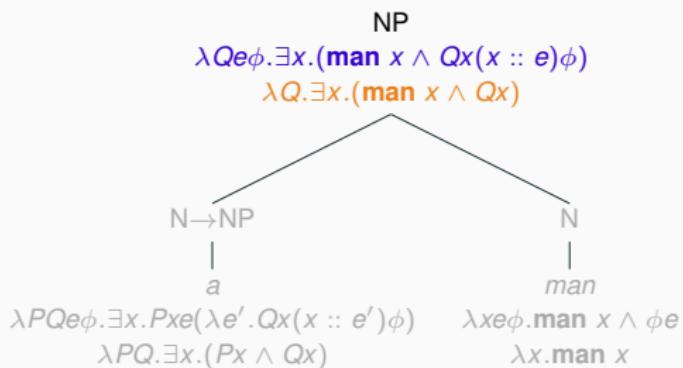
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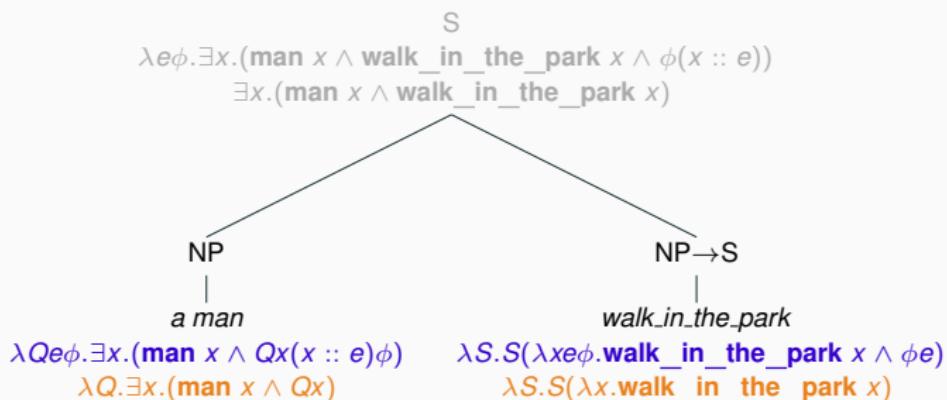
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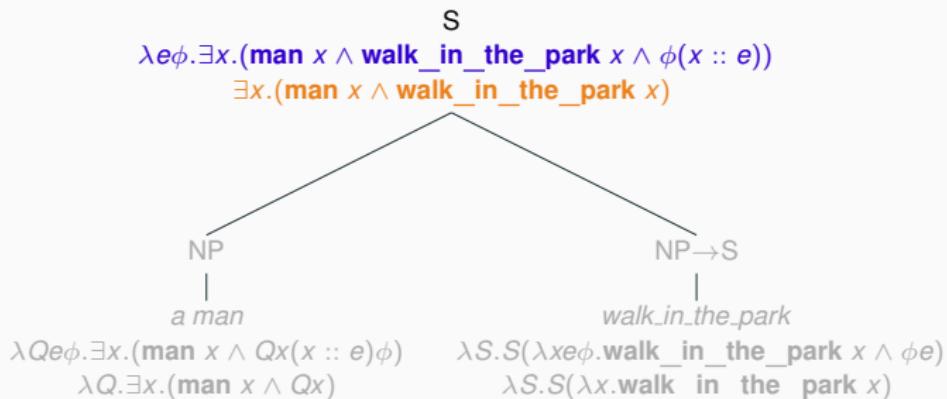
## Anaphore discursive en TTDL *cont.*

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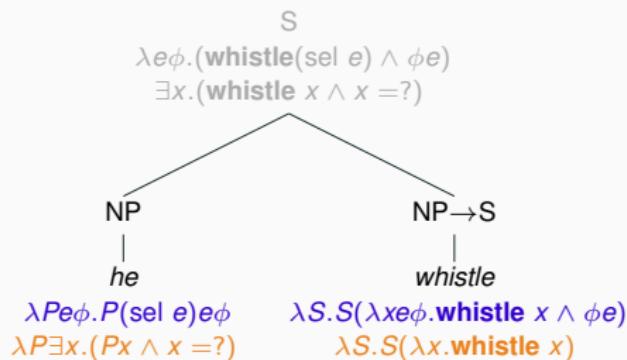
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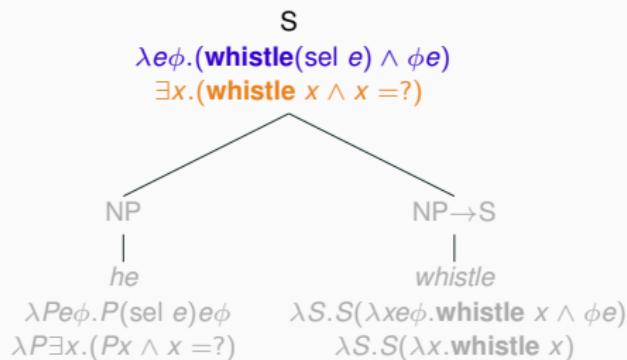
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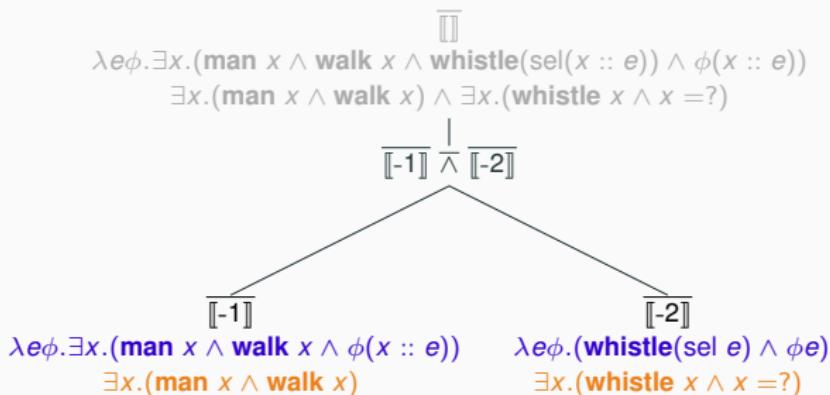
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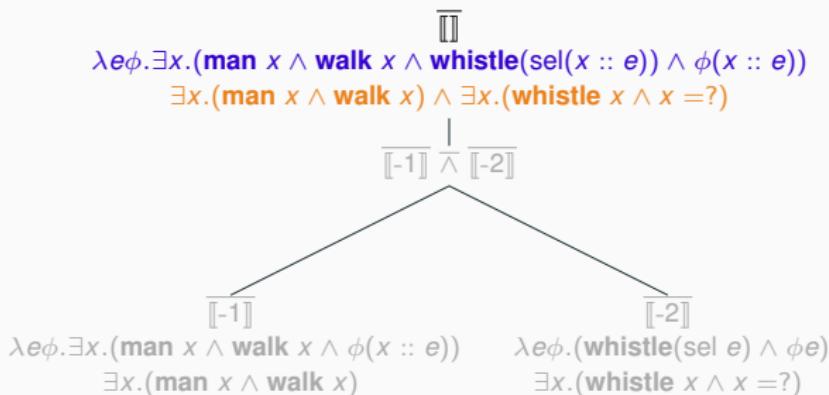
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## **Summary**

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**love(John, Mary)**

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**love(John, Mary)**

- How to use these representations?
- Usefulness of these representations?
  - (2) If a farmer owns a donkey, he beats it

**$\exists x(\exists y.(\text{farmer } x \wedge \text{donkey } y \wedge \text{own } x \ y) \rightarrow \text{beat } x \ y)$**

- Cognitive reality, conceptual reality? ...

# Can we understand madness?

The SLAM project - Schizophrenia and Language: Analyse and Modelling



## **SLAM**

---

- Linguistic studies of mental diseases (Chaika 1974) and (Fromkin 1975)
- Pragmatic discontinuities in performing verbal interaction (Trognon and Musiol 1996)
- Discontinuities **definitive** (Musiol 2009): pathological use of discourse planning for patients with schizophrenia (paranoid)

The project aims to systematize the **study of pathological conversations** under **interdisciplinary approaches**

- Building of a linguistic resource on mental pathology

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  - semi-supervised interviews
  - neuro-cognitive tests
  - double eye-trackers

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- Epistemological and philosophical studies (norm, madness, rationality)

The project aims to systematize the **study of pathological conversations** under **interdisciplinary approaches**

- Building of a linguistic resource on mental pathology
  - semi-supervised interviews
  - neuro-cognitive tests
  - double eye-trackers
- Epistemological and philosophical studies (norm, madness, rationality)
- Identify these purposes with:
  - formal models
  - NLP methods and tools

- Corpus
- Formalization
- Epistemology

- Corpus
  - organize the interviews
  - transcription and tagging
  - analyse different linguistic levels
- Formalization
- Epistemology

- Corpus
- Formalization
  - question the cognitive reality of semantico-pragmatic models,
  - automatically identify unusual uses of the language
- Epistemology

- Corpus
- Formalization
- Epistemology
  - question the normative concepts of rationality and logicity
  - study interpretation under linguistic interaction, and the status of implicit norms

# Discontinuity example

B124 OH OUAIS (↑) ET PIS COMPLIQUÉ (↓) ET C'EST VRAIMENT TRÈS TRÈS COMPLIQUÉ (→) LA POLITIQUE C'EST QUELQUE CHOSE QUAND ON S'EN OCCUPE FAUT ÊTRE GAGNANT PARCE QU'AUTREMENT QUAND ON EST PERDANT C'EST FINI QUOI (↓)

Oh yeah (↑) and complicated (↑) and it's really very very complicated (→) politics, it's really something when you get into it, have to win or else when you lose, well, you're finished (↓)

A125 OUI  
Yes

B126 J. C. D. EST MORT, L. EST MORT, P. EST MORT EUH (...)  
JCD is dead, L is dead, P is dead uh (...)

A127 ILS SONT MORTS PARCE QU'ILS ONT PERDU À VOTRE AVIS (↑)  
So you think they're dead because they lost (↑)

B128 NON ILS GAGNAIENT MAIS SI ILS SONT MORTS, C'EST LA MALADIE QUOI C'EST C'EST (→)  
No they won but if they're dead, it's their disease well it's it's (→)

A129 OUAIS C'EST PARCE QU'ILS ÉTAIENT MALADES, C'EST PAS PARCE QU'ILS FAISAIENT DE LA POLITIQUE (↑)  
Yeah it's because they had a disease, it's not because they were in politics (↑)

B130 SI ENFIN (→)  
Yes I mean (→)

A131 SI VOUS PENSEZ QUE C'EST PARCE QU'ILS FAISAIENT DE LA POLITIQUE (↑)  
Yes you think it's because they were in politics (↑)

B132 OUI TIENS OUI IL Y A AUSSI C. QUI A ACCOMPLI UN MEURTRE LÀ (→) IL ÉTAIT PRÉSENT LUI AUSSI QUI EST À B. MAIS ENFIN (→) C'EST ENCORE À CAUSE DE LA POLITIQUE ÇA  
Yes, so well yeah there was C too who committed murder, uh huh (→) he was there too, the one in B but well (→) it, that, it's because of politics again

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## Conversation example (english only)

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- death (literal)

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The schizophrenic switch twice from a theme to another one:

- politic death (symbolic)
- death (literal)

The two themes are relied but they express two different realities.

## A relatively large corpus

	La Rochelle			Lyon			Total
	♂	♀	tot	♂	♀	tot	
Schizophrenics	15	3	18	22	9	31	49
Controls	15	8	23	4	4	8	31
Total	30	11	41	26	13	39	80

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Total	30	11	41	26	13	39	80

31 575 speeches / 375 000 words

	La Rochelle				Lyon			
	# speeches	# words		# speeches	# words			
S	3 863	46 859	119 762	4 062	66 725	12 356	79 081	
T	7 282	72 903		371	4 433			
P + S	3 819	30 293	138 571	4 098	33 686	4 156	37 842	
P + T	7 698	108 278		382	4 480			
Total	22 662	258 333		8 913	116 923			

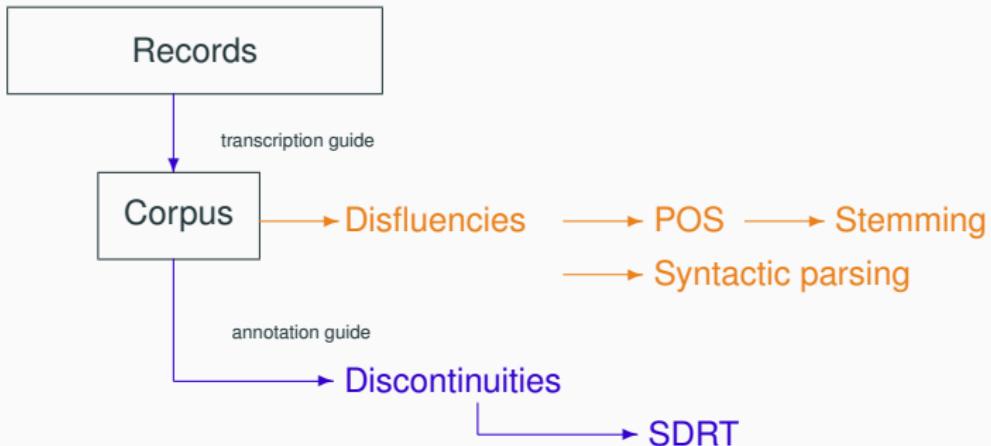
## A corpus hard to constitute

[Amb. et al journée ATALA 2014]

- A lot of administrative steps:
  - CPP of the area of the medical institution (including a finalise description of the all protocol)
  - CNIL
- Data should not be use for/against the patient
- Patient involvement (significant loss of participation >55%)
- Heavy protocol

## Semi-Supervised Interview Schizophrenic / Psychologist

- Interview(s) (hand transcription with a guide)
- Neuro-cognitive tests:
  - Wechsler Adult Intelligence Scale-III  
(IQ)
  - California Verbal Learning Test  
(strategy and cognitive abilities)
  - Trail Making Test  
(depreciation of cognitive flexibility and inhibition).
- Oculomotor behavior (double Eye-Trackers)
- Brain activity (EEG)



# Talking with patient with schizophrenia

[AMR TALN 2011] [AMR Evol. Psychiatrique 2012] [AMR congrès de linguistique romane 2013]  
[AMR Dialogue, Rationality and Formalism Springer 2014] [AMR Philosophie et langage 31 2014]

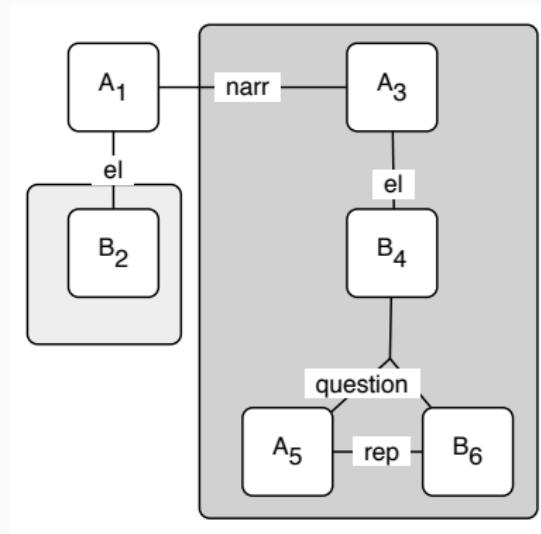
Two interlocutors, thus two (spontaneous) views on the exchange.

Discourse interpretation by	
normal subject (3 <sup>rd</sup> person)	Schizophrenic (1 <sup>st</sup> person)
<b>hypothesis:</b> pragmatic correctness  ↓ semantics incorrectness	pragmatic incorrectness  ↑ <b>hypothesis :</b> semantic correctness
contradictory contents: <i>look like a contradiction</i>	coherent content: <i>possibility of interpretation</i>

⇒ The representation *need more* than logical semantics

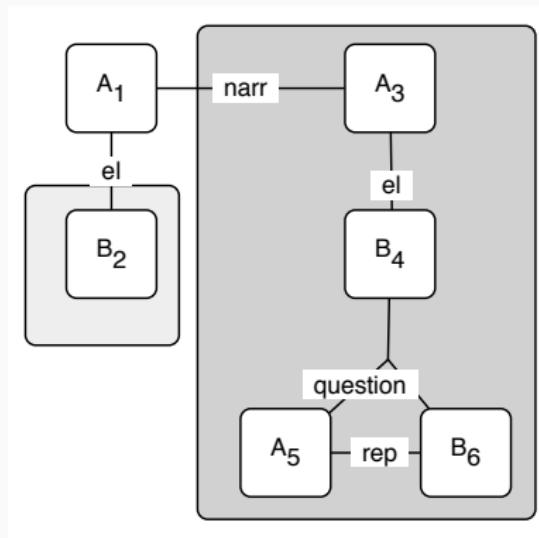
# Representation

Use of SDRT + thematic boxes (grey ones)



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Use of SDRT + thematic boxes (grey ones)



They are thematic islands

## Two conjectures

- Schizophrenics are logically consistent.

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*Slogan:* “A choice is never a definitive one!”

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*Slogan:* “A choice is never a definitive one!”

Phonological, morphological, lexical, discourse, ...

Guy experienced a lovely evening last night

Elaboration

He had a fantastic meal

Elaboration

Elaboration

He ate salmon

He devoured lots of cheese

Narration

Guy experienced a lovely evening last night

Elaboration

He had a fantastic meal

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Elaboration

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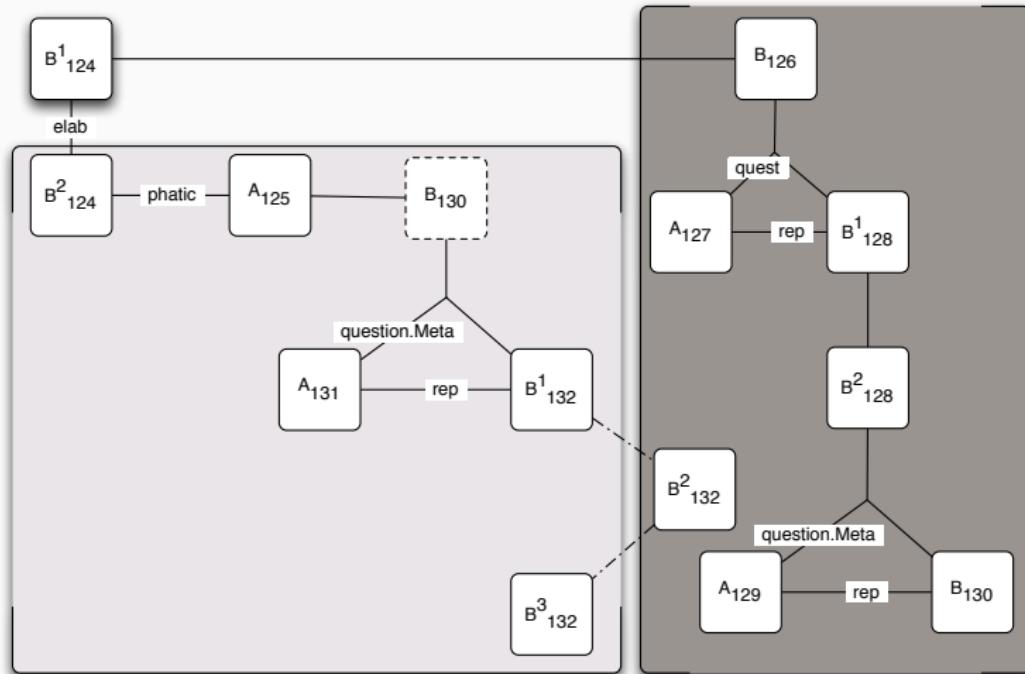
He devoured lots of cheese

Narration

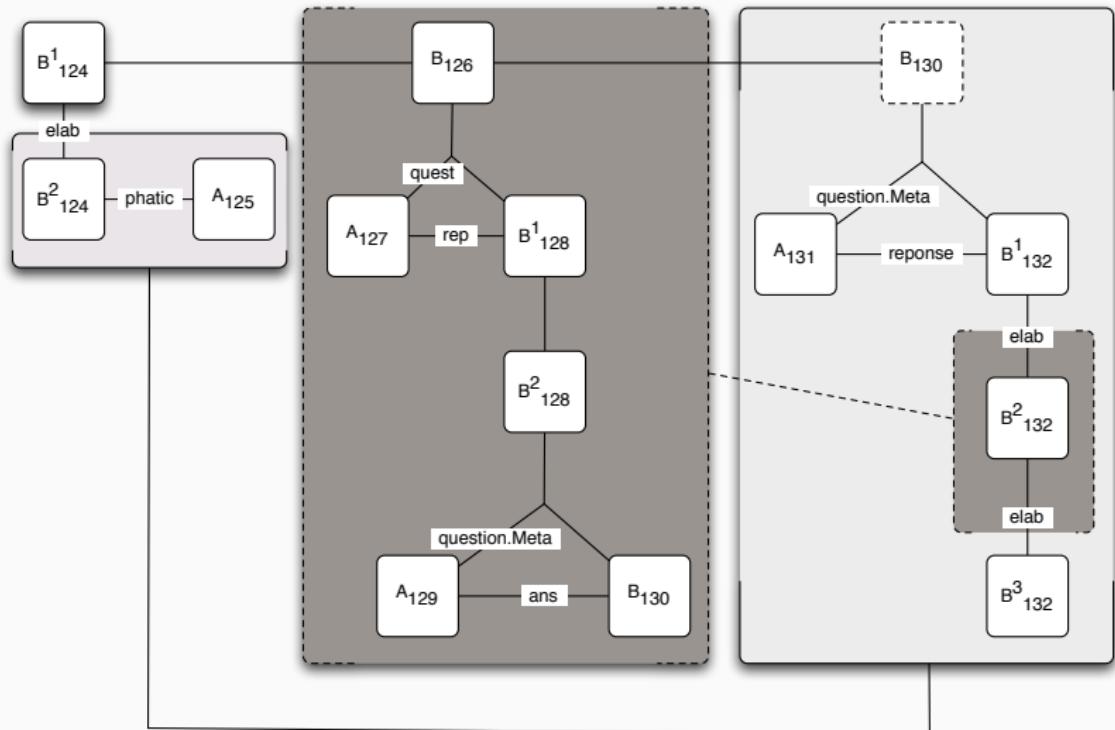
Constraints on attachment: right frontier rule

"He found **it** really marvelous"

# Patient understanding



# Psychologist understanding



## Rise without attachement 1/2

G82 l'an dernier euh (→) j'savais pas comment faire **j'étais perdue** et pourtant j'avais pris mes médicaments j'suis dans un état vous voyez même ma bouche elle est sèche j'suis dans un triste état

**I didn't know what to do. I was lost.**

V83 Vous êtes quand même bien (↑)

G84 J'pense que ma tête est bien mais on croirait à moitié (↓) la moitié qui va et la moitié qui va pas j'ai l'impression de ça vous voyez (↑)

V85 D'accord

G86 Ou alors c'est la conscience peut être la conscience est ce que c'est ça (↑)

V87 Vous savez **ça arrive à tout le monde d'avoir des moments biens et des moments où on est perdu**

**Everybody is lost at times.**

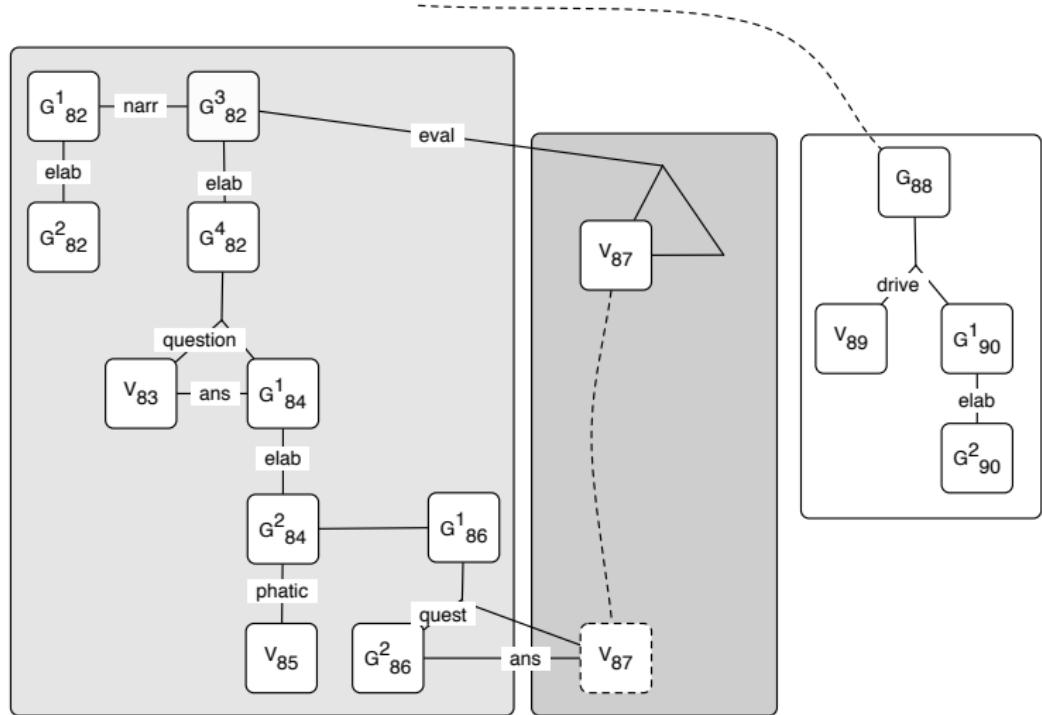
G88 Oui j'ai peur de perdre tout le monde

**Yes I am afraid I lose everybody.**

V89 Mais ils vont plutôt bien vos enfants (↑)

G90 Ils ont l'air ils ont l'air mais ils ont des allergies ils ont (→) mon petit fils il s'est cassé le bras à l'école tout ça

## Rise without attachment 2/2



## Hand annotations

Organization of 3 human annotation campaigns

- Identification of decisive discontinuities
- SDRT representation

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Organization of 3 human annotation campaigns

- Identification of decisive discontinuities
- SDRT representation

Results

- Huge difficulties for discontinuities
- Relative consensus for SDRT

# SDRT annotations

SDRT annotations with Glozz on pretreated texts.

Début

B1 J'aimerais savoir ce que font les personnes qui sont à l'hôpital

ce que vous faites la journée par exemple...

A2 :Je suis très amoureuse de Florence M.

B3 :De Florence M.

A4 :Oui superbe là...

comment elle s'appelle Florence R.

elle a tué quand même plus de un million de personnes

B5 :Qui ça ?

A6 :Florence R.

B7 :C'est qui cette dame là ?

A8 :Elle était psychiatre 40 rue de N.

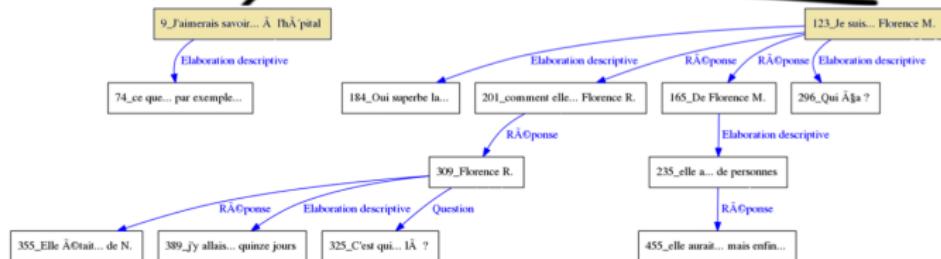
j'y allais une fois par semaine ou deux fois tous les quinze jours

elle aurait pu me tuer mais enfin...

# Analyse of the annotations (ongoing work)

46 annotators on 3 extracts (+ one training text)

## Annotateur A12



- Impossibility of disidentification
  - Task with a small context: randomise speeches
  - Inability to anonymize the history and the geography
- Patient reality
  - Formal analysis of language = define a standard
  - Deviate = dysfunction
  - But, every speaker is confronted daily with language disorders from healthy people
  - The diagnosis can not suffer from approximations

## **Toward a formal treatment**

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## Frame Semantics

Processing dialogue: **access to subparts** of the interaction for **update**.

## Frame Semantics

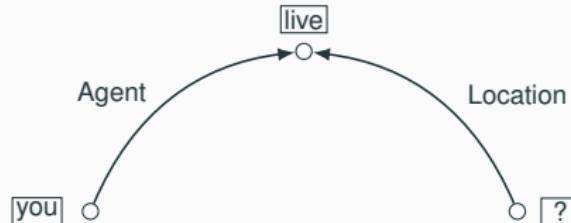
Processing dialogue: **access to subparts** of the interaction for **update**.

**A<sub>1</sub>** Where do you live?

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Processing dialogue: access to subparts of the interaction for update.

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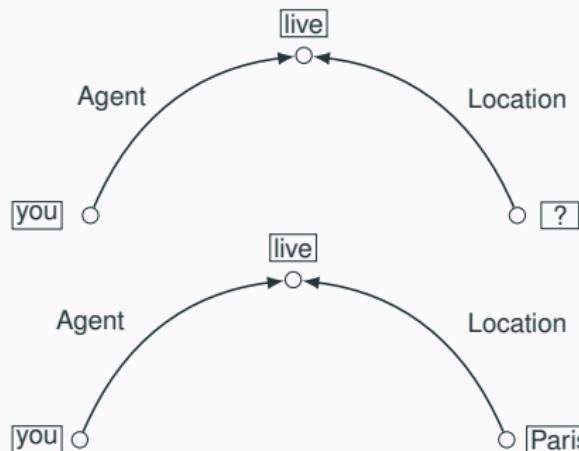


# Frame Semantics

Processing dialogue: access to subparts of the interaction for update.

**A<sub>1</sub>** Where do you live?

**B<sub>2</sub>** In Paris.



Use of :

- TTDL for compositionality
- Frame Semantics for representation of the content

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- TTDL for compositionality
- Frame Semantics for representation of the content
- Ongoing work: defining such a framework and apply it to the SLAM corpus

## Features extraction

- a feature  $v$
- type of frames:  $\gamma$

$$find_v : \gamma \rightarrow v \times (v \rightarrow \gamma)$$

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$$find_v : \gamma \rightarrow v \times (v \rightarrow \gamma)$$

Example:

$$\llbracket A_1 \rrbracket = \begin{bmatrix} LIVE \\ \text{Ag: } A \\ \text{Loc: } Paris \end{bmatrix}$$

$find_{Loc}$  to  $A_1$ :

$$(Paris, \lambda I. \begin{bmatrix} LIVE \\ \text{Ag: } A \\ \text{Loc: } I \end{bmatrix})$$

## Utterances type

*assertion*

$$[u] = \gamma \rightarrow \gamma$$

*question*

$$[q_v] = \gamma \rightarrow v \times (v \rightarrow \gamma)$$

*answer*

$$[a_v] = v \times (v \rightarrow \gamma) \rightarrow \gamma$$

## Example 1/2

**A<sub>1</sub>** I live in Paris.

**B<sub>2</sub>** How long have you been living there?

**A<sub>3</sub>** For five years.

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**A<sub>1</sub>** I live in Paris.

**B<sub>2</sub>** How long have you been living there?

**A<sub>3</sub>** For five years.

$$\begin{aligned} \llbracket A_1. {}^q B_2. {}^a A_3 \rrbracket c_e &= \lambda c. \llbracket A_3 \rrbracket \left( \llbracket B_2 \rrbracket (\llbracket A_1 \rrbracket c) \right) c_e \\ &\rightarrow_{\beta} \llbracket A_3 \rrbracket \left( \llbracket B_2 \rrbracket (\llbracket A_1 \rrbracket c_e) \right) \end{aligned}$$

## Example 2/2

$$[A_1]c_e = \begin{bmatrix} \text{LIVE} \\ \text{Ag: } A \\ \text{Loc: } \textit{Paris} \end{bmatrix} = \textcircled{1}$$

$$[B_2] \textcircled{1} = \lambda t. \begin{bmatrix} \text{LIVE} \\ \text{Ag: } A \\ \text{Loc: } \textit{Paris} \\ \text{TmP: } t \end{bmatrix} = \textcircled{2}$$

$$[A_3] \textcircled{2} = \begin{bmatrix} \text{LIVE} \\ \text{Ag: } A \\ \text{Loc: } \textit{Paris} \\ \text{TmP: } \textit{Five years} \end{bmatrix}$$

## Perspectives

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- Increase the phenomena analyzed in SLAMtk  
Especially work on syntax and lexical statistics
- Try DDN approaches on the SLAM corpus  
Need more ressources in French
- Deeply study the human annotations of the corpus
- Increase the coverage of the corpus in volume and number of pathologies studied  
Collection of data at the Montperrin Hospital of Aix-En-Provence
- Define remedial help process
- Refine the analysis of dysfunction, opening towards a cognitive interpretation and give more complex context for the interpretation

- Defining robust semantics grammars for TTDL
- Definition of a TTDL for dialogue framework  
*Ongoing work on questions and answers with Maria Boritchev*
- (French translation of Fracas)

**Thanks!**

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## **Modélisation sémantique**

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# Événements, négations et modalités

co-encadrement thèse Sai Qian avec Philippe de Groote

[Qian et Amb. LACL 2011] [Qian et Amb. LENLS 2012] [Qian et Amb. LNAI 2013] [Qian, de Groote, Amb. LiLT 2016]

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- Structure de couple

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- Structure de couple

(5) Jean **pourrait** avoir une voiture<sub>i</sub>. \*C'est une Peugeot.

# Événements, négations et modalités

co-encadrement thèse Sai Qian avec Philippe de Groote

[Qian et Amb. LACL 2011] [Qian et Amb. LENLS 2012] [Qian et Amb. LNAI 2013] [Qian, de Groote, Amb. LiLT 2016]

(3) Jean n'a pas de voiture<sub>i</sub>. \* Elle<sub>i</sub> est rouge.

(4) Il n'est pas vrai que Jean n'a pas de voiture<sub>i</sub>. Elle<sub>i</sub> est rouge.

- Structure de couple

(5) Jean **pourrait** avoir une voiture<sub>i</sub>. \* C'est une Peugeot.

- Intensionalisation  $o_i = s \rightarrow o$
- $T_{env} = o_i \times o_i$  (background  $\times$  base)
- $\llbracket s \rrbracket = \gamma_i \rightarrow (\gamma_i \rightarrow o_i) \rightarrow o_i$

## Double négation

( 4 ) Il n'est pas vrai que Jean n'a pas de voiture. Elle est rouge.

## Double négation

( 4 ) Il n'est pas vrai que Jean n'a pas de voiture. Elle est rouge.

$$\begin{aligned}&\equiv (\neg (\neg (\text{have}(\text{[a] [car]})(\text{[Jean]})))) \\&\rightarrow_{\beta} \langle \lambda e \phi. (\exists x. (\text{car } x \wedge \text{own jean } x \wedge \phi(x :: e))), \\&\quad \lambda e \phi. (\neg (\exists x. (\text{car } x \wedge \text{have jean } x)) \wedge \phi e) \rangle\end{aligned}$$

## Double négation

( 4 ) Il n'est pas vrai que Jean n'a pas de voiture. Elle est rouge.

$$\begin{aligned}& \neg(\neg(\overline{\llbracket \text{have} \rrbracket (\llbracket a \rrbracket \llbracket \text{car} \rrbracket) \llbracket \text{Jean} \rrbracket})) \\& \rightarrow_{\beta} \langle \lambda e \phi. (\exists x. (\text{car } x \wedge \text{own } \text{jean } x \wedge \phi(x :: e))), \\& \quad \lambda e \phi. (\neg(\exists x. (\text{car } x \wedge \text{have } \text{jean } x)) \wedge \phi e) \rangle\end{aligned}$$

$$\begin{aligned}& \overline{\llbracket \text{être\_rouge} \rrbracket \llbracket \text{elle} \rrbracket} \\& \rightarrow_{\beta} \lambda e \phi. (\text{red } (\text{sel } e) \wedge \phi e, \neg(\text{red } (\text{sel } e)) \wedge \phi e)\end{aligned}$$

## Double négation

( 4 ) Il n'est pas vrai que Jean n'a pas de voiture. Elle est rouge.

$$\begin{aligned} & \neg(\neg(\overline{\text{have}}(\overline{[a][car]}))\overline{[Jean]})) \\ \rightarrow_{\beta} & (\lambda e\phi.(\exists x.(\mathbf{car}\ x \wedge \mathbf{own}\ \mathbf{jean}\ x \wedge \phi(x :: e))), \\ & \quad \lambda e\phi.(\neg(\exists x.(\mathbf{car}\ x \wedge \mathbf{have}\ \mathbf{jean}\ x)) \wedge \phi e)) \end{aligned}$$

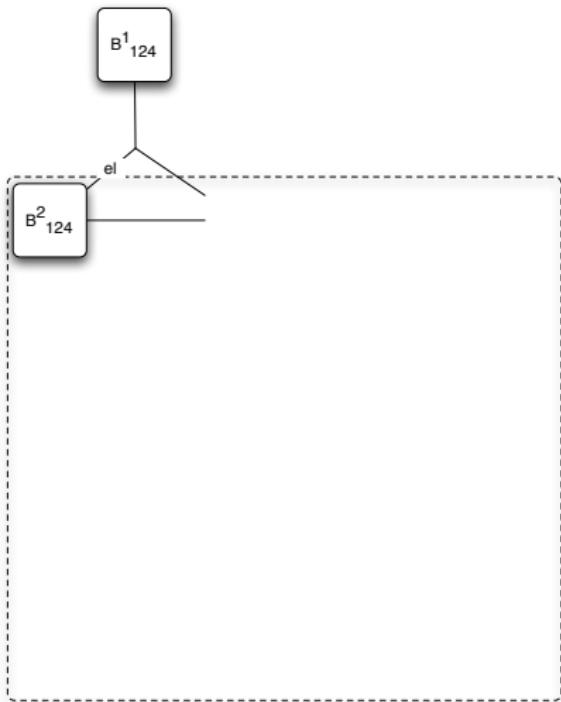
$$\begin{aligned} & \overline{[\mathit{être\_rouge}]\overline{[elle]}} \\ \rightarrow_{\beta} & \lambda e\phi.(\mathbf{red}\ (\mathbf{sel}\ e) \wedge \phi e, \neg(\mathbf{red}\ (\mathbf{sel}\ e)) \wedge \phi e) \end{aligned}$$

$$\begin{aligned} & \mathbf{update}_{DN-TTDL} \overline{[4]} \\ \rightarrow_{\beta} & \lambda e\phi.\exists x.(\mathbf{car}\ x \wedge \mathbf{have}\ \mathbf{jean}\ x \wedge \mathbf{red}\ (\mathbf{sel}(x :: e)) \wedge \phi(x :: e)) \end{aligned}$$

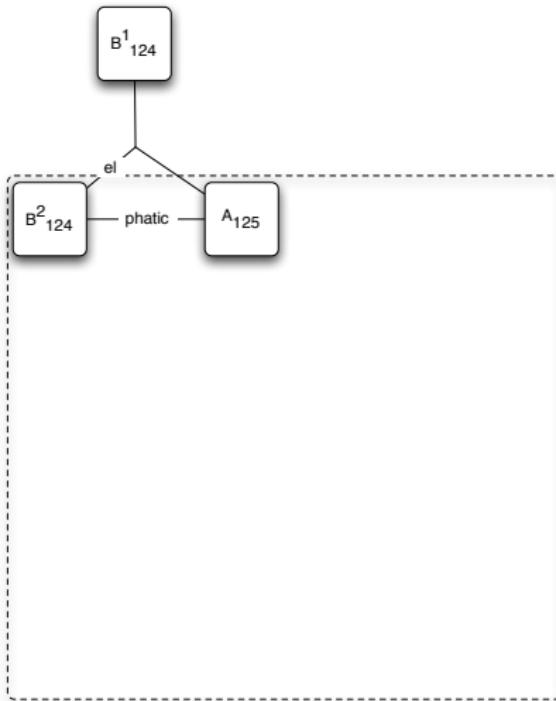
(B124) Oh yeah (↑) and complicated (↑) and it's really very very complicated (→)



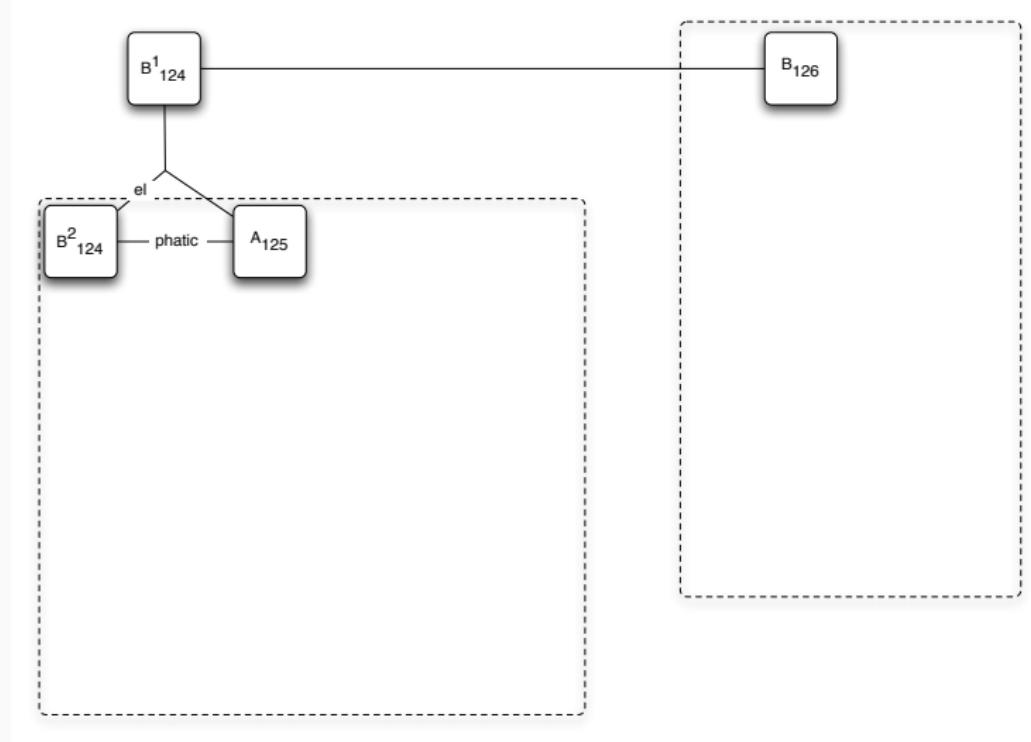
politics, it's really something when you get into it, have to win or else when you lose, well, you're finished (↓)



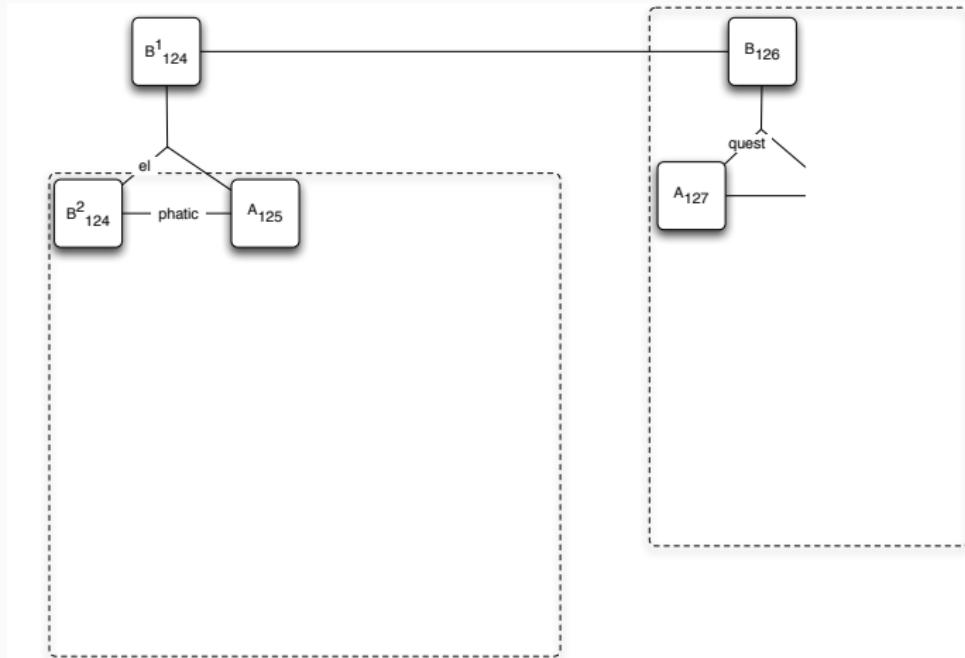
(A125) Yes



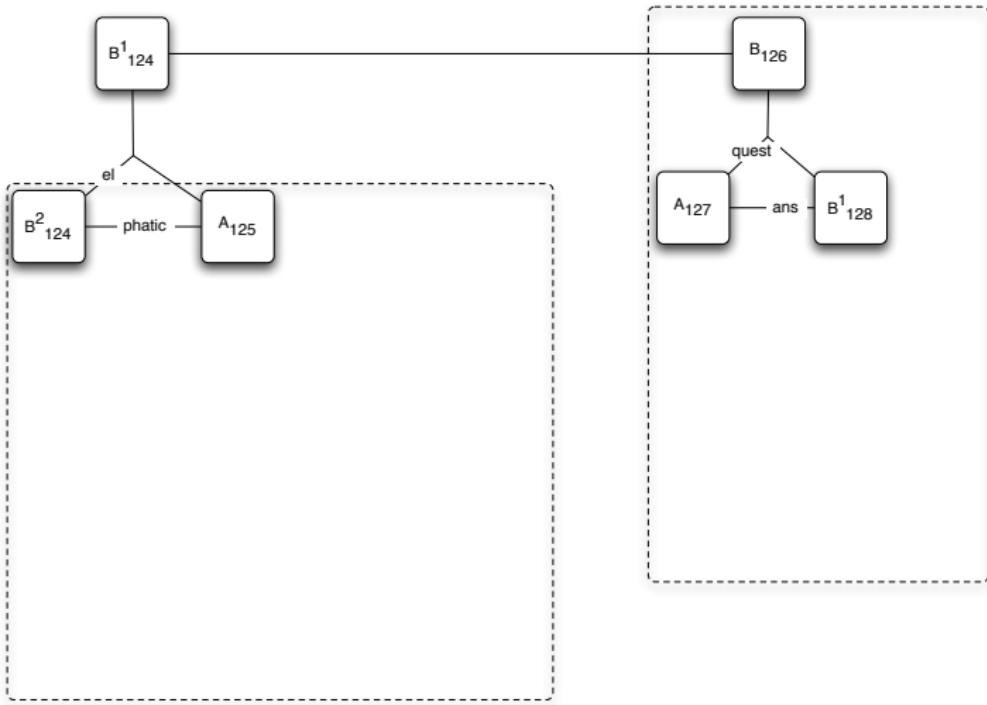
(B126) JCD is dead, L is dead, P is dead uh (...)



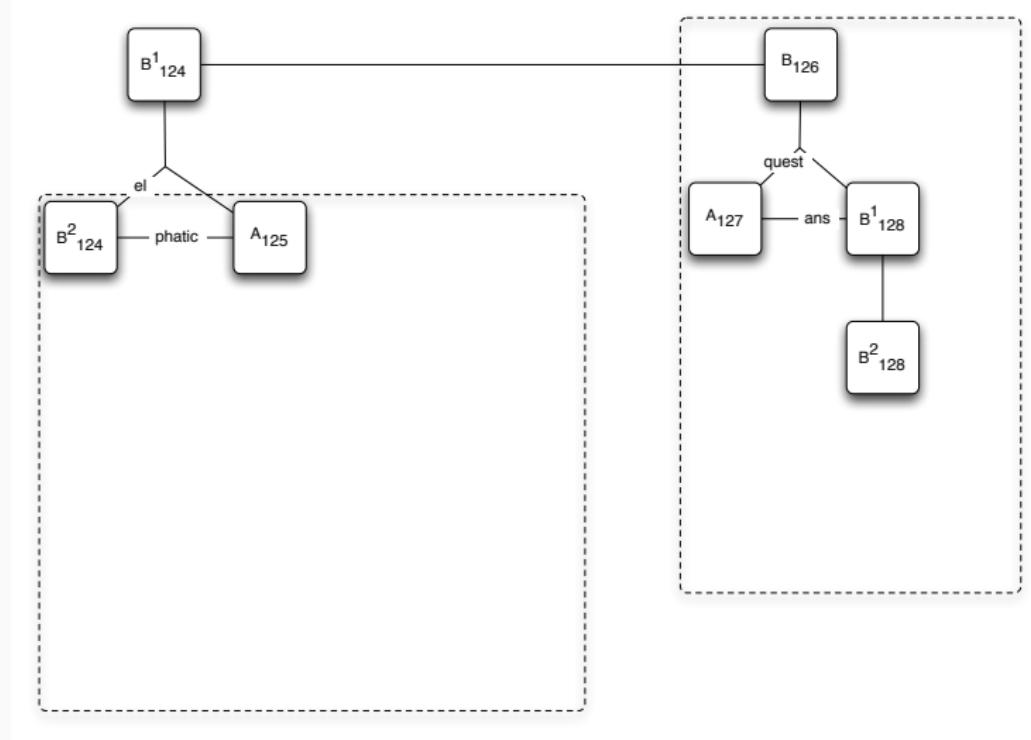
(A127) So you think they're dead because they lost (↑)



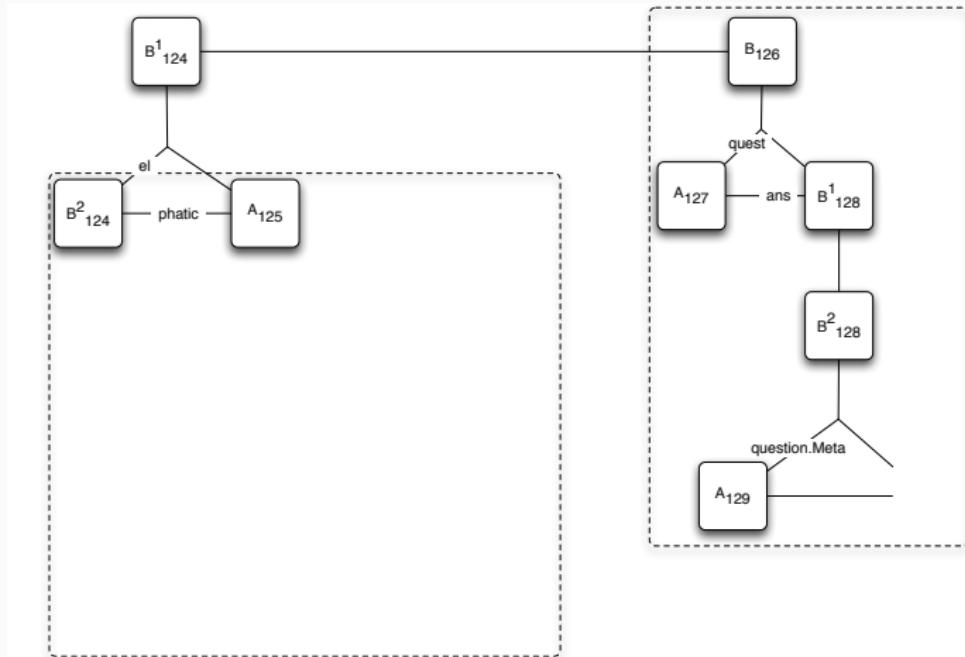
(B128) No they won but if they're dead, it's their disease well it's it's (→)



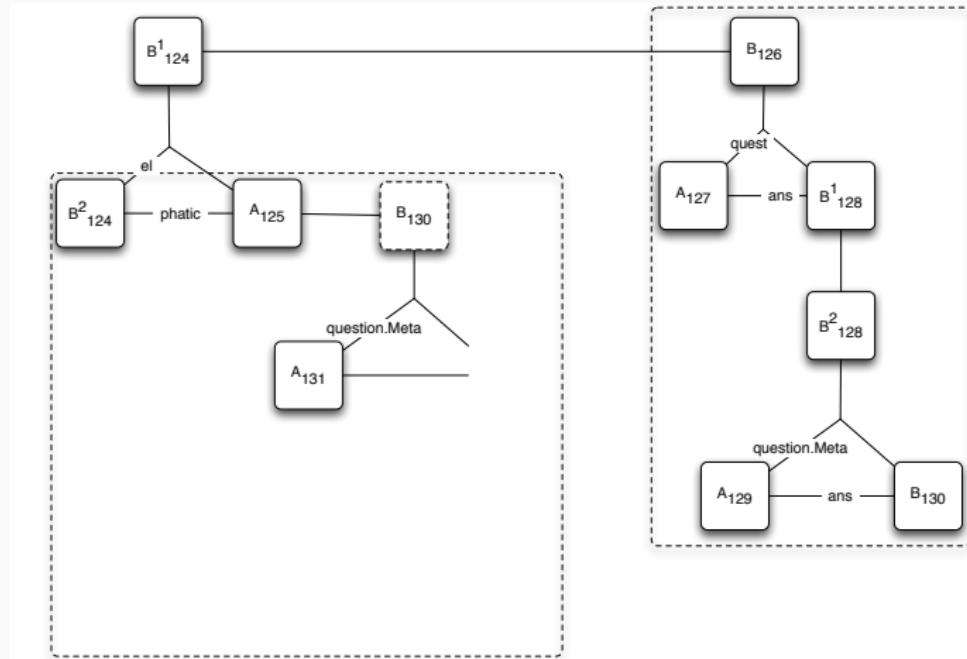
(B128) No they won but if they're dead, it's their disease well it's it's (→)



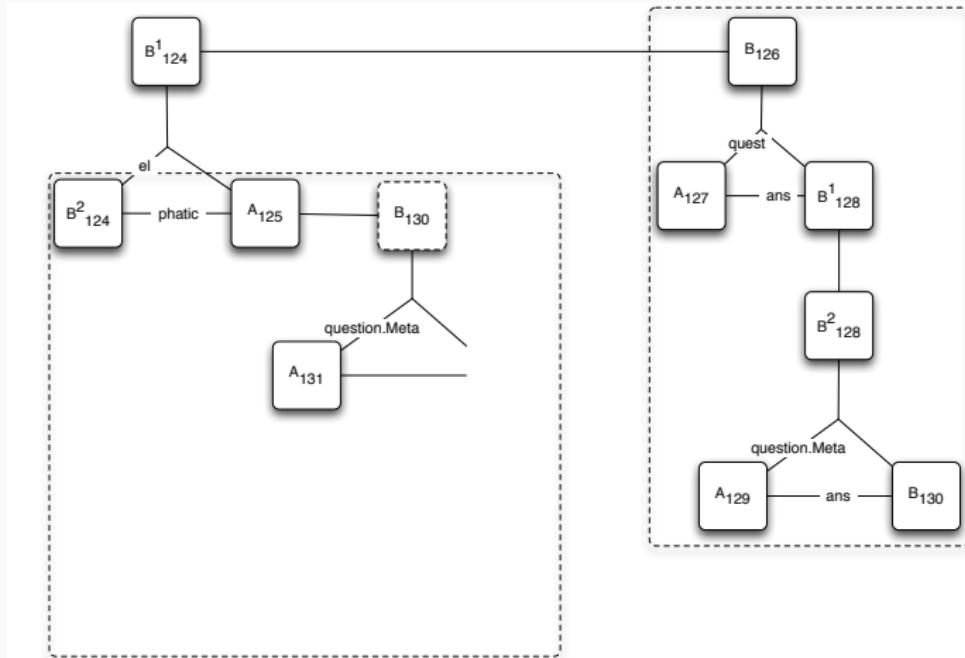
(A129) Yeah it's because they had a disease, it's not because they were in politics (↑)



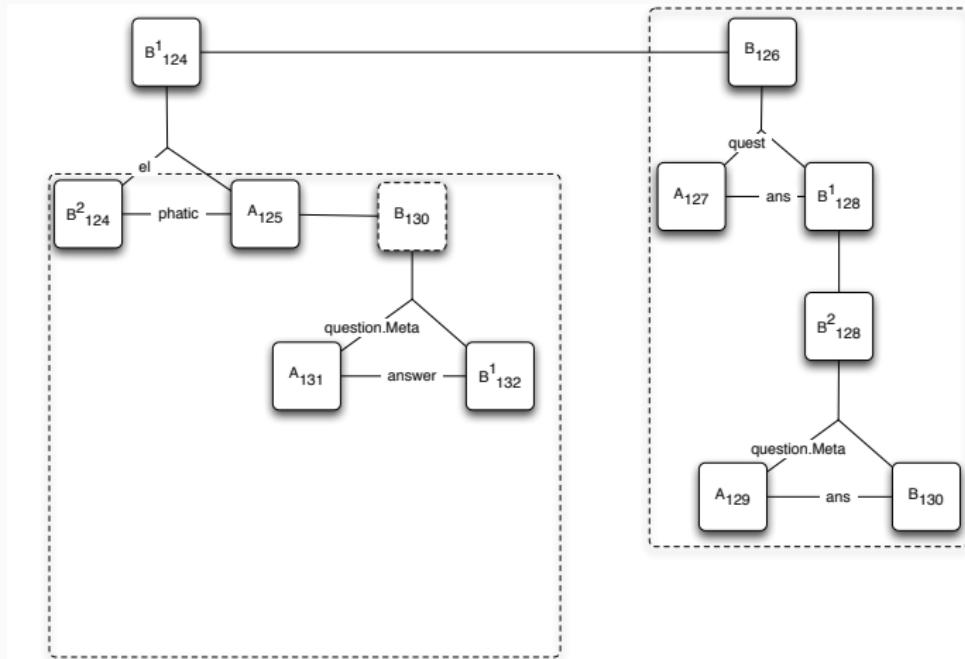
(B130) Yes I mean (→)



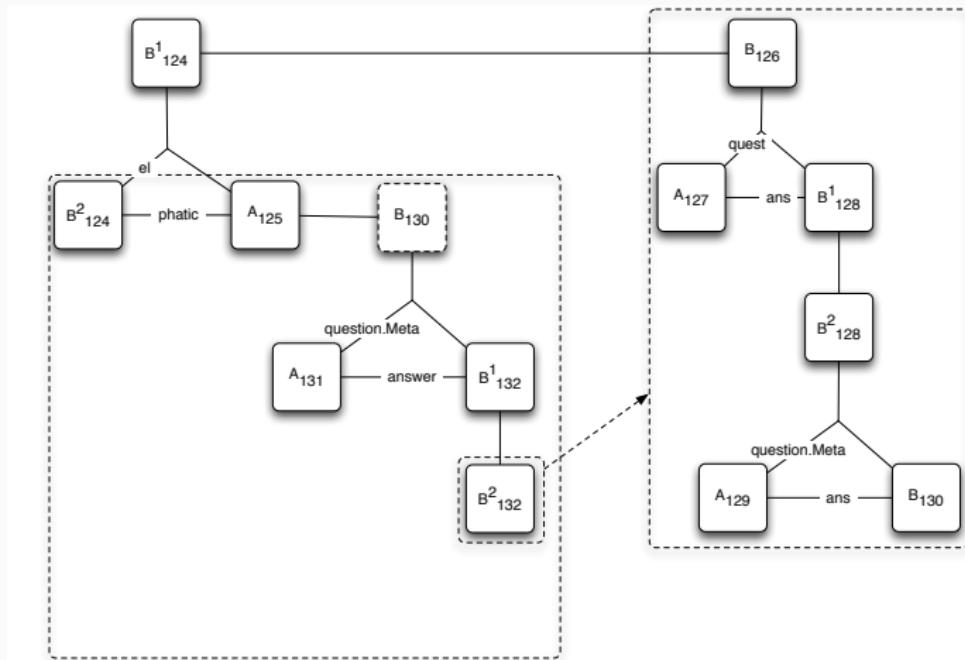
(A131) Yes you think it's because they were in politics (↑)



(B132) Yes, so well yeah there was C too who committed murder, uh huh (→) he was there too, the one in B but well  
(→) it, that, it's because of politics again



(B132) Yes, so well yeah there was C too who committed murder, uh huh (→) he was there too, the one in B but well  
(→) it, that, it's because of politics again



(B132) Yes, so well yeah there was C too who committed murder, uh huh (→) he was there too, the one in B but well  
(→) it, that, it's because of politics again

