Anaphora and Ambiguity in Narratives

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SDRT

- SDRT is a formal, integrated theory of coherence relations.
  - What coherence relations mean.
  - How coherence structures (graphs) are constructed.

- Two main component logics:
- Logic of Information Content for the truth-conditional semantics of graphs.
  - Logical form, meaning.
- Glue Logic to construct these logical forms.
  - Underspecification, construction.

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- $\boxed{\text{Natural Language Discourses}} \rightsquigarrow \boxed{\text{Representations}} \mapsto \boxed{\text{Models}}$

  $\rightsquigarrow :=$ the *construction algorithm*,

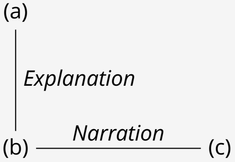
  $\mapsto :=$ a truth-conditional model-theoretic *embedding*.

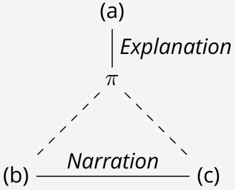
Complex Discourse Units

(1) a. Arash doesn't trust Akna.

b. She promised to help him once,

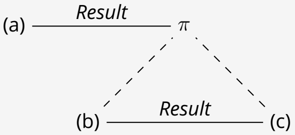
c. and then later forgot about it.



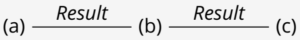


Subtleties

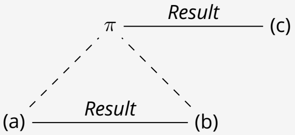
(2) a. John overslept.
b. So he missed his flight.
c. So he got angry at himself.



(3) a. John overslept.
b. So he missed his flight.
c. So he took a train.



(4) a. John overslept.
b. So he missed his flight.
c. So he bought an alarm clock.



Notational Variation

(5) a. John overslept.
b. So he missed his flight.
c. So he got angry at himself.

Result
Result

(6) a. John overslept.
b. So he missed his flight
c. So he took a train.

Result
Result

(7) a. John overslept.
b. So he missed his flight.
c. So he bought an alarm clock.

Result
Result

The Right Frontier

One of the most exciting facts in all of linguistics

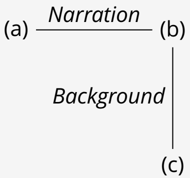
Anaphora follow coherence structure

The anaphora-accessible referents are on the right-most nodes of the graphed discourse structure.

Improving on DRT

- DRT does not (always) make the right predictions for anaphora.

(8) a. John dropped off his car for repairs.
b. Then he got a rental.
c. It had a broken fuel pump.



- DRT: flat structure.
  - > *his car* available for *it*.
- coherence relations: complex structure.
  - > Narration(a,b) blocks this binding.

Semantics for Discourse

Truth-conditions of *discourses*

- We assign truth conditional meaning postulates to the coherence relations themselves.
  - These postulates tell us something about the constituent units of a relation.

- (this is in fact perfectly analogous to “modes of composition” in Fregean-Montogovian semantics)

- The Big Picture:
- Discourse logical forms are built from two languages:
  - Microstructure (clause level, EDUs)
  - Macrostructure (discourse level, CDUs)

Microstructure Vocabulary

Variables ($x, y, \ldots, e_1, e_2, \ldots$); Name symbols (John, Max, ...); Predicate symbols (`eat`, `overlap`, `actor`, ...); connectives ($=, \Rightarrow, \neg, \Diamond$).

Microstructure Formulas (DRSs)

A DRS is a tuple $\langle U, Cond \rangle$ where U is a set of variables, and $Cond$ is a set of conditions.

- For a name N and a variable x, $N(x)$ is a condition.
- For a predicate P and variables $x_1, \ldots, x_n$, $P(x_1, \ldots, x_n)$ is a condition.
- For variables x and y, $x = y$ is a condition.
- If C_1 and C_2 are DRSs, $C_1 \Rightarrow C_2$, $\neg C_1$ and $\Diamond C_1$ are conditions.

(add more as needed!)

- I'll use a lot of event variables for neo-Davidsonian semantics.

- Plan: Macrostructure formulas contain labels for other formulas and state how the labelled contents form a discourse.

Macrostructure Vocabulary

DRSs; coherence relation symbols (Elaboration, Narration, ...); label variables (π, λ, ...); logical connectives ($\neg$, $\Rightarrow$, $\wedge$, $\Diamond$).

Macrostructure Formulas

- Any DRS *K* is a macrostructure formula.
  (DRSs are like the atoms of the macrostructure)
- For a coherence relation *R* and label variables α, β, $R(\alpha, \beta)$ is a macrostructure formula.
- If *P* and *Q* are macrostructure formulae, then so are $P \wedge Q$, $\neg P$, $\Diamond P$, $P \Rightarrow Q$.

Segmented Discourse Representation Structure

An SDRS is a triple $(\Pi, \mathcal{F}, L)$ where Π is a set of label variables, $L \in \Pi$ and $\mathcal{F}$ is a function from Π to the macrostructure formulae such that for any $\pi \in \Pi$, either:

- $\mathcal{F}(\pi) = K$ for some DRS K (microstructure).
- $\mathcal{F}(\pi)$ is a conjunction of formulas of the form $R(\alpha, \beta)$ (where $\alpha, \beta \in \Pi$).

- Typically $\pi : K$ abbreviates $\mathcal{F}(\pi) = K$.
- Typically π_0 denotes the CDU constituting the full discourse.
- L is the right-most or *last* label: the label for the discourse-final clause (in the linear surface order).

(9) a. John overslept.

b. So he missed his flight. $\pi_a \xrightarrow{\textit{Result}} \pi_b \xrightarrow{\textit{Result}} \pi_c$

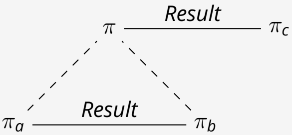
c. So he took a train.

$$\mathcal{F}(\pi_a) = [\![(a)]\!]$$
$$\mathcal{F}(\pi_b) = [\![(b)]\!]$$
$$\mathcal{F}(\pi_c) = [\![(c)]\!]$$
$$\mathcal{F}(\pi_0) = \text{Result}(\pi_a, \pi_b) \wedge \text{Result}(\pi_b, \pi_c)$$

(10) a. John overslept.

b. So he missed his flight.

c. So he bought an alarm clock.



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$$\mathcal{F}(\pi_b) = [\![(b)]\!]$$
$$\mathcal{F}(\pi_c) = [\![(c)]\!]$$
$$\mathcal{F}(\pi_0) = \text{Result}(\pi, \pi_c)$$
$$\mathcal{F}(\pi\ \ ) = \text{Result}(\pi_a, \pi_b)$$

What about the Right Frontier?

- Some more definitions:

Outscoping

- Note that $\mathcal{F}$ induces an order on Π.
- Say that $\alpha < \beta$ iff α occurs in $\mathcal{F}(\beta)$.
- Let $\prec$ denote the reflexive transitive closure of $<$.
- Call this relation “outscoping”.

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Interpretable SDRS

- A SDRS $(\Pi, \mathcal{F}, L)$ is well formed if:
- There is a unique outscoping-maximal label in Π (“root”).
- $\prec$ is anti-symmetric (in particular, then, it has no circles)

The Right Frontier (formally)

- Let $(\Pi, \mathcal{F}, L)$ be a well-formed SDRS.

SDRT-Accessibility

Accessibility is defined recursively:

- L is accessible.
- If α is accessible and $\alpha \prec \beta$, then β is accessible.
- If (i) α is accessible, and
  (ii) $R(\beta, \alpha)$ occurs in some $\mathcal{F}(\gamma)$, and
  (iii) R is subordinating
  then β is accessible.

(11) a. John dropped off his car for repairs.

b. Then he got a rental.

c. It had a broken fuel pump.

$$\begin{tikzcd} \pi_a \arrow[r, dash, "Narration"] & \pi_b \arrow[d, dash, "Background"'] \\ & \pi_c \end{tikzcd}$$

$L = \pi_c$

$\mathcal{F}(\pi_a) = [\![(a)]\!]$
$\mathcal{F}(\pi_b) = [\![(b)]\!]$
$\mathcal{F}(\pi_c) = [\![(c)]\!]$
$\mathcal{F}(\pi_0) = \text{Narration}(\pi_a, \pi_b) \wedge \text{Background}(\pi_b, \pi_c)$

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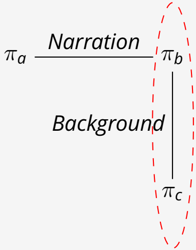

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$\mathcal{F}(\pi_a) = [\![(a)]\!]$
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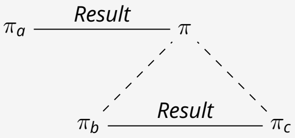
(12) a. John overslept.

b. So he missed his flight.

c. So he got angry at himself.



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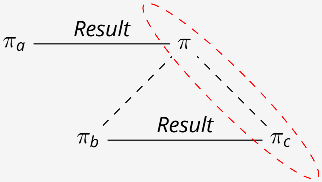

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$$\mathcal{F}(\pi\ \ ) = \text{Result}(\pi_a, \pi)$$

Summary

- Elementary Discourse Units are Discourse Representation Structures.
- Segmented Discourse Representation Structures are discourse structures on top of these EDUs
- EDUs (microstructure) are constructed by the DRS construction algorithm.
- Within EDUs, anaphora are guided by DRT-accessibility.
- *Across* EDUs, anaphora are guided by the right frontier.

Macrostructure Evaluation

- We already know how to evaluate DRSs.
- We recursively translate a macrostructure formula P into a *microstructure* K such that update with K represents the information in P (not as hard as it sounds!).

The Plan

Linguistic Forms

are interpreted to

SDRSs — describe discourse structure

are converted to

DRSs — describe event structure

are evaluated in

Models

- A bit of notation:

- For two DRSs $K_1 = \langle U_1, C_1 \rangle$, $K_2 = \langle U_2, C_2 \rangle$, define $K_1 + K_2 = \langle U_1 \cup U_2, C_1 \cup C_2 \rangle$.

Macrostructure-to-Microstructure

Given an SDRS $S = (\Pi, \mathcal{F}, L)$, translate a macro formula P to a DRS $[\![P]\!]^S$ (say, *P interpreted in the discourse structure S*).

1. If $P = K$ for a DRS K, then $[\![P]\!]^S = K$.

2a. If $P = Q_1 \wedge Q_2$, then $[\![P]\!]^S = [\![Q_1]\!]^S + [\![Q_2]\!]^S$.

2b. If $P = \neg Q$, then $[\![P]\!]^S = \boxed{\begin{array}{c} \\ \hline \neg[\![Q]\!]^S \end{array}}$

2c. If $P = \Diamond Q$, then $[\![P]\!]^S = \boxed{\begin{array}{c} \\ \hline \Diamond[\![Q]\!]^S \end{array}}$

2d. If $P = Q_1 > Q_2$, then $[\![P]\!]^S = \boxed{\begin{array}{c} \\ \hline [\![Q_1]\!]^S \Rightarrow [\![Q_2]\!]^S \end{array}}$.

3. If $P = R(\alpha, \beta)$ for a coherence relation R, then $[\![P]\!]^S = [\![\mathit{Info}_R(\mathcal{F}(\alpha), \mathcal{F}(\beta))]\!]^S$

   where Info_R is the specific semantic contribution provided by the relation R (a meaning postulate).

Veridicality

- Most coherence relations are veridical: they compose to content that entails their parts.

- If R is veridical,
  $[\![Info_R(\alpha, \beta)]\!]^S = [\![\mathcal{F}(\alpha) \wedge \mathcal{F}(\beta) \wedge Info'_R(\mathcal{F}(\alpha), \mathcal{F}(\beta))]\!]^S$
  where $Info'_R$ is the specific semantic contribution provided by the relation R (a meaning postulate).

- Not all are veridical.

One more preliminary...

- Note that “microstructure” is just about clauses.
- Recall that we associated events with verb phrases.
- Let’s call the event associated with the main verb phrase of a clause its semantic index.
- Let’s refer to the semantic index of a microstructure K e_K.
- Or, if K is labelled by π, also e_π.

Info for Elab

- Elaboration is veridical and adds that the second content *typically* entails the first, but not vice versa, and that the evens overlap:
  - > "typically entails" $\rightarrow$ tomorrow, Friday.

$$
\begin{aligned}
\textit{Info}'_{\text{Elab}}(\mathcal{F}(\alpha), \mathcal{F}(\beta)) = \quad & \mathcal{F}(\beta) > \mathcal{F}(\alpha) \\
& \wedge \neg(\mathcal{F}(\alpha) > \mathcal{F}(\beta)) \\
& \wedge \boxed{\begin{array}{l} \hline \texttt{part-of}(e_\beta, e_\alpha) \end{array}}
\end{aligned}
$$

(13) a. John had a great meal.
b. He had salmon.
c. And he had cheese.

- Do salmon and cheese individually suffice for a great meal, or are they only jointly a great meal

CDUs

- Wait, Julian, what about CDUs that are parts of further coherence relations?

CDUs

- Wait, Julian, what about CDUs that are parts of further coherence relations?
- I'm glad you ask: we also need to assign non-microstructure events a semantic index. So, technically:

$$
\begin{aligned}
\mathit{Info}'_{\text{Elab}}(\mathcal{F}(\alpha), \mathcal{F}(\beta)) = \quad & \mathcal{F}(\beta) > \mathcal{F}(\alpha) \\
& \wedge \neg(\mathcal{F}(\alpha) > \mathcal{F}(\beta)) \\
& \wedge \boxed{\begin{array}{l} e \\ \hline \texttt{part-of}(e_\beta, e_\alpha) \\ e = e_\alpha \end{array}}
\end{aligned}
$$

While we are being technical...

- Actually, if we are being *super* precise, we need to keep track of which label in the SDRS we are evaluating gave rise to this $\mathit{Info}_{\mathrm{Elab}}$ so that we can assign e to that label.
- So we *should* write this: (keeping track of which label the relation belongs to)

3. $f[\![\pi : R(\alpha, \beta)]\!]^S_{M,w} g$ iff $f[\![\mathit{Info}_R({\color{red}\pi}, \mathcal{F}(\alpha), \mathcal{F}(\beta))]\!]^S_{M,w} g$.

$$\mathit{Info}'_{\mathrm{Elab}}(\pi, \mathcal{F}(\alpha), \mathcal{F}(\beta)) = \begin{array}{l} \mathcal{F}(\beta) > \mathcal{F}(\alpha) \\ \wedge \neg(\mathcal{F}(\alpha) > \mathcal{F}(\beta)) \\ \wedge \boxed{\begin{array}{l} e_\pi \\ \hline \mathtt{part\text{-}of}(e_\beta, e_\alpha) \\ e_\pi = e_\alpha \end{array}} \end{array}$$

Shared Topic

- This is the topic constraint for events e_α, e_β:

$$\begin{array}{|l|}\hline e_\pi \\ \hline \texttt{part-of}(e_\alpha, e_\pi) \\ \texttt{part-of}(e_\beta, e_\pi) \\ (K_\alpha \sqcap K_\beta)^{e_\pi} \\ \hline \end{array}$$

- $(K_\alpha \sqcap K_\beta)^{e_\pi}$ is the DRS with index e_π that records 'the common content' of K_α and K_β.
  - Asher & Lascarides 2003: "very difficult to define in practice".

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  - > Asher & Lascarides 2003: "very difficult to define in practice".

- An approximation:
- For a DRS K, let K^e be like K where the semantic index of K has been uniformly replaced by e. Define $(K_\alpha \sqcap K_\beta)^{e_\pi} = K_\alpha^{e_\pi} \cap K_\beta^{e_\pi}$

Continuation

- Continuation is the simplest topic relation.

$$
\mathit{Info}'_{\text{Continuation}}(\pi, \mathcal{F}(\alpha), \mathcal{F}(\beta)) = \boxed{\begin{array}{l} e_\pi \\ \hline \texttt{part-of}(e_\alpha, e_\pi) \\ \texttt{part-of}(e_\beta, e_\pi) \\ (K_\alpha \sqcap K_\beta)^{e_\pi} \end{array}}
$$

Continuation

- Continuation is the simplest topic relation.

$$Info'_{\text{Continuation}}(\pi, \mathcal{F}(\alpha), \mathcal{F}(\beta)) = \begin{array}{|l|}\hline e_\pi \\ \hline \texttt{part-of}(e_\alpha, e_\pi) \\ \texttt{part-of}(e_\beta, e_\pi) \\ (K_\alpha \sqcap K_\beta)^{e_\pi} \\ \hline \end{array}$$

(14) a. Essun told the children to search for the cat.
b. Binof searched the garden.
c. Tonkee looked in the kitchen.

$\left.\begin{array}{l}\text{a} \\ \left.\begin{array}{l}\text{b} \\ \text{c}\end{array}\right] \text{Continuation}\end{array}\right] \text{Result}$

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(14) a. Essun told the children to search for the cat.
b. Binof searched the garden.
c. Tonkee looked in the kitchen.
searching for the cat

Continuation

Result

A closer look

(15) a. Essun told the children to search for the cat.
b. Binof searched the garden.
c. Tonkee looked in the kitchen.
searching for the cat

Continuation

Result

$$K_b = \begin{array}{|l|}\hline e_b, b, x, g \\ \hline \text{Binof}(b) \\ \mathtt{searching}(e_b) \\ \mathtt{actor}(e_b, b) \\ \mathtt{object}(e_b, x) \\ \mathtt{location}(e_b, g) \\ \mathtt{garden}(g) \\ \hline \end{array} \quad K_c = \begin{array}{|l|}\hline e_c, t, x, k \\ \hline \text{Tonkee}(t) \\ \mathtt{searching}(e_c) \\ \mathtt{actor}(e_c, t) \\ \mathtt{object}(e_b, x) \\ \mathtt{location}(e_c, k) \\ \mathtt{kitchen}(k) \\ \hline \end{array}$$

A closer look

(15) a. Essun told the children to search for the cat.
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c. Tonkee looked in the kitchen.

Continuation (b–c); Result (a–c)

searching for the cat

$$K_b = \boxed{\begin{array}{l} e_b, b, x, g \\ \hline \text{Binof}(b) \\ \texttt{searching}(e_b) \\ \texttt{actor}(e_b, b) \\ \texttt{object}(e_b, x) \\ \texttt{location}(e_b, g) \\ \texttt{garden}(g) \end{array}} \quad K_c = \boxed{\begin{array}{l} e_c, t, x, k \\ \hline \text{Tonkee}(t) \\ \texttt{searching}(e_c) \\ \texttt{actor}(e_c, t) \\ \texttt{object}(e_b, x) \\ \texttt{location}(e_c, k) \\ \texttt{kitchen}(k) \end{array}} \quad (K_b \sqcap K_c)^e = \boxed{\begin{array}{l} e, x \\ \hline \texttt{searching}(e) \\ \texttt{object}(e, x) \end{array}}$$

(I've already resolved the anaphor for the search-event object to the same x in K_b and K_c.)

Info for Narration

- Narration is veridical and adds the information that events are temporally close and reported in order:
  - "close" is sensitive to context (like "tall").
- Let $e_1 \approx e_2$ mean that e_1 and e_2 are temporally close.

$$Info'_{\text{Narration}}(\pi, \mathcal{F}(\alpha), \mathcal{F}(\beta)) = \boxed{\begin{array}{l} e_\pi \\ \hline \texttt{part-of}(e_\alpha, e_\pi) \\ \texttt{part-of}(e_\beta, e_\pi) \\ (K_\alpha \sqcap K_\beta)^{e_\pi} \\ \texttt{post}(e_\alpha) \approx \texttt{pre}(e_\beta)) \end{array}}$$

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(16) a. The terrorist went to the bridge.
b. Then he planted a bomb.

$\left.\begin{array}{l} \text{(16a)} \\ \text{(16b)} \end{array}\right]$ Narration

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(16) a. The terrorist went to the bridge.
b. Then he planted a bomb.
on or near the bridge

$\left.\begin{array}{l} \text{a} \\ \text{b} \end{array}\right]$ Narration

Another closer look

(17) a. Binof went to the garden.
b. And looked for the cat.
looking in the garden

$\left.\begin{array}{l}\\ \\ \end{array}\right]$ Narration

$$K_b = \boxed{\begin{array}{l} e_a, b, x, g \\ \hline \text{Binof}(b) \\ \texttt{going}(e_a) \\ \texttt{actor}(e_a, b) \\ \texttt{object}(e_b, g) \\ \texttt{garden}(g) \end{array}} \quad K_c = \boxed{\begin{array}{l} e_b, c \\ \hline \texttt{cat}(c) \\ \texttt{searching}(e_b) \\ \texttt{actor}(e_c, b) \\ \texttt{object}(e_b, c) \end{array}} \quad (K_b \sqcap K_c)^e = \boxed{\begin{array}{l} e \\ \hline \texttt{actor}(e, b) \end{array}}$$

No common topic

(18) a. It rained in Riga.
??b. Then Arshak made dinner in Yerevan.
Narration

(19) a. My car broke down.
??b. Then the sun set.
Narration

No common topic

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Narration

(19) a. My car broke down.
??b. Then the sun set.
Narration

(20) a. My car broke down.
b. Then the sun set.
c. I knew I was in trouble.
Result
Narration

Explanation and Result

- Explanation is subordinating and Result is coordinating.
  - Homework: verify this for yourself with examples involving anaphora.
  - If you find a cool one, show it to us!
- Both are veridical.

Explanation and Result

- Explanation is subordinating and Result is coordinating.
  - Homework: verify this for yourself with examples involving anaphora.
  - If you find a cool one, show it to us!
- Both are veridical.

$$\mathit{Info}'_{\text{Explanation}}(\pi, \mathcal{F}(\alpha), \mathcal{F}(\beta)) = \boxed{\begin{array}{l} e_\pi \\ \hline \texttt{cause}(e_\beta, e_\alpha) \\ \neg\texttt{before}(e_\alpha, e_\beta) \\ e_\pi = e_\beta + e_\alpha \end{array}}$$

Explanation and Result

- Explanation is subordinating and Result is coordinating.
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$$\mathit{Info}'_{\text{Result}}(\pi, \mathcal{F}(\alpha), \mathcal{F}(\beta)) = \begin{array}{|l|}\hline e_\pi \\ \hline \texttt{cause}(e_\alpha, e_\beta) \\ \neg\texttt{before}(e_\beta, e_\alpha) \\ e_\pi = e_\alpha + e_\beta \\ \hline \end{array}$$

Backgrounds and Backgrounds

(21) a. (π_1) John walked (π_2) while it was raining.

$Background_{bckw}(\pi_1, \pi_2)$

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$\textit{Background}_{fwd}(\pi_1, \pi_2)$

- These tell (arguably) the same story.
- So we need two backgrounds:
  - > The main story PRECEDES the background (Background$_{backward}$)
  - > The main story FOLLOWS the background (Background$_{foward}$)
- (Because we want the narrative structure to track the order of utterance; also see Asher, Prevot & Vieu (2007).)

- Both are veridical and subordinating.
  - Is that right? The thing about subordination?
  - Think about it. The cue-phrase is *while*.
- The following meaning postulate goes for both:

$$\mathit{Info}'_{\text{Background}}(\pi, \mathcal{F}(\alpha), \mathcal{F}(\beta)) = \boxed{\begin{array}{l} e_\pi \\ \hline \texttt{overlap}(e_\alpha, e_\beta) \end{array}}$$

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- Easy enough, but...

Background has Magic Anaphora Properties!

(22)

a. While it was just drizzling,

b. a woman searched for shelter,

c. to not get wet.

Expl

Background$_{fwd}$

Background has Magic Anaphora Properties!

(22)

a. While it was just drizzling,
b. a woman searched for shelter,
c. to not get wet.
d. then it started pouring
e. while **she** was still searching

Expl (b–c)
Background$_{fwd}$ (a–c)
Narration (a–d)
Background$_{bckw}$ (d–e)

Background has Magic Anaphora Properties!

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a. While it was just drizzling,
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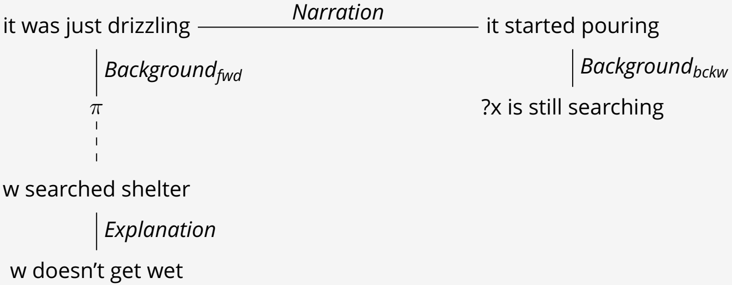
Expl (b–c); Background$_{fwd}$ (a–c); Narration (a–e); Background$_{bckw}$ (d–e)



The FBP Construct

To anaphorical intents and purposes *Background* CDUs are EDUs.

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The FBP Construct

To anaphorical intents and purposes *Background* CDUs are EDUs.

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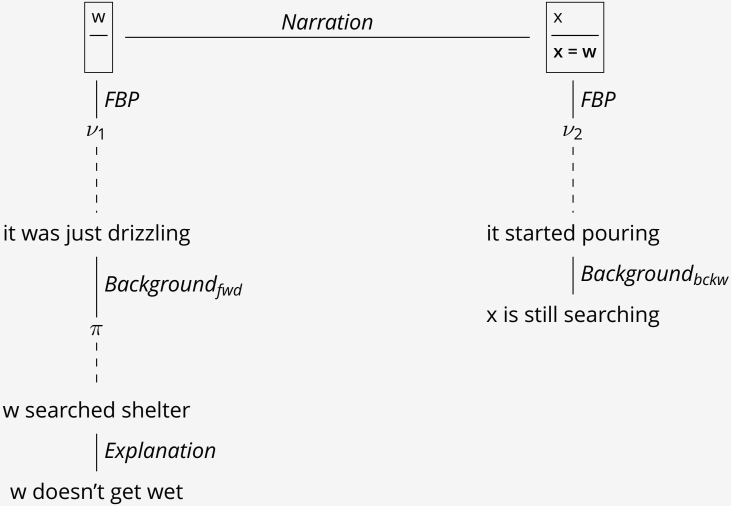
- and add ν : *Foreground-Background-Pair*(λ, π). (henceforth, *FBP*)


w
Narration
x
x = w
FBP
ν_1
FBP
ν_2
it was just drizzling
$Background_{fwd}$
π
w searched shelter
Explanation
w doesn't get wet
it started pouring
$Background_{bckw}$
x is still searching

We will put a full glossary of the SDRT coherence relations and their *Info*'s online.

Evaluating SDRSs

- When we evaluate an entire SDRS $S = (\Pi, \mathcal{F}, L)$, we find its root label π_0 and compute $[\![\mathcal{F}(\pi_0)]\!]^S$.
  - This is why the root label has to be unique: you need to know where to start.
- By design, this runs through the entire SDRS.
  - This is why there cannot be any circles: this would never stop
- In some SDRSs we might hit the same label multiple times; this is harmless since this just repeats information we already know.

And if you want a classical truth-condition

- Let $S = (\Pi, \mathcal{F}, L)$ be an SDRS, w be a world, f, g be variable assignments and M be a model.
- So you start with a *set* of possible worlds W and an assignment f,
  - > Typically ("null context"): W is all possible worlds, and f is empty
- And you compute which world-assignment pairs are not ruled out by the content of P:

$$\{(w, g) \mid f[\![P]\!]^{S}_{M,w} g)\}$$

(23) π_1 : John had a great lunch.

π_2 : He ate soup

π_3 : Then he ate pasta.

Narration

Elaboration

.

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$$\mathcal{F}(\pi_1) = K_1 = \boxed{\begin{array}{l} j, l, e_{\pi_1} \\ \hline \text{John}(j) \\ \texttt{lunch}(l) \\ \texttt{eating}(e_{\pi_1}) \\ \texttt{great}(e_{\pi_1}) \\ \texttt{object}(e_{\pi_1}, l) \\ \texttt{actor}(e_{\pi_1}, j) \end{array}}, \mathcal{F}(\pi_2) = K_2 = \boxed{\begin{array}{l} s, e_{\pi_2} \\ \hline \texttt{soup}(s) \\ \texttt{eating}(e_{\pi_2}) \\ \texttt{object}(e_{\pi_2}, s) \\ \texttt{actor}(e_{\pi_2}, j) \end{array}}, \mathcal{F}(\pi_3) = K_3 = \boxed{\begin{array}{l} p, e_{\pi_3} \\ \hline \texttt{pasta}(p) \\ \texttt{eating}(e_{\pi_2}) \\ \texttt{object}(e_{\pi_2}, s) \\ \texttt{actor}(e_{\pi_2}, j) \end{array}}$$

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$[\![\mathcal{F}(\pi_0)]\!]^S = [\![\mathit{Elaboration}(\pi_1, \lambda)]\!]^S$

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Narration (π_2, π_3); Elaboration (π_1, π_2–π_3).

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$$[\![\mathcal{F}(\pi_0)]\!]^S = [\![\textit{Elaboration}(\pi_1, \lambda)]\!]^S$$
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Narration (π_2, π_3)
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$$\llbracket \mathcal{F}(\pi_0) \rrbracket^S = \llbracket \mathit{Elaboration}(\pi_1, \lambda) \rrbracket^S$$
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$$\begin{aligned}
&[\![\mathcal{F}(\pi_0)]\!]^S = [\![\mathit{Elaboration}(\pi_1, \lambda)]\!]^S \\
&= [\![\mathcal{F}(\pi_1) \wedge \mathcal{F}(\lambda) \wedge \mathit{Info}_{Elab}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S \\
&= [\![\mathcal{F}(\pi_1)]\!]^S + [\![\mathcal{F}(\lambda)]\!]^S + [\![\mathit{Info}_{Elab}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S \\
&= [\![K_1]\!]^S + [\![\mathit{Narration}(\pi_2, \pi_3)]\!]^S + [\![\mathit{Info}'_{Elab}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S
\end{aligned}$$

$$[\![\mathcal{F}(\pi_0)]\!]^S = [\![K_1]\!]^S + [\![\mathit{Narration}(\pi_2, \pi_3)]\!]^S + [\![\mathit{Info}'_{\mathit{Elab}}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S$$

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$$= [\![K_1]\!]^S + [\![\mathcal{F}(\pi_2) \wedge \mathcal{F}(\pi_3) \wedge \mathit{Info}'_{\mathit{Narr}}(\lambda, \mathcal{F}(\pi_1), \mathcal{F}(\pi_2))]\!]^S + [\![\mathit{Info}'_{\mathit{Elab}}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S$$

$$
\begin{aligned}
&[\![\mathcal{F}(\pi_0)]\!]^S = [\![K_1]\!]^S + [\![\mathit{Narration}(\pi_2, \pi_3)]\!]^S + [\![\mathit{Info}'_{\mathit{Elab}}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S \\
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&= [\![K_1]\!]^S + [\![\mathcal{F}(\pi_2)]\!]^S + [\![\mathcal{F}(\pi_3)]\!]^S + [\![\mathit{Info}'_{\mathit{Narr}}(\lambda, \mathcal{F}(\pi_1), \mathcal{F}(\pi_2))]\!]^S + [\![\mathit{Info}'_{\mathit{Elab}}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S
\end{aligned}
$$

$$
\begin{aligned}
&[\![\mathcal{F}(\pi_0)]\!]^S = [\![K_1]\!]^S + [\![\mathit{Narration}(\pi_2, \pi_3)]\!]^S + [\![\mathit{Info}'_{\mathit{Elab}}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S \\
&= [\![K_1]\!]^S + [\![\mathcal{F}(\pi_2) \wedge \mathcal{F}(\pi_3) \wedge \mathit{Info}'_{\mathit{Narr}}(\lambda, \mathcal{F}(\pi_1), \mathcal{F}(\pi_2))]\!]^S + [\![\mathit{Info}'_{\mathit{Elab}}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S \\
&= [\![K_1]\!]^S + [\![\mathcal{F}(\pi_2)]\!]^S + [\![\mathcal{F}(\pi_3)]\!]^S + [\![\mathit{Info}'_{\mathit{Narr}}(\lambda, \mathcal{F}(\pi_1), \mathcal{F}(\pi_2))]\!]^S + [\![\mathit{Info}'_{\mathit{Elab}}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S \\
&= [\![K_1]\!]^S + [\![K_2]\!]^S + [\![K_3]\!]^S + [\![\mathit{Info}'_{\mathit{Narr}}(\lambda, \mathcal{F}(\pi_1), \mathcal{F}(\pi_2))]\!]^S + [\![\mathit{Info}'_{\mathit{Elab}}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S
\end{aligned}
$$

$$
\begin{aligned}
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\end{aligned}
$$

$$
= [\![K_1]\!]^S + [\![K_2]\!]^S + [\![K_3]\!]^S + \begin{array}{|l|}
\hline
e_\lambda \\
\hline
\texttt{part-of}(e_{\pi_2}, e_\lambda) \\
\texttt{part-of}(e_{\pi_3}, e_\lambda) \\
\texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\
(K_1 \sqcap K_2)^{e_\lambda} \\
\hline
\end{array} + [\![\mathit{Info}'_{\mathit{Elab}}(\pi_0, \mathcal{F}(\pi_1), \mathcal{F}(\lambda))]\!]^S
$$

$$= [\![K_1]\!]^S + [\![K_2]\!]^S + [\![K_3]\!]^S + \boxed{\begin{array}{l} e_\lambda \\ \hline \texttt{part-of}(e_{\pi_2}, e_\lambda) \\ \texttt{part-of}(e_{\pi_3}, e_\lambda) \\ \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\ (K_1 \sqcap K_2)^{e_\lambda} \end{array}} + [\![\mathcal{F}(\lambda) > K_1 \wedge \neg(K_1 > \mathcal{F}(\lambda)) \wedge \boxed{\begin{array}{l} e_{\pi_0} \\ \hline \texttt{part-of}(e_\lambda, e_{\pi_0}) \\ e_{\pi_0} = e_\lambda \end{array}}\ ]\!]^S$$

$$= [\![K_1]\!]^S + [\![K_2]\!]^S + [\![K_3]\!]^S + \begin{array}{|l|}\hline e_\lambda \\ \hline \texttt{part-of}(e_{\pi_2}, e_\lambda) \\ \texttt{part-of}(e_{\pi_3}, e_\lambda) \\ \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\ (K_1 \sqcap K_2)^{e_\lambda} \\ \hline \end{array} + [\![\mathcal{F}(\lambda) > K_1 \wedge \neg(K_1 > \mathcal{F}(\lambda)) \wedge \begin{array}{|l|}\hline e_{\pi_0} \\ \hline \texttt{part-of}(e_\lambda, e_{\pi_0}) \\ e_{\pi_0} = e_\lambda \\ \hline \end{array}\,]\!]^S$$

$$\begin{array}{c} [\![K_1]\!]^S \\ = + [\![K_2]\!]^S \\ + [\![K_3]\!]^S \end{array} + \begin{array}{|l|}\hline e_\lambda \\ \hline \texttt{part-of}(e_{\pi_2}, e_\lambda) \\ \texttt{part-of}(e_{\pi_3}, e_\lambda) \\ \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\ (K_1 \sqcap K_2)^{e_\lambda} \\ \hline \end{array} + \begin{array}{|l|}\hline \\ \hline [\![\mathcal{F}(\lambda)]\!]^S > K_1 \\ \hline \end{array} + \begin{array}{|l|}\hline \\ \hline \neg \begin{array}{|l|}\hline \\ \hline K_1 > [\![\mathcal{F}(\lambda)]\!]^S \\ \hline \end{array} \\ \hline \end{array} + \begin{array}{|l|}\hline e_{\pi_0} \\ \hline \texttt{part-of}(e_\lambda, e_{\pi_0}) \\ e_{\pi_0} = e_\lambda \\ \hline \end{array}$$

$$= \llbracket K_1 \rrbracket^S + \llbracket K_2 \rrbracket^S + \llbracket K_3 \rrbracket^S + \boxed{\begin{array}{l} e_\lambda \\ \hline \texttt{part-of}(e_{\pi_2}, e_\lambda) \\ \texttt{part-of}(e_{\pi_3}, e_\lambda) \\ \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\ (K_1 \sqcap K_2)^{e_\lambda} \end{array}} + \llbracket \mathcal{F}(\lambda) > K_1 \wedge \neg (K_1 > \mathcal{F}(\lambda)) \wedge \boxed{\begin{array}{l} e_{\pi_0} \\ \hline \texttt{part-of}(e_\lambda, e_{\pi_0}) \\ e_{\pi_0} = e_\lambda \end{array}} \rrbracket^S$$

$$\begin{array}{r} \llbracket K_1 \rrbracket^S \\ = + \llbracket K_2 \rrbracket^S \\ + \llbracket K_3 \rrbracket^S \end{array} + \boxed{\begin{array}{l} e_\lambda \\ \hline \texttt{part-of}(e_{\pi_2}, e_\lambda) \\ \texttt{part-of}(e_{\pi_3}, e_\lambda) \\ \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\ (K_1 \sqcap K_2)^{e_\lambda} \end{array}} + \boxed{\begin{array}{l} \\ \hline \llbracket \mathcal{F}(\lambda) \rrbracket^S > K_1 \end{array}} + \boxed{\begin{array}{l} \\ \hline \neg \boxed{\begin{array}{l} \\ \hline K_1 > \llbracket \mathcal{F}(\lambda) \rrbracket^S \end{array}} \end{array}} + \boxed{\begin{array}{l} e_{\pi_0} \\ \hline \texttt{part-of}(e_\lambda, e_{\pi_0}) \\ e_{\pi_0} = e_\lambda \end{array}}$$

$$= \llbracket K_1 \rrbracket^S + \llbracket K_2 \rrbracket^S + \llbracket K_3 \rrbracket^S + \boxed{\begin{array}{l} e_\lambda \\ \hline \texttt{part-of}(e_{\pi_2}, e_\lambda) \\ \texttt{part-of}(e_{\pi_3}, e_\lambda) \\ \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\ (K_1 \sqcap K_2)^{e_\lambda} \end{array}} + \boxed{\begin{array}{l} e_{\pi_0} \\ \hline \llbracket \mathcal{F}(\lambda) \rrbracket^S > K_1 \\ \neg \boxed{\begin{array}{l} \\ \hline K_1 > \llbracket \mathcal{F}(\lambda) \rrbracket^S \end{array}} \\ \texttt{part-of}(e_\lambda, e_{\pi_0}) \\ e_{\pi_0} = e_\lambda \end{array}}$$

$$
\begin{array}{|l|}
\hline
j, l, e_{\pi_1} \\
\hline
\text{John}(j) \\
\mathtt{lunch}(l) \\
\mathtt{eating}(e_{\pi_1}) \\
\mathtt{great}(e_{\pi_1}) \\
\mathtt{object}(e_{\pi_1}, l) \\
\mathtt{actor}(e_{\pi_1}, j) \\
\hline
\end{array}
+
\begin{array}{|l|}
\hline
s, e_{\pi_2} \\
\hline
\mathtt{soup}(s) \\
\mathtt{eating}(e_{\pi_2}) \\
\mathtt{object}(e_{\pi_2}, s) \\
\mathtt{actor}(e_{\pi_2}, j) \\
\hline
\end{array}
+
\begin{array}{|l|}
\hline
p, e_{\pi_3} \\
\hline
\mathtt{pasta}(p) \\
\mathtt{eating}(e_{\pi_2}) \\
\mathtt{object}(e_{\pi_2}, s) \\
\mathtt{actor}(e_{\pi_2}, j) \\
\hline
\end{array}
+
\begin{array}{|l|}
\hline
e_{\lambda} \\
\hline
\mathtt{part\text{-}of}(e_{\pi_2}, e_{\lambda}) \\
\mathtt{part\text{-}of}(e_{\pi_3}, e_{\lambda}) \\
\mathtt{post}(e_{\pi_2}) \approx \mathtt{pre}(e_{\pi_3}) \\
(K_1 \sqcap K_2)^{e_{\lambda}} \\
\hline
\end{array}
+
\begin{array}{|l|}
\hline
e_{\pi_0} \\
\hline
\llbracket \mathcal{F}(\lambda) \rrbracket^{S} > K_1 \\
\neg \begin{array}{|l|}
\hline
\\
\hline
K_1 > \llbracket \mathcal{F}(\lambda) \rrbracket^{S} \\
\hline
\end{array} \\
\mathtt{part\text{-}of}(e_{\lambda}, e_{\pi_0}) \\
e_{\pi_0} = e_{\lambda} \\
\hline
\end{array}
$$

$$\boxed{\begin{array}{l} j, l, e_{\pi_1} \\ \hline \mathrm{John}(j) \\ \texttt{lunch}(l) \\ \texttt{eating}(e_{\pi_1}) \\ \texttt{great}(e_{\pi_1}) \\ \texttt{object}(e_{\pi_1}, l) \\ \texttt{actor}(e_{\pi_1}, j) \end{array}} + \underbrace{\boxed{\begin{array}{l} s, e_{\pi_2} \\ \hline \texttt{soup}(s) \\ \texttt{eating}(e_{\pi_2}) \\ \texttt{object}(e_{\pi_2}, s) \\ \texttt{actor}(e_{\pi_2}, j) \end{array}} + \boxed{\begin{array}{l} p, e_{\pi_3} \\ \hline \texttt{pasta}(p) \\ \texttt{eating}(e_{\pi_2}) \\ \texttt{object}(e_{\pi_2}, s) \\ \texttt{actor}(e_{\pi_2}, j) \end{array}} + \boxed{\begin{array}{l} e_{\lambda} \\ \hline \texttt{part-of}(e_{\pi_2}, e_{\lambda}) \\ \texttt{part-of}(e_{\pi_3}, e_{\lambda}) \\ \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\ (K_1 \sqcap K_2)^{e_{\lambda}} \end{array}}}_{= \mathcal{F}(\lambda)} + \boxed{\begin{array}{l} e_{\pi_0} \\ \hline \llbracket \mathcal{F}(\lambda) \rrbracket^S > K_1 \\ \neg \boxed{\begin{array}{l} \\ \hline K_1 > \llbracket \mathcal{F}(\lambda) \rrbracket^S \end{array}} \\ \texttt{part-of}(e_{\lambda}, e_{\pi_0}) \\ e_{\pi_0} = e_{\lambda} \end{array}}$$

$$
\boxed{\begin{array}{l} j, l, e_{\pi_1} \\ \hline \text{John}(j) \\ \texttt{lunch}(l) \\ \texttt{eating}(e_{\pi_1}) \\ \texttt{great}(e_{\pi_1}) \\ \texttt{object}(e_{\pi_1}, l) \\ \texttt{actor}(e_{\pi_1}, j) \end{array}}
+
\underbrace{
\boxed{\begin{array}{l} s, e_{\pi_2} \\ \hline \texttt{soup}(s) \\ \texttt{eating}(e_{\pi_2}) \\ \texttt{object}(e_{\pi_2}, s) \\ \texttt{actor}(e_{\pi_2}, j) \end{array}}
+
\boxed{\begin{array}{l} p, e_{\pi_3} \\ \hline \texttt{pasta}(p) \\ \texttt{eating}(e_{\pi_2}) \\ \texttt{object}(e_{\pi_2}, s) \\ \texttt{actor}(e_{\pi_2}, j) \end{array}}
+
\boxed{\begin{array}{l} e_\lambda \\ \hline \texttt{part-of}(e_{\pi_2}, e_\lambda) \\ \texttt{part-of}(e_{\pi_3}, e_\lambda) \\ \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\ (K_1 \sqcap K_2)^{e_\lambda} \end{array}}
}_{= \mathcal{F}(\lambda)}
+
\boxed{\begin{array}{l} e_{\pi_0} \\ \hline [\![\mathcal{F}(\lambda)]\!]^S > K_1 \\ \neg \boxed{\begin{array}{l} \\ \hline K_1 > [\![\mathcal{F}(\lambda)]\!]^S \end{array}} \\ \texttt{part-of}(e_\lambda, e_{\pi_0}) \\ e_{\pi_0} = e_\lambda \end{array}}
$$

$$
(K_1 \sqcap K_2)^{e_\lambda} = \boxed{\begin{array}{l} e_\lambda \\ \hline \texttt{eating}(e_\lambda) \\ \texttt{actor}(e_\lambda, j) \end{array}}
$$

$$
\begin{array}{|l|}
\hline
j, l, e_{\pi_1} \\
\hline
\text{John}(j) \\
\mathtt{lunch}(l) \\
\mathtt{eating}(e_{\pi_1}) \\
\mathtt{great}(e_{\pi_1}) \\
\mathtt{object}(e_{\pi_1}, l) \\
\mathtt{actor}(e_{\pi_1}, j) \\
\hline
\end{array}
+
\begin{array}{|l|}
\hline
s, e_{\pi_2}, p, e_{\pi_3}, e_\lambda \\
\hline
\mathtt{soup}(s) \\
\mathtt{eating}(e_{\pi_2}) \\
\mathtt{object}(e_{\pi_2}, s) \\
\mathtt{actor}(e_{\pi_2}, j) \\
\mathtt{pasta}(p) \\
\mathtt{eating}(e_{\pi_2}) \\
\mathtt{object}(e_{\pi_2}, s) \\
\mathtt{actor}(e_{\pi_2}, j) \\
\mathtt{part\text{-}of}(e_{\pi_2}, e_\lambda) \\
\mathtt{part\text{-}of}(e_{\pi_3}, e_\lambda) \\
\mathtt{post}(e_{\pi_2}) \approx \mathtt{pre}(e_{\pi_3}) \\
\mathtt{eating}(e_\lambda) \\
\mathtt{actor}(e_\lambda, j) \\
\hline
\end{array}
+
\begin{array}{|l|}
\hline
e_{\pi_0} \\
\hline
[\![\mathcal{F}(\lambda)]\!]^S > K_1 \\
\neg \begin{array}{|l|}
\hline
\\
\hline
K_1 > [\![\mathcal{F}(\lambda)]\!]^S \\
\hline
\end{array} \\
\mathtt{part\text{-}of}(e_\lambda, e_{\pi_0}) \\
e_{\pi_0} = e_\lambda \\
\hline
\end{array}
$$

$$
\begin{array}{|l|}\hline
j, l, e_{\pi_1} \\ \hline
\text{John}(j) \\
\texttt{lunch}(l) \\
\texttt{eating}(e_{\pi_1}) \\
\texttt{great}(e_{\pi_1}) \\
\texttt{object}(e_{\pi_1}, l) \\
\texttt{actor}(e_{\pi_1}, j) \\ \hline
\end{array}
+
\begin{array}{|l|}\hline
s, e_{\pi_2}, p, e_{\pi_3}, e_\lambda \\ \hline
\texttt{soup}(s) \\
\texttt{eating}(e_{\pi_2}) \\
\texttt{object}(e_{\pi_2}, s) \\
\texttt{actor}(e_{\pi_2}, j) \\
\texttt{pasta}(p) \\
\texttt{eating}(e_{\pi_2}) \\
\texttt{object}(e_{\pi_2}, s) \\
\texttt{actor}(e_{\pi_2}, j) \\
\texttt{part-of}(e_{\pi_2}, e_\lambda) \\
\texttt{part-of}(e_{\pi_3}, e_\lambda) \\
\texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\
\texttt{eating}(e_\lambda) \\
\texttt{actor}(e_\lambda, j) \\ \hline
\end{array}
+
\begin{array}{|l|}\hline
\\ \hline
\begin{array}{|ll|}\hline
\multicolumn{2}{|l|}{s, e_{\pi_2}, p, e_{\pi_3}, e_\lambda} \\ \hline
\texttt{soup}(s) & \texttt{object}(e_{\pi_2}, s) \\
\texttt{eating}(e_{\pi_2}) & \texttt{actor}(e_{\pi_2}, j) \\
\texttt{object}(e_{\pi_2}, s) & \texttt{part-of}(e_{\pi_2}, e_\lambda) \\
\texttt{actor}(e_{\pi_2}, j) & \texttt{part-of}(e_{\pi_3}, e_\lambda) \\
\texttt{pasta}(p) & \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\
\texttt{eating}(e_{\pi_2}) & \texttt{actor}(e_\lambda, j) \\
\texttt{eating}(e_\lambda) & \\ \hline
\end{array}
>
\begin{array}{|l|}\hline
j, l, e_{\pi_1} \\ \hline
\text{John}(j) \\
\texttt{lunch}(l) \\
\texttt{eating}(e_{\pi_1}) \\
\texttt{great}(e_{\pi_1}) \\
\texttt{object}(e_{\pi_1}, l) \\
\texttt{actor}(e_{\pi_1}, j) \\ \hline
\end{array}
\\
\neg
\begin{array}{|l|}\hline
\\ \hline
\begin{array}{|l|}\hline
j, l, e_{\pi_1} \\ \hline
\text{John}(j) \\
\texttt{lunch}(l) \\
\texttt{eating}(e_{\pi_1}) \\
\texttt{great}(e_{\pi_1}) \\
\texttt{object}(e_{\pi_1}, l) \\
\texttt{actor}(e_{\pi_1}, j) \\ \hline
\end{array}
>
\begin{array}{|ll|}\hline
\multicolumn{2}{|l|}{s, e_{\pi_2}, p, e_{\pi_3}, e_\lambda} \\ \hline
\texttt{soup}(s) & \texttt{object}(e_{\pi_2}, s) \\
\texttt{eating}(e_{\pi_2}) & \texttt{actor}(e_{\pi_2}, j) \\
\texttt{object}(e_{\pi_2}, s) & \texttt{part-of}(e_{\pi_2}, e_\lambda) \\
\texttt{actor}(e_{\pi_2}, j) & \texttt{part-of}(e_{\pi_3}, e_\lambda) \\
\texttt{pasta}(p) & \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\
\texttt{eating}(e_{\pi_2}) & \texttt{actor}(e_\lambda, j) \\
\texttt{eating}(e_\lambda) & \\ \hline
\end{array}
\\ \hline
\end{array}
\\
\texttt{part-of}(e_\lambda, e_{\pi_0}) \\
e_{\pi_0} = e_\lambda \\ \hline
\end{array}
$$

$$
\begin{array}{|l|}
\hline
j, l, e_{\pi_1}, s, e_{\pi_2}, p, e_{\pi_3}, e_{\lambda}, e_{\pi_0} \\
\hline
\begin{array}{lll}
\text{John}(j) & \mathtt{soup}(s) & \mathtt{object}(e_{\pi_2}, s) \\
\mathtt{lunch}(l) & \mathtt{eating}(e_{\pi_2}) & \mathtt{actor}(e_{\pi_2}, j) \\
\mathtt{eating}(e_{\pi_1}) & \mathtt{object}(e_{\pi_2}, s) & \mathtt{part\text{-}of}(e_{\pi_2}, e_{\lambda}) \\
\mathtt{great}(e_{\pi_1}) & \mathtt{actor}(e_{\pi_2}, j) & \mathtt{part\text{-}of}(e_{\pi_3}, e_{\lambda}) \\
\mathtt{object}(e_{\pi_1}, l) & \mathtt{pasta}(p) & \mathtt{post}(e_{\pi_2}) \approx \mathtt{pre}(e_{\pi_3}) \\
\mathtt{actor}(e_{\pi_1}, j) & \mathtt{eating}(e_{\pi_2}) & \mathtt{part\text{-}of}(e_{\lambda}, e_{\pi_0}) \\
\mathtt{eating}(e_{\lambda}) & \mathtt{actor}(e_{\lambda}, j) & e_{\pi_0} = e_{\lambda}
\end{array} \\
\begin{array}{|ll|}
\hline
s, e_{\pi_2}, p, e_{\pi_3}, e_{\lambda} & \\
\hline
\mathtt{soup}(s) & \mathtt{object}(e_{\pi_2}, s) \\
\mathtt{eating}(e_{\pi_2}) & \mathtt{actor}(e_{\pi_2}, j) \\
\mathtt{object}(e_{\pi_2}, s) & \mathtt{part\text{-}of}(e_{\pi_2}, e_{\lambda}) \\
\mathtt{actor}(e_{\pi_2}, j) & \mathtt{part\text{-}of}(e_{\pi_3}, e_{\lambda}) \\
\mathtt{pasta}(p) & \mathtt{post}(e_{\pi_2}) \approx \mathtt{pre}(e_{\pi_3}) \\
\mathtt{eating}(e_{\pi_2}) & \mathtt{actor}(e_{\lambda}, j) \\
\mathtt{eating}(e_{\lambda}) & \\
\hline
\end{array}
>
\begin{array}{|l|}
\hline
j, l, e_{\pi_1} \\
\hline
\text{John}(j) \\
\mathtt{lunch}(l) \\
\mathtt{eating}(e_{\pi_1}) \\
\mathtt{great}(e_{\pi_1}) \\
\mathtt{object}(e_{\pi_1}, l) \\
\mathtt{actor}(e_{\pi_1}, j) \\
\hline
\end{array} \\
\neg
\begin{array}{|c|}
\hline
\\
\hline
\begin{array}{|l|}
\hline
j, l, e_{\pi_1} \\
\hline
\text{John}(j) \\
\mathtt{lunch}(l) \\
\mathtt{eating}(e_{\pi_1}) \\
\mathtt{great}(e_{\pi_1}) \\
\mathtt{object}(e_{\pi_1}, l) \\
\mathtt{actor}(e_{\pi_1}, j) \\
\hline
\end{array}
>
\begin{array}{|ll|}
\hline
s, e_{\pi_2}, p, e_{\pi_3}, e_{\lambda} & \\
\hline
\mathtt{soup}(s) & \mathtt{object}(e_{\pi_2}, s) \\
\mathtt{eating}(e_{\pi_2}) & \mathtt{actor}(e_{\pi_2}, j) \\
\mathtt{object}(e_{\pi_2}, s) & \mathtt{part\text{-}of}(e_{\pi_2}, e_{\lambda}) \\
\mathtt{actor}(e_{\pi_2}, j) & \mathtt{part\text{-}of}(e_{\pi_3}, e_{\lambda}) \\
\mathtt{pasta}(p) & \mathtt{post}(e_{\pi_2}) \approx \mathtt{pre}(e_{\pi_3}) \\
\mathtt{eating}(e_{\pi_2}) & \mathtt{actor}(e_{\lambda}, j) \\
\mathtt{eating}(e_{\lambda}) & \\
\hline
\end{array} \\
\hline
\end{array} \\
\hline
\end{array}
$$

$$
\begin{array}{|l|}
\hline
j, l, e_{\pi_1}, s, e_{\pi_2}, p, e_{\pi_3}, e_\lambda, e_{\pi_0} \\
\hline
\begin{array}{lll}
\text{John}(j) & \texttt{soup}(s) & \texttt{object}(e_{\pi_2}, s) \\
\texttt{lunch}(l) & \texttt{eating}(e_{\pi_2}) & \texttt{actor}(e_{\pi_2}, j) \\
\texttt{eating}(e_{\pi_1}) & \texttt{object}(e_{\pi_2}, s) & \texttt{part-of}(e_{\pi_2}, e_\lambda) \\
\texttt{great}(e_{\pi_1}) & \texttt{actor}(e_{\pi_2}, j) & \texttt{part-of}(e_{\pi_3}, e_\lambda) \\
\texttt{object}(e_{\pi_1}, l) & \texttt{pasta}(p) & \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\
\texttt{actor}(e_{\pi_1}, j) & \texttt{eating}(e_{\pi_2}) & \texttt{part-of}(e_\lambda, e_{\pi_0}) \\
\texttt{eating}(e_\lambda) & \texttt{actor}(e_\lambda, j) & e_{\pi_0} = e_\lambda
\end{array} \\
\begin{array}{|ll|}
\hline
\multicolumn{2}{|l|}{s, e_{\pi_2}, p, e_{\pi_3}, e_\lambda} \\
\hline
\texttt{soup}(s) & \texttt{object}(e_{\pi_2}, s) \\
\texttt{eating}(e_{\pi_2}) & \texttt{actor}(e_{\pi_2}, j) \\
\texttt{object}(e_{\pi_2}, s) & \texttt{part-of}(e_{\pi_2}, e_\lambda) \\
\texttt{actor}(e_{\pi_2}, j) & \texttt{part-of}(e_{\pi_3}, e_\lambda) \\
\texttt{pasta}(p) & \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\
\texttt{eating}(e_{\pi_2}) & \texttt{actor}(e_\lambda, j) \\
\texttt{eating}(e_\lambda) & \\
\hline
\end{array}
>
\begin{array}{|l|}
\hline
j, l, e_{\pi_1} \\
\hline
\text{John}(j) \\
\texttt{lunch}(l) \\
\texttt{eating}(e_{\pi_1}) \\
\texttt{great}(e_{\pi_1}) \\
\texttt{object}(e_{\pi_1}, l) \\
\texttt{actor}(e_{\pi_1}, j) \\
\hline
\end{array} \\
\neg
\begin{array}{|c|}
\hline
\\
\hline
\begin{array}{|l|}
\hline
j, l, e_{\pi_1} \\
\hline
\text{John}(j) \\
\texttt{lunch}(l) \\
\texttt{eating}(e_{\pi_1}) \\
\texttt{great}(e_{\pi_1}) \\
\texttt{object}(e_{\pi_1}, l) \\
\texttt{actor}(e_{\pi_1}, j) \\
\hline
\end{array}
>
\begin{array}{|ll|}
\hline
\multicolumn{2}{|l|}{s, e_{\pi_2}, p, e_{\pi_3}, e_\lambda} \\
\hline
\texttt{soup}(s) & \texttt{object}(e_{\pi_2}, s) \\
\texttt{eating}(e_{\pi_2}) & \texttt{actor}(e_{\pi_2}, j) \\
\texttt{object}(e_{\pi_2}, s) & \texttt{part-of}(e_{\pi_2}, e_\lambda) \\
\texttt{actor}(e_{\pi_2}, j) & \texttt{part-of}(e_{\pi_3}, e_\lambda) \\
\texttt{pasta}(p) & \texttt{post}(e_{\pi_2}) \approx \texttt{pre}(e_{\pi_3}) \\
\texttt{eating}(e_{\pi_2}) & \texttt{actor}(e_\lambda, j) \\
\texttt{eating}(e_\lambda) & \\
\hline
\end{array} \\
\hline
\end{array} \\
\hline
\end{array}
$$

(24)

π_1 : John had a great lunch .

π_2 : He ate soup.

π_3 : Then he ate pasta.