Temporal prepositional phrases and implicit variables

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1 Introduction

- Some challenging properties of temporal modification (Pratt and Francez, 2001; von Stechow, 2002; Beaver and Condoravdi, 2007):

  1. A temporal modifier can depend on another one for its interpretation.

     (1) a. Last year / Two years ago / In most years, it rained *in July.*
     b. Last year / Two years ago / In most years, it rained *every day.*
     c. Yesterday / On most days, it rained *in the afternoon.*

  2. Such temporal dependencies are sensitive to hierarchical structure:

     (2) a. ?*In July* / ?*Every day*, it rained last year.
     b. It rained *every day* last year.

  3. They can be iterated (what Pratt and Francez (2001) call "cascades"):

     (3) a. Wolfgang hat während des letzten Sommers in keinem Monat an jedem Sonntag Tennis gespielt. (von Stechow, 2002)
     b. Last summer, in no month did Wolfgang play tennis every Sunday.

- von Stechow (2002) gives a movement-based account of such dependencies:

(4) [Last summer] λi [[no month (within) t_i] λj [every Sunday (within) t_j] λk [Wolfgang played (within) t_k]].

> "The thesis defended in this article is that only one tPP is adjoined to the VP. A quantifier embedded in a PP must be QRed and be adjoined to the VP at LF, in German even at S-structure." (von Stechow, 2002)

- He reacts to an earlier account by Pratt and Francez (2001) where these dependencies are expressed semantically and there is no movement:

(5) a. ⟦Wolfgang play tennis on every Sunday⟧ = λI.every Sunday within I contains a tennis-playing event by Wolfgang
b. ⟦in no month⟧ = $\lambda P \lambda J$. no month within J contains a P-interval
c. ⟦(3b)⟧ = no month within last summer contains an interval within which every Sunday contains a tennis-playing event by Wolfgang

- Stechow objects to Pratt and Francez (2001) because it is "too local" – its system doesn't model long-distance temporal dependencies.
- Like wh-movement, temporal dependencies can be long-distance:

(6) a. Last year^{i}, I think we went to France in August$_{i}$.
b. When^{i} do you think we went to France t$_{i}$?

- As von Stechow (2002) notes, attitude-verb dependencies are also long-distance:

(7) I saw Mary in New York before$^{i/j}$ she claimed$_{i}$ that she would arrive$_{j}$. (Geis, 1970)

(8) John arrived when$^{i/j}$ Harry told$_{i}$ Mary that she should$_{j}$ leave. (Larson, 1990)

- It is well known that attitude-verb dependencies are subject to island constraints:

(9) I saw Mary in New York before$^{i/*j}$ she made the claim$_{i}$ that she would arrive$_{j}$. (Geis, 1970)

(10) John arrived when$^{i/*j}$ Harry told$_{i}$ Mary about his desire that she should leave$_{j}$. (Larson, 1990)

- So von Stechow (2002) analyzes all temporal dependencies as movement-based.
- On the face of it, an additional argument for a movement-based account is that it explains asymmetries like (11): movement always goes up and never down.

(11) a. [Every year]$_{i}$, it rains in July t$_{i}$.
b. *In July t_i, it rains [every year]$_{i}$.

2 This talk

- Most temporal dependencies can **not** be reduced to movement.
- The ones that matter to Pratt and Francez (2001) should be analyzed as implicit variables (or perhaps as domain restrictions), not as movement traces.

3 Temporal dependencies are not movement

From now on, I explicitly set aside attitude-verb dependencies. We have seen that these are subject to island constraints. Pratt and Francez (2001) do not discuss them and von Stechow (2002) only mentions them to make the case for long-distance dependencies.

3.1 Island violations

Temporal dependencies can occur across islands

- Because-clauses

(12) Every year, John got anxious because he needed to file taxes in April.

(13) *In what month did John get anxious this March because he needed to file taxes?

- Relative clauses

(14) Every year, some guy who needs to file taxes in April gets anxious in March.

(15) *In what month did some guy who needs to file taxes get anxious in March?

- *If*-questions

(16) Last year, I wonder if John went to France in August or in September.

(17) *When do you wonder if John went to France?

- Sentential subjects

(18) On most days, that it rains in the afternoon is a good possibility.

(19) *On which days is that it rains a good possibility?

Conclusion: At least some temporal dependencies are not movement because they systematically violate island constraints.

4 Temporal dependencies are pronoun-like

I use the coindexation that is common in dynamic semantics: antecedents have superscripts, anaphoric/bound elements have subscripts.

4.1 Quantificational binding

Quantificational binding typically involves a quantifier that c-commands a pronoun:

(20) [Every man]^i thinks he$_i$ is smart.

But other binders and bindees are also possible:

- Binding of implicit variables (Dowty, 1981; Mitchell, 1986; Partee, 1989):

(21) [Every man]^i is worried that his wife will call$_i$ while his mistress is visiting$_i$. (Dowty, 1981)

(22) [Every sports fan in the country]^i was at a local$_i$ bar watching the payoffs. (Mitchell, 1986)

(23) [Every participant]^i had to confront and defeat an enemy$_i$. (Partee, 1989)

- Binding of implicit variables by temporal antecedents:

(24) [In most years]^i, I passed the exam$_i$.

- Binding of domain restrictions (of quantifiers and definites):

(25) [Only one class]^i was so bad that no student$_i$ passed the exam$_i$. (Heim, 1991)

- Binding of domain restrictions (of quantifiers and definites) by temporal antecedents:

(26) [Last year]^i, [on most days$_i$]^j it rained in the afternoon$_j$. (Beaver and Condoravdi, 2007)

- The temporal cascades of interest to us can of course be seen as an instance of this pattern:

(27) a. Wolfgang hat [während des letzten Sommers]^i [in keinem Monat$_i$]^j an jedem Sonntag$_j$ Tennis gespielt. (von Stechow, 2002)

Summary: Both regular and temporal quantificational antecedents can bind implicit variables and domain restrictions.

4.2 Binding out of DP

Binding out of DP is one configuration where the binder doesn't c-command the pronoun:

(28) [Every boy]^i's mother likes him$_i$.

It also occurs in the temporal domain:

(29) [Every leap year]^i's leap day falls on [February 29th]$_i$.

4.3 Donkey readings

Donkey readings involve quantificational binding from the antecedent into the consequent of a conditional, or from the restrictor into the nuclear scope of a strong quantifier. Like binding out of DP, the binder doesn't c-command the pronoun.

(30) a. If/Whenever [a man]^i owns [a donkey]^j, he$_i$ beats it$_j$.
b. Every man who owns [a donkey]^j beats it$_j$.

Donkey readings have been observed with all kinds of silent anaphoric elements:

- Donkey tense:

(31) Whenever Ann looked, Ben was dancing.[1]

- Donkey implicit variables:

(32) If a farmer has a wife, he should make sure he calls _ when he is traveling. (Dowty, 1981)

- Donkeys in the temporal domain:

[1] Jonathan Schaffer, Necessitarian Propositions, forthcoming in *Synthese*. Does anyone know an earlier reference?

(33) a. Whenever Arnim spends a week in the mountains, he hikes every day.
b. If a linguist spends a week in the mountains, he hikes every day.
c. Every linguist who spends a week in the mountains hikes every day.

4.4 Weak crossover

If a wh-phrase or quantifier is raised across a pronoun, it cannot bind it:

(34) a. Who^i t$_i$ likes his$_i$ mother?
b. *Who^i does his$_i$ mother like t$_i$?

- The asymmetry data from above can be reanalyzed as weak crossover:

(35) a. Every year, it rains in July.
b. *In July, it rains every year.

(36) a. [Every year]^i, it rains in July$_i$.
b. *[Every year]^i In July$_i$, it rains t$_i$.

4.5 Intersentential binding by indefinites

4.5.1 The standard case

(37) A man walks in the park. He whistles.

(38) This year Arnim spent a month in France. He hiked every day.

4.5.2 Quantificational subordination

(39) Most books contain a table of contents. In some, it is at the end.
(Heim, 1990)

(40) Every year, Arnim spends a week in the mountains. In some years, he hikes every day.

4.5.3 Modal subordination

(41) A wolf might come in. It would eat you first.
(Groenendijk and Stokhof, 1991)

(42) Arnim might spend the next summer in the mountains. He would hike every day.

4.6 Paycheck readings

Paycheck readings arise when an expression picks up an entity x and a function f, and denotes $f(x)$.

- The classical example involves binding of paycheck pronouns:

(43) The man who^i gave [his$_i$ paycheck]^f to his wife was wiser than the one who^j gave **it**$_{f(j)}$ to his mistress.
($f = \lambda x.x$'s paycheck; $j =$ the second man) (Karttunen, 1969)

- The functional anaphora can span sentences, just like regular anaphora:

(44) [The wise man]^i gave [his$_i$ paycheck]^f to his wife. The foolish one^j gave **it**$_{f(j)}$ to his mistress.

- Paycheck readings have also been observed with implicit variables:

(45) [Every good father]^i visits [his$_i$ daughter]^f on her birthday. Bill's a deadbeat dad, so he^j only calls$_{f(j)}$.
($f = \lambda x.x$'s daughter; $j =$ Bill) (Dowty, 1981)

(46) [Every Englishman]^i loves [his$_i$ daughter]^f but [every American]^j loves someone else$_{f(j)}$.
(Culicover and Jackendoff, 1995)

- We can also observe them in the temporal domain:

(47) a. [This year]^i I did my taxes in [March$_i$]^f. **That**$_{f(j)}$'s also when I did them last year^j.
b. [This year]^i I did my taxes in [March$_i$]^f. Last year^j, I also did them **then**$_{f(j)}$.
($f = \lambda I.$the March in I; $j =$ last year)

Section summary: Temporal dependencies give rise to the same kinds of readings as dependencies between pronouns and their antecedents.

5 Pratt and Francez (2001)

- P&F argue that both sentence meanings and tPPs must incorporate a temporal context variable:

(48) $[\![\text{Mary kiss John}]\!] = \lambda I \exists e[\text{kiss}(m, j, e) \wedge \tau(e) \subseteq I]$[2]

- Here, I can be thought of as the Reichenbachian reference time, while $\tau(e)$ is the event time.

(49) $[\![\text{every meeting}]\!] = \lambda P \lambda I \forall x[\text{meeting}(x) \wedge \tau(x) \subseteq I \rightarrow P(x)]$

- Prepositions are defined in a way that they can take arguments of the type of (49), i.e. temporal quantifiers are interpreted in situ:

(50) $[\![\text{during}]\!] = \lambda Q_{\langle et\rangle\langle i\langle et\rangle\rangle} \lambda P_{et} \lambda I_i[Q(\lambda y[P(\tau(y))])(I)$

(51) $[\![\text{during}]\!]([\![\text{every meeting}]\!]) = \lambda P \lambda I \forall y[\text{meeting}(y) \wedge \tau(y) \subseteq (I) \rightarrow P(\tau(y))]$

- *before* and *after* are of the same type as *during.*
- To be able to apply *during every meeting* (type $\langle et, it\rangle$) to *Mary kiss John* (type it), P&F assume that times are a subset of individuals (i is a subtype of e).

(52) $[\![\text{during every meeting}]\!]([\![\text{Mary kiss John}]\!])$
$= \lambda I \forall y[\text{meeting}(y) \wedge \tau(y) \subseteq I \rightarrow \exists e[\text{kiss}(m, j, e) \wedge \tau(e) \subseteq I]$

If we add another tPP, it binds the context variable: below, the meetings all have to lie on the Monday.

(53) On a Monday, Mary kiss John during every meeting.

(54) $[\![\text{on a Monday}]\!]([\![\text{Mary kiss John during every meeting}]\!])$
$= \lambda I \exists z[\text{Monday}(z) \wedge z \subseteq I \wedge$
$\forall y[\text{meeting}(y) \wedge \tau(y) \subseteq \tau(z) \rightarrow$
$\exists e[\text{kiss}(m, j, e) \wedge \tau(e) \subseteq \tau(y)]]]$

If instead, we apply (referential) past tense, the meetings all have to lie in the past:

(55) Mary kissed John during every meeting.

(56) $[\![\text{PAST}_1]\!]([\![\text{Mary kiss John during every meeting}]\!])$
$= \forall y[\text{meeting}(y) \wedge \tau(y) \subseteq \text{PAST}_1 \rightarrow \exists e[\text{kiss}(m, j, e) \wedge \tau(e) \subseteq \text{PAST}_1]]$

As noted by von Stechow (2002), the context variable resolves the scope paradox in Ogihara (1994): although PAST takes scope over *every meeting*, it still enters its restrictor.

[2]This is what P&F call the "finalized" meaning of the sentence. Finalization existentially binds the event quantifier.

This system can correctly model cascades like *Last summer, in no month did Wolfgang play tennis every Sunday.*

6 Drawbacks of P&F

Von Stechow (2002) accepts P&F's claim that temporal quantifiers have a time variable, but he criticizes it for the following reasons:

- The system does not give sentences like *John was in Boston today* the right meaning.
- The meaning of *during*, *before*, and *after* is very unintuitive. They should instead express simple relations between times: $[\![\text{during}]\!] = \lambda I \lambda J. I \subseteq J$ for example.
- Since temporal quantifiers are interpreted in situ, there is no way to express long-distance dependencies.

  To these criticisms we can add that the system is not very elegant in its handling of time variables. The meaning of *every meeting* is derived from its constituents via an ad hoc rule called Pseudo Application One, which "suspends" the time variable so that function application can take place.

(57) a. $[\![\text{every}]\!] = \lambda P'_{et} \lambda P_{et} \forall x[P'(x) \rightarrow P(x)]$
b. $[\![\text{meeting}]\!] = \lambda x_e \lambda I_i[\text{meeting}(x) \wedge \tau(x) \subseteq I]$
c. $[\![\text{every meeting}]\!] = \lambda P \lambda I \forall x[\text{meeting}(x) \wedge \tau(x) \subseteq I \rightarrow P(x)]$

7 Fixing the drawbacks

Since most temporal dependencies are not movement-based, I will revert to the system P&F, but improve on it.

7.1 John was in Boston today

- I think this type of sentence can in fact be handled by P&F (who don't discuss it). The trick is to analyze *today* as something like *during today.*

(58) [PAST$_1$ [today [John be in Boston]]].

(59) a. $[\![\text{John be in Boston}]\!] = \lambda I \exists e[\text{be-in}(j, b, e) \wedge \tau(e) \subseteq I]$[3]
b. $[\![\text{today}]\!] = \lambda V_{it} \lambda I[I \subseteq \text{today} \wedge V(I)]$

[3] Again, this is the finalized meaning (see previous footnote).

c. $[\![\text{PAST}_1]\!]([\![\text{today}]\!]([\![\text{John be in Boston}]\!]))$
$= \text{PAST}_1 \subseteq \text{today} \wedge \exists e[\text{be-in}(j, b, e) \wedge \tau(e) \subseteq \text{PAST}_1]$

- Analyzing *today* as *during today* is against the advice of von Stechow (2002), who writes:

> Clearly we want to analyse adverbs like *today* as truncated tPPs meaning 't is on the actual day' or 't is throughout the actual day'. This is in fact what has always been done in the literature.

- I don't see any reason to prefer an analysis of *today* as *throughout today.* If we want it, we need to pass the event (time) up as an additional contextual variable:

(60) a. $[\![\text{John be in Boston}]\!] = \lambda I \lambda e[\text{be-in}(j, b, e) \wedge \tau(e) \subseteq I]$

- I won't pursue this idea here. Are there any arguments that temporal modifiers or tense need access to the event (or event time) as opposed to the reference time?

7.2 *Before, during, after*

- Let's fix $[\![\text{during}]\!] = \lambda x \lambda y[y \subseteq x]$ as recommended in von Stechow (2002).
- With Stechow, we assume that x can be of type e or i. By convention, we extend τ (runtime) so that it also applies to intervals. In that case, we set $\tau(I) = (I)$ for any interval I.
- This means we can think of *during* as type-polymorphic on its first argument:

(61) $[\![\text{during}]\!] = \lambda x_\alpha \lambda J_i[J \subseteq \tau(x)]$, where $\alpha \in \{e, i\}$

- Evidence comes from the synonymity of *during the meeting* and *during the time of the meeting.*
- *Before* and *after* are treated similarly:

(62) a. $[\![\text{before}]\!] = \lambda x_\alpha \lambda J_i[J < \tau(x)]$, where $\alpha \in \{e, i\}$
b. $[\![\text{after}]\!] = \lambda x_\alpha \lambda J_i[J > \tau(x)]$, where $\alpha \in \{e, i\}$

- I assume a silent adverbial *[some time]* that introduces an existential quantifier and provides a slot for the sentence radical:

(63) a. $[\![\text{[some time]}]\!] = \lambda R_{\langle\alpha,it\rangle} \lambda x_\alpha \lambda S_{it} \exists J_i[S(J) \wedge R(J)(x)]$
b. $[\![\text{[some time] during}]\!] = \lambda x_\alpha \lambda V_{it} \exists J_i[V(J) \wedge J \subseteq \tau(x)]$

c. $[\![$[some time] before$]\!] = \lambda x_\alpha \lambda S_{it} \exists J_i[S(J) \wedge J < \tau(x)]$
d. $[\![$[some time] after$]\!] = \lambda x_\alpha \lambda S_{it} \exists J_i[S(J) \wedge J < \tau(x)]$

- This makes sense when you consider that *during* has the same distribution as *before*. *before* needs a slot for such an adverbial: (64a) is synonymous to (64b), and *before* needs to handle both of them as well as (65).

(64) a. Mary kissed John before the meeting.
b. Mary kissed John some time before the meeting.

(65) Mary kissed John three hours before the meeting.

- This is similar to the optionality of differentials in comparatives:

(66) John is { taller / (by) some extent taller / (by) 3cm taller } than Mary.

(67) The kiss was { earlier / some time earlier / three hours earlier } than the meeting.

- I assume the same meaning as P&F and Stechow for sentence radicals (this is compatible with Stechow's assumption that $\subseteq$ is introduced by aspect):

(68) $[\![\text{Mary kiss John}]\!] = \lambda I \exists e[\text{kiss}(m, j, e) \wedge \tau(e) \subseteq I]$

- If we disregard tense, we can already form simple sentences:

(69) a. Mary kissed John before noon.
b. [[Mary kiss John] [[some time] [before noon]]]
c. $[\![\text{noon}]\!] = \text{noon}$ *to be revised*
d. $[\![$[some time] before noon$]\!] = \lambda S_{it} \exists J_i[S(J) \wedge J < \text{noon}]$
e. $[\![$Mary kiss John some time before noon$]\!]$
$= \exists J < \text{noon}\ \exists e[\text{kiss}(m, j, e) \wedge \tau(e) \subseteq J]$

- For quantified tPPs, we could use QR as in von Stechow (2002). But to stay closer to P&F, let us instead use argument raising (Hendriks, 1993):

(70) a. $[\![$[some time] before$]\!] = \lambda x_\alpha \lambda S_{it} \exists J_i[S(J) \wedge J < \tau(x)]$
b. $[\![$AR([some time] before)$]\!] = \lambda Q_{\alpha t,t} \lambda S_{it} Q(\lambda x_\alpha \exists J_i[S(J) \wedge J < \tau(x)])$
c. $[\![$every meeting$]\!] = \lambda S_{it} \forall x[\text{meeting}(x) \rightarrow S(\tau(x))]$ *(to be revised)*
d. $[\![$AR([some time] before)$]\!]([\![$every meeting$]\!])$
$= \lambda S_{it} \forall x[\text{meeting}(x) \rightarrow \exists J_i[S(J) \wedge J < \tau(x)])$

- I will suppress the silent [some time] in the notation from now on.

7.3 Contextualization without pseudo application

- Now let's contextualize the complement of *before*:

(71) $[\![\text{noon}]\!] = \lambda I[\text{the-noon-of}(I)]$
(type *ii*)

(72) $[\![\text{every meeting}]\!] = \lambda I \lambda S_{it} \forall x[\text{meeting}(x) \wedge \tau(x) \subseteq I \rightarrow S(\tau(x))]$
(type $\langle i, \langle it, t\rangle\rangle$)

- The λI slot should be bound by the next highest temporal antecedent: tense or a tPP.

(73) PAST^i Mary kiss John before noon$_i$.

(74) PAST^i [On every Sunday$_i$]^j, Mary kiss John before noon$_j$.

- We want to combine *every meeting* with *some time before*, then with *Mary kiss John*, and get the λI on the outside so it can be bound by tense or another tPP:

(75) $[\![\text{Mary kiss John before every meeting}]\!]$
$= \lambda I \exists J < \text{noon}(I)\ \exists e[\text{kiss}(m, j, e) \wedge \tau(e) \subseteq J]$

- But of course, the entries we have lead to type mismatches: α can only be e or i, otherwise we can't meaningfully apply τ to it.

(76) $[\![\text{before}]\!] = \lambda x_\alpha \lambda S_{it} \exists J_i[S(J) \wedge J < \tau(x)]$
(expects an arg of type e or i, but *noon* is of type $\langle ii\rangle$)

(77) $[\![\text{AR(before)}]\!] = \lambda Q_{\alpha t,t} \lambda S_{it} Q(\lambda x_\alpha \exists J_i[S(J) \wedge J < \tau(x)])$
(expects an arg of type $\langle et, t\rangle$ or $\langle it, t\rangle$, but *every meeting* is $\langle i, \langle it, t\rangle\rangle$)

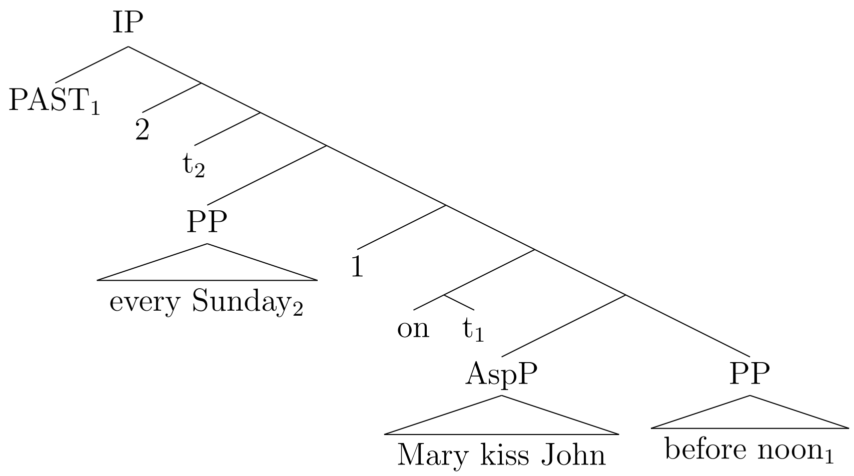
- P&F have solved this mismatch using an ad hoc rule of Pseudo Application. We want a principled solution.
- We have seen above that temporal dependencies are anaphoric.
- So let's use a framework which has been developed specifically for anaphoric relations.

8 Cooper/Heim & Kratzer

- Heim and Kratzer (1998) handles pronoun binding through variable assignments.

- We would say that *Sunday* and *noon* are anaphoric elements.
- tPPs and tense are binders.

(78) On every Sunday, Mary kissed John before noon.



- We need string-vacuous movement of every binder in order to be able to bind anaphoric elements, as known from sentences like *Every woman blamed herself* – (Heim and Kratzer, 1998, p. 201)
- I will not pursue this line here since there is another approach which keeps the system more similar to P&F.

9 Variable-free semantics (VFS)

9.1 VFS basic idea

- VFS (Jacobson, 1999) represents anaphoric elements as functions:

(79) a. $[\![\text{he/she/it}]\!] = \lambda x.x$
b. $[\![\text{his paycheck}]\!] = \lambda x.x$'s paycheck

- The meaning of an anaphoric element is a function from the type of its referent to the type of its referent.
- The meaning of a larger constituent C that contains an unbound anaphoric element E is a function from the type of E's referent to the type that C would have if it didn't contain E.

(80) a. $[\![\text{John loves Mary}]\!] = \text{love(john, mary)}$ (type t)
b. $[\![\text{John loves her}]\!] = \lambda x[\text{love(john}, x)]$ (type e, t)
c. $[\![\text{John thinks everyone loves her}]\!] = \lambda x[\text{think(john}, \forall y[\text{love}(y, x)])]$ (type e, t)
d. $[\![\text{He loves her}]\!] = \lambda y \lambda x[\text{love}(x, y)]$ (type e, et)

- A generalized Geach (function composition) rule called $\mathbf{g}_c$ passes up an anaphoric dependence of type c:

(81) $[\![\text{John thinks everyone loves her}]\!]$
$= [\![\text{g}_e(\text{John})(\text{g}_e(\text{thinks})(\text{g}_e(\text{everyone})((\text{g}_e(\text{loves}))(\text{her}))))]\!]$
$= \lambda x[\text{think(john}, \forall y[\text{love}(y, x)])]$

- Informally: g_c tells a function f that its argument has one more lambda slot than expected, namely one of type c. It passes the slot upwards.
- Formally: If f is a function of type $\langle a, b\rangle$ then $\mathbf{g}_c$(f) is the function $\lambda V_{ca} \lambda C_c[f(V(C))]$, whose type is $\langle\langle c, a\rangle, \langle c, b\rangle\rangle$.
- Some examples:

(82) a. $[\![\text{love}]\!] = \lambda y \lambda x[\text{love}(x, y)]$
b. $[\![\mathbf{g}_e(\text{love})]\!] = \lambda y_{ee} \lambda z_e \lambda x_e[\text{love}(y(z), x)]$

(83) a. $[\![\text{John}]\!] = \lambda P_{et}[P(\text{john})]$
b. $[\![\mathbf{g}_e(\text{John})]\!] = \lambda P_{e,et} \lambda z[P(z)(\text{john})]$

(84) a. $[\![\text{think}]\!] = \lambda p_t \lambda x[\text{think}(x, p)]$
b. $[\![\mathbf{g}_e(\text{think})]\!] = \lambda p_{et} \lambda z \lambda x[\text{think}(x, p(z))]$

9.2 Application to contextualization

- Jacobson's $\mathbf{g}_c$ provides the principled solution for the type mismatches:

(85) $[\![\text{before}]\!] = \lambda x_\alpha \lambda S_{it} \exists J_i[S(J) \wedge J < \tau(x)]$
(expects an arg of type e or i, but *noon* is of type $\langle ii\rangle$)

- $\mathbf{g}_I$ tells a function f that its argument has one more lambda slot than expected, namely one of type I.

(86) $[\![\mathbf{g}_I(\text{before})]\!] = \lambda x_{\langle I\alpha\rangle} \lambda I \lambda S_{it} \exists J_i[S(J) \wedge J < \tau(x(I))]$
(expects an arg of type $\langle ie\rangle$ or $\langle ii\rangle$)

(87) $[\![\mathbf{g}_I(\text{AR(before)})]\!] = \lambda Q_{\langle I,\langle \alpha t,t\rangle\rangle} \lambda I \lambda S_{it} Q(I)(\lambda x_\alpha \exists J_i[S(J) \wedge J < \tau(x)])$
(expects an arg of type $\langle i, \langle et, t\rangle\rangle$ or $\langle i, \langle it, t\rangle\rangle$)

(88) $[\![\mathbf{g}_I(\text{before})]\!]([\![\text{noon}]\!])$
$= \lambda I \lambda S_{it} \exists J_i[S(J) \wedge J < \tau(\text{the-noon-of}(I))]$

(89) $[\![\mathbf{g}_I(\text{AR(before)})]\!]([\![\text{every meeting}]\!])$
$= \lambda I \lambda S_{it} \forall x[\text{meeting}(x) \wedge \tau(x) \subseteq I \rightarrow \exists J_i[S(J) \wedge J < \tau(x)]]$

- To apply a tPP to a sentence radical S (of type it) such as *Mary kiss John*, we first lift S so that it takes the tPP as an argument:

(90) $[\![\text{Mary kiss John}]\!] = \lambda I \exists e[\text{kiss}(m, j, e) \wedge \tau(e) \subseteq I]$
Shorthand: λIMary-kiss-John-within(I)

(91) $[\![\textbf{lift}([\![\text{Mary kiss John}]\!])]\!] = \lambda R_{\langle i,it\rangle}[R(\lambda I.\text{Mary-kiss-John-within}(I))]$

- This lifting is necessary because $\mathbf{g}_I$ only applies to functions. We could avoid it by generalizing $\mathbf{g}_I$ so that it also applies to arguments (see Jacobson (1999)).
- Then we tell S via $\mathbf{g}_I$ that the tPP has one more lambda slot than expected:

(92) $[\![\mathbf{g}_I(\textbf{lift}([\![\text{Mary kiss John}]\!]))]\!] = \lambda R_{\langle i,\langle i,it\rangle\rangle} \lambda J_i[R(J)(\lambda I.\text{Mary-kiss-John-within}(I))]$

- We can now apply this to any contextualized tPP:

(93) $[\![(92)]\!]([\![(88)]\!])$ ("Mary kiss John before noon")
$= \lambda I \exists J[\text{Mary-kiss-John-within}(J) \wedge J < \tau(\text{the-noon-of}(I))]$

(94) $[\![(92)]\!]([\![(89)]\!])$ ("Mary kiss John before every meeting")
$= \lambda I \forall x[\text{meeting}(x) \wedge \tau(x) \subseteq I \rightarrow \exists J[\text{Mary-kiss-John-within}(J) \wedge J < \tau(x)]]$

- We can now apply referential tense, or apply another tPP in the same way.

10 Summary and Outlook

10.1 Results

- Temporal dependencies in cascaded tPPs are anaphoric, not movement-based.
- The surface-close, semantics-oriented account of P&F can be modified to take the remarks of von Stechow (2002) into account.
- The ad hoc mechanisms of P&F can be replaced by the same operator that also handles anaphoric dependencies in variable-free semantics.

10.2 To do

- An account of paycheck dependencies: VFS is well designed for that.
- Intersentential and donkey anaphora perhaps also along the lines of VFS.
- Connections with existing accounts of domain restrictions (e.g. von Fintel, 1994)
- Do we need to pass on the tense variable to the sentence radical?

(95) Mary called John after every meeting.

- In (95), does Mary's last call have to be in the past?

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