ON THE LOGIC OF VERBAL MODIFICATION

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Abstract: We describe Linking Semantics, providing a uniform compositional analysis of argument-dropping inferences, quantifier scope, and temporal modification.

1. Introduction and principal definitions

A Montagovian verb chomps through a set menu of arguments in a set order. Neo-Davidsonian verbs eat *à la carte*, selecting variable numbers of arguments and adjuncts in varying orders. But existing neo-Montagovian and neo-Davidsonian approaches do not exhaust the space of possible analyses of modification, and we present an alternative.[1]

We define the meaning of a verb in terms of the roles specified by expressions the verb combines with. We use partial assignment functions, which act like Davidsonian events: they link the verb to its arguments and modifiers. A verb meaning is a *linking structure*, a function from assignments to truth values. In fact all verbal projections, including sentences, denote *linking structures*, while arguments and modifiers are uniformly functions from linking structures to linking structures.

Let L range over linking structures, f, g over role assignments, and x over individuals, which include times and worlds. We use the following notation for talking about assignments: (i) $g =_{\mathrm{R}} f$ means that g differs from f at most with respect to the value it gives to role R, (ii) $f + [\mathrm{R}, x]$ is defined when f does not have role R in its domain, and in this case denotes the assignment like f except additionally mapping R to x, and (iii) $f[\mathrm{R}, x]$ is defined when f does have role R in its domain, and denotes the assignment like f except mapping R to x.

We use roles like "ARG1" and "ARG2": these are to be understood in terms of surface syntax, so ARG1 (typically called a subject) is the argument that is canonically

[1] As regards Montague Grammar, see, of course, Montague (1973). Relevant developments are in Dowty (1979a; 1979b), and developments specific to §4 are in Pratt and Francez (2001) and von Stechow (2002). For Davidsonian Event Semantics, the original proposals of Davidson (1980) and Castañeda (1967) have been developed in many directions, e.g. Kratzer (2003), Krifka (1992; 1989), Parsons (1990), Pietroski (2006), Schein (1993), and the Rothstein (1998) collection. Our event-free variant of Davidsonian Event Semantics is foreshadowed by proposals of McConnell-Ginet (1982) and Landman (2000:§3.4.3).

realized to the left of a verb in English, and ARG2 is the argument that is typically called a direct object. For any verb V, a set of canonical arguments is given by C(V), thus $\{$T(IME), W(ORLD), ARG1$\}$ for an intransitive verb, $\{$T, W, ARG1, ARG2$\}$ for a transitive verb, and e.g. $\{$T, W, ARG1, ARG2, ILOC$\}$ for *put* (where ILOC means *internal location*). Nominal predicates have the standard $\langle e, t\rangle$ type, and determiners also have their standard $\langle\langle e, t\rangle, \langle\langle e, t\rangle, t\rangle\rangle$ meanings. We assume that syntactic role labels act on DP meanings to produce verbal modifier meanings.

We allow role labels to act on DPs in two ways depending on whether the role is taken to saturate an argument position (1), or not (2). A saturating role, such as ARG1, forms a modifier which maps a set of assignment functions to a new set that is no longer defined on that role: this prevents a verb from combining with two subjects. Non-saturating modification is discussed in §4.

(1) $[\![\text{DP:SROLE}]\!]_M \;=\; \lambda L \lambda f[[\![\text{DP}]\!]_M^{f(\text{W}),f(\text{T})}(\lambda x L(f + [\text{SROLE}, x])))$

(2) $[\![\text{DP:NROLE}]\!]_M \;=\; \lambda L \lambda f[[\![\text{DP}]\!]_M^{f(\text{W}),f(\text{T})}(\lambda x L(f[\text{NROLE}, x]))]$

Here, we take prepositions to contribute nothing more than the identity of the role, and for purposes of this paper we will simple assume that $[\![\text{P DP}]\!]_M = [\![\text{DP:P}]\!]_M$.

We now define truth with respect to a model (taking $[\text{W}, w; \text{T}, t]$ to be an assignment mapping role W to w and T to t), and entailment:

(3) $M, w \models S$ iff $\exists t [\![S]\!]_M([\text{W}, w; \text{T}, t])$

(4) $\phi \models \psi$ iff $\forall M, w \;\; M, w \models \phi \;\; \rightarrow \;\; M, w \models \psi$

Linking Semantics depends on two further axioms. The argument reduction axiom (5) has the effect that missing optional arguments act as if existentially closed. The temporal closure axiom (6) implies that something which happens during an interval can also be said to have happened within all larger intervals.

(5) **Argument reduction axiom** For any verb V and Model M, if $f \in [\![\text{V}]\!]_M$, $C(\text{V}) \subseteq \text{dom}(g)$, and $g \subset f$, then $g \in [\![\text{V}]\!]_M$.

(6) **Temporal closure axiom** For any verb V and Model M, if $f \in [\![\text{V}]\!]_M$, $f =_{\text{T}} g$ and $f(\text{T}) \sqsubset g(\text{T})$, then $g \in [\![\text{V}]\!]_M$.

2. Basic derivations and inferences

Linking Semantics derivations have the following basic format:

(7)
$$
\begin{array}{lcl}
[\![\text{Mary}]\!]_M^{w,t} & = & \lambda P[P(m)] \\
[\![\text{Mary:ARG1}]\!]_M & = & \lambda L \lambda f[\lambda P[P(m)](\lambda x L(f + [\text{ARG1}, x]))] \\
 & = & \lambda L \lambda f[L(f + [\text{ARG1}, m])] \\
[\![\textit{past}]\!]_M & = & \lambda L \lambda f[L(f) \wedge f(\text{T}) < \text{NOW}] \\
[\![\text{laughed}]\!]_M & = & \lambda g[\text{laugh}'(g) \wedge g(\text{T}) < \text{NOW}] \\
[\![\text{Mary laughed}]\!]_M & = & [\![\text{Mary:ARG1}]\!]_M([\![\text{laughed}]\!]_M) \\
 & = & \lambda f[\text{laugh}'(f + [\text{ARG1}, m]) \wedge f(\text{T}) < \text{NOW}] \\
M, w \models \text{Mary laughed} & \text{iff} & \exists t \text{laugh}'([\text{W}, w; \text{T}, t; \text{ARG1}, m]) \wedge t < \text{NOW}
\end{array}
$$

Let us define an *existential* DP to be one such that “DP VP” entails “something VP”, and thence an existential modifier to be either an existential DP or a PP consisting of a preposition and an existential DP. Then the following argument reduction lemma holds: if (i) all DPs and modifiers in a sentence S are existential, (ii) S includes at least the canonical arguments of its main verb, and (iii) S′ is a sentence consisting of S plus any number of additional existential modifiers, then S′ $\models$ S in Linking Semantics. Here is a simple example:

(8) $M, w \models$ Brutus stabbed Caesar with a knife in the forum *iff*
$$\exists t\, \mathit{some}(\text{knife}'_{w,t})(\lambda x\, [\text{stab}'([\textsc{w}, w; \textsc{t}, t; \textsc{arg1}, b; \textsc{arg2}, c; \textsc{with-inst}, x; \textsc{ext-loc}, \text{the\_forum}']) \wedge t < \text{NOW}])$$

It follows from the above argument reduction lemma that *Brutus stabbed Caesar with a knife in the forum* $\models$*Brutus stabbed Caesar with a knife*, and *Brutus stabbed Caesar with a knife* $\models$*Brutus stabbed Caesar*.

However, downward monotone DPs reverse this effect. Claim: if (i) all DPs and modifiers in a sentence S except one are existential, (ii) that one modifier is downward monotone, (iii) S includes at least the canonical arguments of its main verb, and (iv) S′ is a sentence consisting of S plus any number of additional existential modifiers, then S$\models$ S′ in Linking Semantics. So, for example, *Nobody stabbed Caesar* $\models$ *Nobody stabbed Caesar with a sword*.

3. Quantification and Scope

We now consider a more complex derivation, for a sentence involving two quantified arguments:

(9)
$$\begin{aligned}
[\![\text{every country}]\!]^{w,t}_M &= \lambda P \mathit{every}(\text{country}'_{w,t})(P)\\
[\![\text{every country:}\textsc{arg2}]\!]_M &= \lambda L \lambda f[\mathit{every}(\text{country}'_{f(\text{W}),f(\text{T})})(\lambda y L(f + [\textsc{arg2}, y]))]\\
[\![\text{a diplomat}]\!]^{w,t}_M &= \lambda P \mathit{some}(\text{diplomat}'_{w,t})(P)\\
[\![\text{a diplomat:}\textsc{arg1}]\!]_M &= \lambda L \lambda f[\mathit{some}(\text{diplomat}'_{f(\text{W}),f(\text{T})})(\lambda x L(f + [\textsc{arg1}, x]))]
\end{aligned}$$

$$\begin{aligned}
&[\![[\text{a diplomat:}\textsc{arg1}] \text{ visited } [\text{every country:}\textsc{arg2}]]\!]_M = \\
&\quad \lambda f[\mathit{some}(\text{diplomat}'_{f(\text{W}),f(\text{T})})\\
&\quad (\lambda x[\mathit{every}(\text{country}'_{f(\text{W}),f(\text{T})})\\
&\quad (\lambda y[\text{visit}'(f + [\textsc{arg1}, x; \textsc{arg2}, y]) \wedge f(\textsc{t}) < \text{NOW}])])]
\end{aligned}$$

$$\begin{aligned}
&M, w \models [\text{a diplomat:}\textsc{arg1}] \text{ visited } [\text{every country:}\textsc{arg2}] \text{ iff}\\
&\quad \exists t\, \mathit{some}(\text{diplomat}'_{w,t})(\lambda x[\mathit{every}(\text{country}'_{w,t})\\
&\quad (\lambda y[\text{visit}'([\textsc{w}, w; \textsc{t}, t; \textsc{arg1}, x; \textsc{arg2}, y]) \wedge\\
&\quad t < \text{NOW}])])
\end{aligned}$$

Note that the temporal closure axiom plays an essential role in the above interpretation. The meaning of “A diplomat visited every country” comes out as meaning that there is a single interval in the past which contains all the visits, but this does not imply that the visits were simultaneous. For example, suppose the diplomat visited Uganda on Tuesday, and Kenya on Wednesday. Temporal closure guarantees that for any interval containing Tuesday the diplomat visited Uganda in that interval, and for any interval containing Wednesday the diplomat visited Kenya in that interval. Thus the diplomat visited both countries in any interval containing both Tuesday and Wednesday.

We can get the reverse scoping just by raising the object DP:

(10) $M, w \models$ [every country:ARG2][[a diplomat:ARG1] visited] iff
$\exists t\ \textit{every}(\text{country}'_{w,t})(\lambda y[\textit{some}(\text{diplomat}'_{w,t})$
$(\lambda x[\text{visit}'([\text{W}, w; \text{T}, t; \text{ARG}1, x; \text{ARG}2, y]) \wedge$
$t < \text{NOW}])])$

Here we see that in Linking Semantics movement does not need to leave a trace behind. Also note that there is nothing inherent to the framework that requires movement: we could equally well have defined the semantics directly on surface structures in such a way that the set of all meanings of a sentence was given by applying their meanings in every possible order to the meaning of the main verb.

4. Temporal Modification

Up to now we have only considered modifiers which saturate an argument position. A saturating modifier operates on some role in a linking structure so that the resultant linking structure contains only assignments which do not have that role in their domain. For example, an ARG2 modifier outputs a linking structure consisting of assignments which are not defined for ARG2. This is what prevents a verb from combining with two direct objects.

We will now consider temporal modifiers. We take the fact that multiple temporal modifiers can appear simultaneously in a sentential clause, either separately or 'stacked', to indicate that temporal modifiers are non-saturating. In terms of Linking Semantics this means that although a temporal modifier operates on the T role in the linking structure to which it applies, the resultant structure contains assignments which still have T in their domain. Thus this structure can be the object of further temporal modification.

Temporal modification presents special challenges, as Pratt and Francez 2001 make especially clear. First, one temporal modifier can affect the interpretation of another. Thus "July" refers to a different period in (11) than in (12).

(11) Last year, it rained in July.

(12) Two years ago, it rained in July.

When temporal modifiers are quantificational, one modifier may determine the domain for another, as in (13).

(13) Last year, it rained every day.

Furthermore, a quantificational temporal modifier may bind another modifier, so that e.g. "the afternoon" is bound by "most days" in (14).

(14) On most days, it rained in the afternoon.

Finally, order of application matters. We explain the fact that (15) and (16) are infelicitous in terms of two claims: first, clause internal modifiers are interpreted with narrower scope than fronted modifiers, and, second, wider scope temporal modifiers provide a temporal interval within which narrower scope modifiers must be interpreted. Thus, rather obviously, (15) and (16) are bad because "last year" is bigger than "July", and bigger than any day.

(15) ? In July, it rained last year.

(16) ? Every day, it rained last year.

We will now outline how these observations regarding temporal modification can be accounted for using the earlier definitions for Linking Semantics. We assume that both "in July" and "last year" operate on the same role, $\textsc{t}$, and further assume that times are highly structured entities. In particular, a time may be the sum of several intervals, so that, for example, the constant *july* picks out the sum of all intervals which correspond to the entire month of July in some year. We write $x \,\epsilon\, y$ to mean that x is an atomic part of y. Note that the subinterval relation $\sqsubseteq$ is also defined over times. If $x \,\epsilon\, y$, then $x \sqsubseteq y$, but the reverse need not hold. For example, December 2007 is a subinterval of 2007, but is not, in this sense, a part of 2007, since 2007 corresponds to a single (atomic) interval.

We also define $x = \iota y \phi$ to mean that x is the unique entity y such that the condition ϕ holds, and will assume that undefinedness results when this condition fails. However, in this short paper we will not define the formal mechanisms needed to control the propagation of undefinedness. We can now use the iota operator to define *july*$'$, a function from times to intervals, as follows: $\textit{july}'(t) = \iota x[x \,\epsilon\, \textit{july} \wedge x \sqsubseteq t]$. So $\textit{july}'(t)$ is defined when there is a unique part of *july* (the parts being intervals corresponding to particular instances of July) which falls within t. Then $[\![\text{July}]\!]^{w,t}_M = \lambda P P(\textit{july}'(t))$. We deal with "last year" similarly, using a constant *last-year* which has one atomic part, the subinterval corresponding to the year prior to the year utterance.

(17)
$$
\begin{array}{lcl}
[\![\text{in July}]\!]_M & = & [\![\text{July:}\textsc{t}]\!]_M \\
 & = & \lambda L \lambda f[[\![\text{July}]\!]^{f(\text{W}),f(\text{T})}_M(\lambda x[L(f[\textsc{t},x])])] \\
 & = & \lambda L \lambda f[L(f[\textsc{t},\textit{july}'(f(\textsc{t}))])] \\
[\![\text{last year:}\textsc{t}]\!]_M & = & \lambda L \lambda f[L(f[\textsc{t},\textit{last-year}'(f(\textsc{t}))])] \\
[\![\text{it rained}]\!]_M & = & \lambda f[\text{rain}'(f) \wedge\ f(\textsc{t}) < \text{NOW}] \\
[\![\text{it rained in July}]\!]_M & = & \lambda f[\text{rain}'(f[\textsc{t},\textit{july}'(f(\textsc{t}))]) \\
 & & \wedge\ \textit{july}'(f(\textsc{t})) < \text{NOW}] \\
[\![\text{Last year, it rained in July}]\!]_M & = & \\
 & & \lambda f[\text{rain}'(f[\textsc{t},\textit{july}'(\textit{last-year}'(f(\textsc{t})))]) \\
 & & \wedge\ \textit{july}'(\textit{last-year}'(f(\textsc{t}))) < \text{NOW}] \\
M,w \models \text{Last year, it rained in July iff} & & \\
 & & \exists t\ \text{rain}'([\textsc{w},w;\textsc{t},\textit{july}'(\textit{last-year}'(t))])
\end{array}
$$

So "Last year, it rained in July" is true just in case it rained in the interval given by the unique July last year , which, by temporal closure, will be the case if it rained at least once in July last year. It should now be clear why (15) is infelicitous: combining

"July" and "last year" in the opposite order creates undefinedness, since there is no t such that *last-year*$'$(*july*$'(t)$) is defined.[2] Note that the condition introduced by the past tense is redundant, since last year only contains past times. This is why the tense requirement does not appear in the final statement of the truth conditions.

We now turn to a quantificational case. We interpret temporal quantificational and definite DPs compositionally in the obvious way: $[\![\text{det N}]\!]_M^{w,t} = [\![\text{det}]\!]_M([\![\text{N}]\!]_M^{w,t})$. We then interpret an interval denoting noun relative to the temporal index. So given an $\langle e,t\rangle$ type constant *day*, we use a function from times to (temporal) entities $\text{day}'(t) = \lambda x[\text{day}(x) \wedge x \sqsubseteq t]$, and this will be the value of $[\![\text{day}]\!]_M^{w,t}$. We skip the details of the derivation, but the compositional machinery of Linking Semantics works in just the same way for the following example as in those above:

(18) $M, w \models$ Last year, on most days it rained in the afternoon *iff*
$\exists t\, \textit{most}(\text{day}'(\textit{last-year}'(t)))(\lambda t' \text{rain}'([\text{W}, w; \text{T}, \text{afternoon}'(t')]))$

Here the restrictor of *most* is $\text{day}'(\textit{last-year}'(t))$, which picks out the (characteristic fn. of the) set of intervals corresponding to days last year (provided t contains last year). The scope of *most* is $\lambda t' \text{rain}'([\text{W}, w; \text{T}, \text{afternoon}'(t')])$, which picks out the set of intervals containing a unique afternoon such that it rained during that afternoon. So, "Last year, on most days it rained in the afternoon" is defined on intervals containing last year, and says that in most intervals which are days contained in last year, raining took place sometime during the afternoon subinterval of those intervals.

The same type of analysis of quantificational temporal modifiers explains why (16) is infelicitous: its interpretation requires that each daylong interval contains the interval corresponding to last year. Further, the machinery allows arbitrarily many quantificational and non-quantificational temporal modifiers in a sentence, provided only that each modifier is interpreted relative to an interval in which it is defined. Thus, e.g. "In few years is it the case that in most months it rains for over three hours on exactly seven days" should present no problem for our more enthusiastic readers.

5. Conclusion

Linking Semantics is rather more like Davidsonian event semantics than it is like Montague Grammar, but has inherent advantages over both. In Davidsonian Event Semantics the analysis of quantification is problematic: either quantifiers are treated externally to the event system and quantified in (cf. Landman 2000), or else the definitions of the quantifiers must be greatly (and non-uniformly) complicated (cf. Krifka 1989). In general, and though we have not argued for this here, Davidsonian Event Semantics places inappropriate demands on the ontology of events: Linking Semantics makes no commitments at all as regards the nature of events, but denies that events play a special part in the syntax-semantics interface. The advantages of

[2] We note a (fixable) problem with the analysis: "It didn't rain tomorrow" comes out true rather than infelicitous. To solve this we would need to give the past tense morpheme an additional definedness condition saying that the contextually given time interval contains at least some part which is in the past.

Linking Semantics over Montague Grammar for a free word-order language with morphological case marking should be obvious. But even for English the advantages are substantial: (i) verbal alternations (like the dative alternation) as well as valency changes can be analysed without postulating an underlying verbal ambiguity, (ii) quantifiers can be analyzed *in situ* without boosting verb types unnaturally, and (iii) the analysis of sentences with multiple temporal modifiers is much simpler than in neo-Montagovian treatments (Pratt and Francez 2001; von Stechow 2002).

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