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Syntax and Semantics interacting in a Minimalist theory

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1 Introduction

After several proposals of a logical account of minimalism [5, 4, 6, 1], on the basis of the formalization provided by Edward Stabler [7, 8], we explore more precisely the interface between syntax and semantics. The main idea is that, according to many observations made for instance by Ray Jackendoff [3], the logical form is not the mere result of a derivation after the consumption of formal features. Indeed, there are rather two tasks which are performed on a par : the syntactic analysis properly speaking and the semantical analysis. Both analyses are connected by synchronization links in such a way that a parse can crash for (at least) two reasons : either because of a mismatch of syntactic features, or because of a failure in the semantic derivation.

2 Rules for syntax

2.1 Rules

We assume the usual elimination rules for / and \, which are the rules of classical categorial grammars. We consider that syntactic features are also linked together by means of a product \bullet , the rules of which are the following ones, where π_1 and π_2 are projections:

$$\frac{\Gamma \vdash x : A \quad \Delta \vdash y : B}{\Gamma, \Delta \vdash (x, y) : A \bullet B} [i\bullet] \quad \frac{\Gamma \vdash w : A \bullet B \quad \Delta, x : A, y : B, \Delta' \vdash z : C}{\Delta, \Gamma, \Delta' \vdash let(x, y) = (\pi_1(w), \pi_2(w)) in z : C} [e\bullet]$$

Remark: if, like it seems natural, \bullet is the product which gives / and \ as its residuates, then it is of course non commutative and in the $[e\bullet]$ -rule, the hypotheses $x : A$ and $y : B$ must be in that order and with no other hypothesis in between them. Let us have a look on the analysis of the VP *see a movie* with the lexicon:

see : $\vdash /see/ : (acc \backslash v) / d$
a : $\vdash /a/ : (case \bullet d) / n$
movie : $\vdash /movie/ : n$

be strictly synchronized with the steps of the first one. For instance, each *merge*-step in the syntactic dimension corresponds to an application step in the semantic one.

3 A type-logical system for semantics

3.1 Semantic types and rules

For the time being, we limit ourselves to semantic types *à la* Montague, i.e. types based on primitive types **e** and **t** by means of only one constructor: \rightarrow , which corresponds to the intuitionistic implication.

3.2 Correspondence between syntactic and semantic rules

3.2.1 Move and Cyclic Move

We consider two uses of the rule $[e \bullet]^3$: either the left premise is an extra-logical axiom, or it is an instance of the identity axiom. In the first case a full syntactic object is inserted (either a constituent or a lexical item), where as the second case corresponds to *cyclic moves* (a hypothesis y replaces a previous one x). These two variants correspond to two semantic rules, that we call RAISE and NORaise, for the reason that the first one assumes a raised type for the moved object while the second one only makes use of the flat (not raised) semantic type.

$$\frac{\Delta \vdash z : T \rightarrow U \rightarrow V \quad \Gamma \cup [x : T] \vdash \gamma : U}{\Delta \cup \Gamma \vdash z(\lambda x. \gamma) : V} [RAISE] \quad \frac{\Delta \vdash z : T \quad \Gamma \cup [x : T] \vdash \gamma : U}{\Delta \cup \Gamma \vdash (\lambda x. \gamma)(z) : U} [NORaise]$$

3.2.2 Head-Movement

In Chomskyan grammars, head-movement is exemplified by movement from V to I (when verbs raise to their inflection) or from I to C (when auxiliaries raise to the *Comp* position in interrogative sentences). For us, its formulation is:

$$\frac{\Gamma' \vdash \alpha : A \setminus B \bullet \tau(B) \quad \Delta \cup [x' : A \setminus B] \vdash x' : A \setminus B \quad \Gamma \cup [x : \tau(B)] \vdash \gamma : B}{\Gamma', \Delta, \Gamma \vdash \alpha[\epsilon/x]\gamma : A} [HM]$$

Because the verbal semantics does not need to be lifted, we shall also use [NORaise] as its semantic counterpart.

3.2.3 Summary

Figure 3.2.2 sum up the correspondence between semantic and syntactic rules, and between semantic and syntactic types. The translation of syntactic features (like \bar{n} , \bar{a} , \bar{o}) into various semantic types will be clear in the next section. The label *non-var* means that an extra-logical axiom is used to label the syntactic feature, whereas the label *var* means that the identity axiom is used instead. This corresponds respectively to the case where the syntactic feature definitely attracts an item (the movement ends up at this point) and to the case where the item keeps on moving higher (and leftwards). The distinction between \bar{wh} (Q) and \bar{wh} (REL) will be explained by means of examples.

Correspondence Syntax-Semantics	
Syntax	Semantics
ternary- $[\bullet E]$ (non var)	[RAISE]
ternary- $[\bullet E]$ (var)	[NORAISE]
[HM]	[NORAISE]
$[/ E]$ or $[\backslash E]$	$[\rightarrow E]$

Correspondence Syntax-Semantics	
Syntax	Semantics
\bar{d}	e
\bar{n} (non var)	$(e_{subj} \rightarrow t) \rightarrow t$
\bar{a} (non var)	$(e_{obj} \rightarrow t) \rightarrow t$
\bar{o} (non var)	$(e_{indobj} \rightarrow t) \rightarrow t$
\bar{wh} (Q)(non var)	$(e \rightarrow t) \rightarrow t$
\bar{wh} (REL)(non var)	$(e \rightarrow t) \rightarrow ((e \rightarrow t) \rightarrow (e \rightarrow t))$
\bar{n} (var)	e_{subj}
\bar{a} (var)	e_{obj}
\bar{o} (var)	e_{indobj}

Figure 1: The Syntax-Semantics correspondence

3.2.4 Grammatical functions

We shall assume that objects enter verbal expressions before subjects, thus leading to give transitive verbs the type $e_{obj} \rightarrow (e_{subj} \rightarrow t)$ ¹; thus *the first np to combine with a transitive verb is necessarily an object, and the second one the subject* — this can be generalized to ditransitive verbs.

The correct derivations (syntactic + semantic ones) concerning *Peter kisses Mary* are given in figure 2 (applications of the $[\bullet E]$ -rule are indicated by vertical edges). The lexicon used for this example is :

$$\begin{array}{lll}
Peter & \bar{k} \bullet d & \lambda P^{(e,t)}.P(Peter) \\
Mary & \bar{k} \bullet d & \lambda P^{(e,t)}.P(Mary) \\
kisses & (d \backslash (\bar{k} \backslash vp)) / d & \lambda u^e \lambda v^e K(u, v) \\
(infl) & (\bar{k} \backslash ip) / vp & \lambda U^t.U
\end{array}$$

The position of $(e_{obj} \rightarrow t) \rightarrow t$ is due to its correspondence with the accusative case (by figure 3.2.2), and the position of $(e_{subj} \rightarrow t) \rightarrow t$ is due to its correspondence with the nominative case. To avoid type mismatch, a lambda-abstraction the variable of type e_{obj} is needed before applying $(e_{obj} \rightarrow t) \rightarrow t$, and similarly a lambda-abstraction the variable of type e_{subj} is needed before application of $(e_{subj} \rightarrow t) \rightarrow t$.

Thus, the syntactic object only moves to the case position, indexed by "2", corresponding to the accusative place, while the syntactic subject moves to the case position indexed by "1" corresponding to the nominative place.

3.3 The Syntax-Semantics interface

Let us call \mathcal{SYN} the syntactic calculus with \bullet , $/$ and \backslash , rules $[/ E]$, $[\backslash E]$, $[\bullet E]$ ³ and [HM], and \mathcal{SEM} the semantic calculus with only \rightarrow , and rules $[\rightarrow E]$, [RAISE] and [NORAISE]. We assume the following: each step in \mathcal{SYN} has a counterpart in \mathcal{SEM} and reciprocally. The counterpart of any *ternary- $[\bullet E]$* -step (Γ' empty) is a [RAISE]-step and reciprocally. The

¹We have here the choice between considering obj and $subj$ individual constants and $\forall X e(X)$ a polymorphic type replacing e , or considering e_{obj} and e_{subj} subtypes of e .

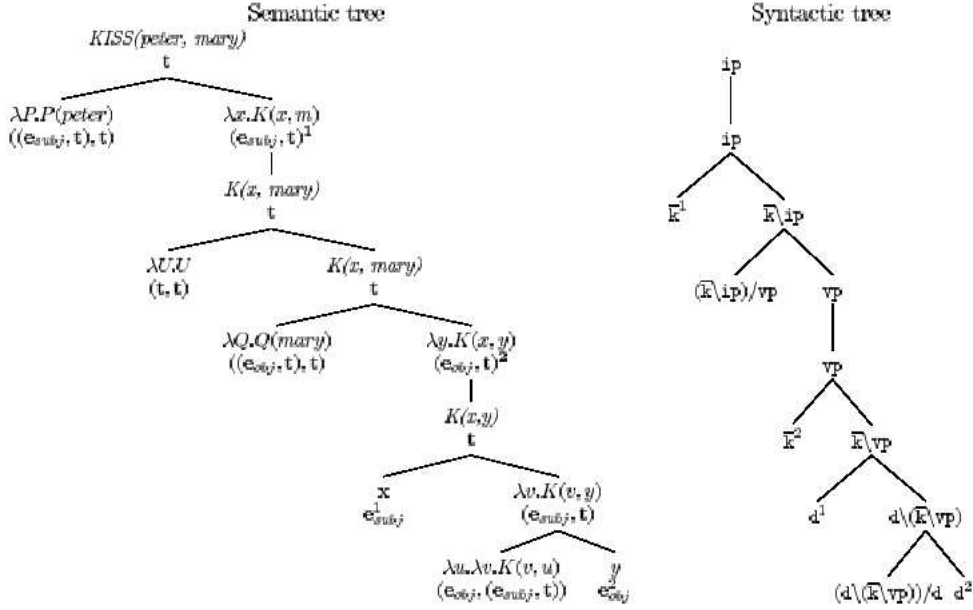


Figure 2: Syntactic and semantic trees for an elementary sentence

counterpart of any *ternary*-[• E]-step with Γ' non empty is a [NORAISE]-step. The counterpart of any [HM]-step is also a [NORAISE]-step. Both [/E] or [\ E] steps correspond to [\rightarrow E] steps. (cf. fig. 3.2.2).

Definition 2 Two proofs, one in \mathcal{SYN} and the other in \mathcal{SEM} , are said to be synchronized if and only if:

- every leaf in \mathcal{SEM} has a coindexed counterpart in \mathcal{SYN} ,
- steps and their counterparts are performed in the same order in the two proofs

This does not say though how semantical items are distributed among the leaves of the deduction tree in \mathcal{SEM} . In fact, semantical items are inserted like phonological features are, during the process of syntactic derivation. The following labeling thus gives the interface between syntax and semantics.

$$\begin{array}{c}
 \frac{\Gamma \vdash u : A/B \quad \Delta \vdash x : B}{\Gamma, \Delta \vdash (u x) : A} [e/] \quad \frac{\Delta \vdash x : B \quad \Gamma \vdash u : B \setminus A}{\Gamma, \Delta \vdash (u x) : A} [e \setminus] \\
 \frac{\vdash (f, u) : A \bullet B \quad x : A \vdash x : A \quad y : B, \Delta \vdash z : C}{\Delta \vdash \text{let}(x, y) = (f, u) \text{ in } z : C} [e \bullet]^3 \\
 \frac{\Gamma \vdash (v, u) : A \bullet B \quad x : A \vdash x : A \quad y : B, \Delta \vdash z : C}{\Gamma, \Delta \vdash \text{let}(x, y) = (v, u) \text{ in } z : C} [e \bullet]^3 \\
 \frac{\Gamma' \vdash (F, G) : A \setminus B \bullet \tau(B) \quad \Delta \cup [x' : A \setminus B] \vdash x' : A \setminus B \quad \Gamma \cup [x : \tau(B)] \vdash \gamma : B}{\Gamma', \Delta, \Gamma \vdash \text{let}(x', x) = (F, G) \text{ in } \gamma : A} [HM]
 \end{array}$$

Evaluation by beta-reduction of the formulae obtained by inserting the lambda terms from the lexicon yields the expected result.

4 Conclusion

The precise definition of the correspondence would require to handle lambda-terms with context rather than plain lambda terms. In this precise setting, movement corresponds to lambda-abstraction of the variable which is substituted with the moved term, while movement performs type raising on the term which is substituted. [1]

A comparison can be made with the standard correspondence between categorial grammars (say Lambek grammars) and Montague semantics, since this is basically an extension of this correspondence to a richer syntactic formalism. For instance, what happens when we deal with quantifiers in this minimalist setting? Firstly there is no need to introduce different syntactic types for different syntactic positions of the quantifier: movement enables a single syntactic type to apply in various syntactic positions, with a perfect correspondence with the semantics of the quantifier. Secondly, there are readings which are possible in the categorial settings but not in this setting — e.g. when the leftmost quantifier is in the scope of a quantifier on its right. It is not easy to tell whether this property of our model is welcome, since some claim that this reading is a topicalisation while others equally accept both readings.

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