Semantic Types and Type-shifting. Conjunction and Type Ambiguity. Noun Phrase Interpretation and Type-Shifting Principles.

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1. Linguistic background:

1.1. Categorial grammar and syntax-semantics correspondence: centrality of function-argument application

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*: not in PTQ

1.2. Tensions among simplicity, generality, uniformity and flexibility

Example: Natural language NP's (noun phrases)
   John, every man both NP's. Same type?
   Montague: Yes: all NP's type <<e,t>,t>.
   John: \( \lambda P. P(j) \)
   every man: \( \lambda P. \forall x[man(x) \rightarrow P(x)] \)
2. Conjunction and Type Ambiguity (from Partee & Rooth, 1983)

Structure of empirical argument: from cross-linguistic uniformity of generalized conjunction and elegance of its recursive definition, take its semantics as established. From that we get evidence for non-uniform typing of English transitive verb phrases and for type-shifting rules to shift simpler types to higher types by coercion as opposed to Montague's uniform typing at higher types.

2.0. To be explained: cross-categorial distribution and meaning of ‘and’, ‘or’.

With limited exceptions, it is apparently a linguistic universal that every major category can be conjoined with *and* and *or*. Partee and Rooth (1983) addressed the question of whether we could give a single meaning for *and* and a single meaning for *or* that covers their uses across the full range of categories. The core of that explanation has proven robust, and the semantics of cross-categorial conjunction now serves as one test in evaluating semantic proposals of various sorts.

We treat here only the central or “Boolean” *and*, whose core meaning is the meaning of ordinary logical conjunctio; examples are given in (1).

(1) (a) John and Mary are in Chicago.
    (b) Bacon and eggs are (both) high in cholesterol.
    (c) She was wearing a new and expensive dress.
    (d) Cats purr, meow, and growl. Dogs bark and growl but they don’t purr.
    (e) Susan will retire and buy a farm.

Other uses which we do not treat are given in (2); these include the “group-forming” *and* of (2a-b), the “partly this and partly that” *and* of (2c-d), and the idiosyncratic *try and* construction of (2e). With the exception of the last of these, interesting proposals for further unification have emerged in more recent work that we will not discuss here: Krifka (19xx) gave an elegant unification of (2c-d) with (2a-b) based on a part-whole mereology, and Winter (1996, 1998) has shown a way to unify those with the Boolean *and* of (1).

(2) (a) John and Mary are a happy couple.
    (b) Bacon and eggs is my favorite breakfast.
    (c) She was wearing a blue and white dress.
    (d) Can you rub your stomach and pat your head? [at the same time]
    (e) Susan will try and sell her house.

• Early attempts to use syntactic transformations: “Conjunction-reduction”
• Derive (1a) from *John is in Chicago and Mary is in Chicago*.
• Implicit assumption: transformations are meaning-preserving; same meaning is to be captured by assigning same ‘deep structure’.
• Downfall: *Every number is even or odd; Few rules are both explicit and easy to read.*

2.1. Generalized conjunction

1. Conjoinable categories: S, NP, IV, TV, CNP, ADJP,...
2. Boolean and and or of basic type t, vs. "group-forming" and of basic type e.
3. Boolean and, or on type t: can be viewed in terms of truth tables, 2-element algebra, sets of possible worlds, or sets of assignment functions; all give familiar Boolean structure.
4. Recursive definition of conjoinable types:
   (i) t is a conjoinable type
   (ii) if b is a conjoinable type, then for all a, <a,b> is a conjoinable type.
5. Types for and, or: <X,<X,X>> for all conjoinable types X. (This is "curried" form, one-argument-at-a-time; in examples I will draw trees for uncurried form.)
6. Semantics for generalized and (\(\land\)): pointwise lifting from codomain to function space.
   (i) for conjoinable type t, \(\land=\land\) (basic Boolean operation)
   (ii) for \(f_1,f_2\) of conjoinable type <a,b>, \(f_1\land f_2\) is defined by the condition
       \[f_1\land f_2](x) = f_1(x)\land f_2(x)\].
7. Examples
   a. \(<e,t>: walk'\land talk' = \lambda x[walk'(x) \land talk'(x)]\]
   b. \(<<e,t>,e>: (every man)'\land (some woman)' = \lambda P[(every man)(P) \land (some woman')(P)]\]
   c. \(<<e,t>,<e,t>>: old'\land useless' = \lambda P[old'(P)\land useless'(P)]
      = \lambda P[\lambda x[old'(P)(x) \land useless'(P)(x)]]\]

2.2. Repercussions on the type theory: against uniformity, for "simplicity" and type-shifting

1. If the type of all transitive verbs (TV, or IV/NP) is, as Montague had it, <type(T), type(IV)>, then generalized conjunction predicts:
   \([TVP1 \land TVP2] = \lambda P\lambda x[TVP1(P)(x) \land TVP2(P)(x)]\]
   -- Wrong result for:
   (1) John caught and ate a fish.
   (2) John hugged and kissed three women.
   -- Right result for:
   (3) John wants and needs two secretaries.
   (4) John needed and bought a new coat.

2. If the type of TV were <e, type(IV)>, then generalized conjunction would predict:
   \([TVP1 \land TVP2] = \lambda y\lambda x[TVP1(y)(x) \land TVP2(y)(x)]\]
   -- Right for (1), (2), wrong for (3), (4)
   -- Matches the first-order relations catch*, eat* predicted by Montague's meaning postulate for first-order-reducible transitive verbs.
2.3. Proposal:
(partly from Cooper, Dowty):

(i) Each verb entered lexically in its minimal type (to be defined) (give up Montague's strategy of putting all items of a given syntactic category in the "highest" type needed for any of them)

(ii) Each "low-type" verb has predictable homonyms of higher type. E.g. from buy₁ of type <e,<e,t>> predict buy₂ of type <type(T),<e,t>>:

\[ \text{buy}_2' = \lambda P \lambda x[P(\lambda y[\text{buy}_1'(y)(x)])] \]

(iii) Conjoined expressions are interpreted at the lowest type they both have. Abbreviating as TV1 (eat, buy) and TV2 (seek, need, etc.), we have:

\[
\begin{array}{cccc}
\text{TV1} & \text{TV1} & \text{TV2} & \text{TV2} \\
\text{TV1 and} & \text{TV2 and} & \text{TV2 and} & \text{TV2} \\
\text{catch} & \text{want} & \text{need} & \text{TV1} \\
\text{eat} & \text{need} & & \text{buy} \\
\end{array}
\]

(iv) This predicts all of (1)-(4) above correctly; (iii) may be taken as a "performance" strategy -- a natural "least effort" strategy.

(v) General form of above type-shifting operation. e-argument-functions to <e,t>-argument-functions:

2.4. Parallel issues with intransitive verbs

a. IV as <e,t>: PTQ, Bennett, Partee (1975).
b. IV as <type(T),t>: UG, Keenan and Faltz, Gazdar, Bach and Partee (1980), Bach (1979)
c. Parallel differences in generalized conjunction;
   -- lower type gives right result for
   (5) A fish walked and talked.
   (6) Every participant sent in an abstract or apologized.
   -- higher type gives right result for
   (7) An easy model theory textbook is badly needed and will surely be written within this decade (both high type)
   (8) A tropical storm was expected to form off the coast of Florida and did form there within a few days of the forecast. (high type and low type)
d. Infinite ambiguity + 'least effort' principle.

2.5. General processing strategy:

"Use the simplest types consistent with coherent typing of entire sentence." Higher types invoked by "coercion": e.g. to conjoin John and every woman, needed and bought. There is in principle nothing wrong with infinite ambiguity if the system is designed to access higher types only when there is some reason to do so.

Query: What does it take to insure that such a system of flexible typing and type-shifting will always yield a unique "simplest" result? Under what conditions or by what measures does such a strategy offer greater overall simplicity than Montague's strategy of uniformly generalizing to the "hardest case"?
3. NP Type Multiplicity (from Partee 1986)

3.1. Montague tradition:
Uniform treatment of NP's as generalized quantifiers, type (e→t)→t.

\[
\begin{align*}
John & : \lambda P[P(j)] \\
a \ man & : \lambda P\exists x[\text{man}(x) \land \ P(x)] \\
every \ man & : \lambda P\forall x[\text{man}(x) \rightarrow \ P(x)]
\end{align*}
\]

Intuitive type multiplicity of NP's:

\[
\begin{align*}
John & : \ "\text{referential use}": \ j \ (\text{or John}) \ \text{type e} \\
a \ \text{fool} & : \ "\text{predicative use}": \ \text{fool} \ \text{type e} \rightarrow t \\
every \ man & : \ "\text{quantifier use}": \ \text{as above} \ \text{type (e} \rightarrow t) \rightarrow t
\end{align*}
\]

Resolution: All NP's have meaning of type (e→t)→t; some also have meanings of types e and/or e→t. Find general principles for predicting these. Predicates may semantically take arguments of type e, e→t, or (e→t)→t, among others.

Type choice determined by a combination of factors including coercion by demands of predicates, "try simplest types first" strategy, and default preferences of particular determiners.

3.2. Evidence for multiple types for NP's.
Evidence for type e (Kamp-Heim): While any singular NP can bind a singular pronoun in its (c-command or f-command) domain, only an e-type NP can normally license a singular discourse pronoun.

(9) John /the man/ a man walked in. He looked tired.
(10) Every man /no man/ more than one man walked in. *He looked tired.

Evidence for type <e,t>: subcategorization for predicative arguments and conjoinablility of predicative NPs and APs in such positions.

(11) Mary considers John competent in semantics and an authority on unicorns.
(12) Mary considers that an island /two islands / many islands / the prettiest island / the harbor / *every island / *most islands / *this island / *?Hawaii / Utopia.

In general, the possibility of an NP having a predicative interpretation is predictable from the model-theoretic properties of its interpretation as a generalized quantifier; apparent counterexample (13) from Williams (1983) can be explained (see Partee (1987))

(13) This house has been every color.
3.3. Some type-shifting functors for NPs.

See DIAGRAM 1 in APPENDIX

- **lift**: \( j \rightarrow P[P(j)] \)  
  total; injective

- **lower**: maps a principal ultrafilter onto its generator  
  partial; surjective

- **ident**: \( j \rightarrow x[x = j] \)  
  total; injective

- **iota**: \( P \rightarrow \iota[P(x)] \)  
  partial; surjective

\[ \text{iota}(\text{ident}(j)) = j \]

- **nom**: \( P \rightarrow \cap P \)  
  almost total; injective

- **pred**: \( x \rightarrow \cup x \)  
  partial; surjective

\[ \text{pred}(\text{nom}(P)) = P \]

3.4. "Naturalness" arguments: THE, A, and BE.

\[ (14) \quad \text{THE}: Q \Rightarrow \lambda P[ \exists x[\forall y[Q(y) \leftrightarrow y = x]] \& P(x)] \]
\[ \Lambda: \quad Q \Rightarrow \lambda P[\exists x[Q(x) \& P(x)]] \]
\[ \text{BE}: \quad P \Rightarrow \lambda x[ P(\lambda y[y = x])] \quad \text{or} \quad \lambda x[\{x\} \in P] \]

3.4.1 THE

The argument offered in Partee (1987) for the naturalness of THE comes largely from considering the interpretations of definite singular NPs like "the king" in all three types. I will not go through the argument here in detail, but will just summarize the main points with the aid of Diagram 2.

See DIAGRAM 2 in APPENDIX

**iota** and **THE** are related to each other by the fact that whenever **iota** is defined, i.e. whenever there is one and only one king, **lift** (**iota**(king)) = **THE**(king) and **lower** (**THE**(king)) = **iota**(king), and furthermore whenever **iota** is not defined, **THE**(king) is vacuous in that it denotes the empty set of properties.

(15) **Proposal about BE**: **BE** is not the meaning of English *be* but rather a type-shifting functor that is applied to the generalized quantifier meaning of an NP whenever we find the NP is an \(<e,t>\) position.

(16) **Proposal about be**: (following Williams (1983)) The English *be* subcategorizes semantically for an e argument and an \(<e,t>\) argument, and has as its meaning "apply predicate", i.e. \( \lambda P\lambda x[P(x)] \).

Then the predicative reading of *the king* is as given in (17).

(17) **Predicative reading of the king**: **BE**(THE(king))
In terms of logical formulas, $BE(\text{T}
oline{\text{HE}}(\text{king}))$ works out to be $\lambda x[\text{king}(x) \& \forall y[\text{king}(y) \leftrightarrow y = x]]$, or equivalently, $\lambda x \exists y[\text{king}(x) \rightarrow x = y]]$. This gives the singleton set of the unique king if there is one, the empty set otherwise. It is always defined, so the predicative reading also requires no presuppositions.

Note that if there is at most one king, then $\text{king} = BE(\text{T}
oline{\text{HE}}(\text{king}))$

(18)  
(a) John is \{the president / president\}  
(b) John is \{the teacher / *teacher\}

The double-headed arrow on the $\text{ident}$ mapping in Diagram 2 reflects the fact that for $\text{iota}$ to be defined there must be one and only one king, hence $\text{king} = BE(\text{T}
oline{\text{HE}}(\text{king})) = \text{ident}(\text{iota}(\text{king}))$. In fact, when $\text{iota}$ is defined, the diagram is fully commutative: $\text{king} = BE(\text{T}
oline{\text{HE}}(\text{king})) = \text{ident}(\text{iota}(\text{king})) = \text{ident}(\text{lower}(\text{T}
oline{\text{HE}}(\text{king}))) = BE(\text{lift}(\text{iota}(\text{king})))$, etc. This property of the mappings lends some formal support to the idea that there is a unity among the three meanings of the $\text{king}$ in spite of the difference in type.

3.4.2 $A$ and $BE$

Let $A$ be the categorematic version of Montague's treatment of $a/an$: in IL terms, $\lambda Q[ \lambda P[ \exists x[Q(x) \& P(x)]]$]. If we focus first on the naturalness of $BE$, we can then argue that $A$ is natural in part by virtue of being an inverse of $BE$. The operation $BE$ has some very nice formal properties that are summarized in (19) and (20) below.

(19)  **Fact 1:** $BE$ is a homomorphism from $<<e,t>,t>$ to $<e,t>$ viewed as Boolean structures, i.e:

\[
BE(P_1 \cap P_2) = BE(P_1) \cap BE(P_2)
\]
\[
BE(P_1 \cup P_2) = BE(P_1) \cup BE(P_2)
\]
\[
BE(\neg P_1) = \neg BE(P_1)
\]

(20)  **Fact 2:** (thanks to Johan van Benthem, p.c.) $BE$ is the unique homomorphism $h$ that makes Diagram 3 commute.

Now what exactly does $BE$ do? We can write an expression equivalent to Montague's IL interpretation of English *be* but in set-theoretical terms as follows: $\lambda P \lambda x[\{x\} \in P]$. That is, it applies to a generalized quantifier, finds all the singletons therein, and collects their elements into a set. The commutativity of Diagram III is then straightforward. So $BE$ is indeed a particularly nice, structure-preserving mapping from $<<e,t>,t>$ to $<e,t>$.

(21)  **(MG) $be(\text{TR(a man)}) = be(\lambda P \exists x[\text{man}(x) \& P(x)])$**  
= $\lambda x[\text{man}(x)]$
= $\text{man}$

**(MG) $be(\text{TR(John)}) = be(\lambda P P(j))$**  
= $\lambda x[x=j]$

**(MG) $be(\text{TR(no man)}) = \lambda x[\neg \text{man}(x)]$**

**(MG) $be(\text{TR(every man)}) = \lambda x[\forall y[\text{man}(y) \rightarrow y=x]]$**
Now, having given some grounds for claiming that $BE$ is a "natural" type-shifting functor, we can use that to support the naturalness of $A$, since it turns out that $A$ is an inverse of $BE$ in that $BE(A(P)) = P$ for all $P$.

I (BHP) would conjecture, in fact, that among all possible DET-type functors, $A$ (which combines English $a$ and some) and THE are the most "natural" and hence the most likely to operate syncategorematically in natural languages, or not to be expresses at all, and that $BE$ is the most "natural" functor from <<e,t>,t> meanings to <e,t> meanings.

References


van Benthem, Johan (1983a) "Determiners and logic", Linguistics and Philosophy 6, 447-478.


Klein, Ewan and Ivan Sag (1985), "Type-driven translation", Linguistics and Philosophy 8, 163-201.


