Binding into Hamblin alternatives calls for variable-free semantics

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Alternative sets, first introduced by Hamblin (1973) into Montague grammar to treat questions, have found their way into theories of focus (Rooth 1985), indeterminate pronouns (Shimoyama 2001), and free-choice indefinites (Kratzer and Shimoyama 2002). Applying type abstraction (Reynolds 1983) to natural language semantics for the first time, I show that these formulations cannot account for binding into alternatives, for instance binding *his* in *which book by him*. This shortcoming is easy to fix, even without syntactic movement or Karttunen's (1977) use of quantifying-in, as long as we adopt a variable-free theory of binding (Jacobson 1999, 2000). This work thus constitutes a novel argument either for variable-free semantics or against Hamblin alternatives.

Although my argument applies to any NP that can be bound into, I illustrate it here using in-situ *wh*-phrases. Hamblin takes a *wh*-constituent to denote a set of alternatives. A *wh*-NP denotes a set of individuals, and a *wh*-clause denotes a set of propositions, which an answer to the question would select from. Semantic combination of alternative sets proceeds pointwise; for example, the Function Application rule (Heim and Kratzer 1998) becomes (Kratzer and Shimoyama 2002):

(1) If α is a branching node whose daughters are β and γ, where $[\![\beta]\!]$ has the type $\langle g, \langle\langle\tau,\sigma\rangle, t\rangle\rangle$ and $[\![\gamma]\!]$ has the type $\langle g, \langle\tau, t\rangle\rangle$, then $[\![\alpha]\!]$ has the type $\langle g, \langle\sigma, t\rangle\rangle$ and is defined by the equation

$$[\![\alpha]\!](g) = \{\, f(x) \mid f \in [\![\beta]\!](g) \wedge x \in [\![\gamma]\!](g) \,\}.$$

The type g is that of assignment functions, that is, functions from indices to individuals.

In questions like (2–3), a quantifier (*at most six people*$_j$) intervenes between a binder (*who*$_i$) and a *wh*-phrase it binds into (*which book by him*$_i$). For concreteness, I assume that *at most six people*$_j$ and *who*$_i$ both undergo QR to A′-positions, triggering Predicate Abstraction (Heim and Kratzer 1998). (My conclusions still hold if, say, Partee's (1973) Derived VP rule were used instead.)

(2) Who$_i$ thought at most six people$_j$ read which book by him$_i$?
'For which male x and which book p by x did x think that at most six people read p?'

(3) Who$_i$ thought I asked at most six people$_j$ to show which book by him$_i$ to her$_j$ mother?
'For which male x and which book p by x did x think that, for at most six females y, I asked y to show p to y's mother?'

Kratzer and Shimoyama define Predicate Abstraction for alternative sets as follows.

(4) If α is a branching node whose daughters are an index i and β, where $[\![\beta]\!]$ has the type $\langle g, \langle\sigma, t\rangle\rangle$, then $[\![\alpha]\!]$ has the type $\langle g, \langle\langle e,\sigma\rangle, t\rangle\rangle$ and is defined by the equation

$$[\![\alpha]\!](g) = \{\, f \in D_{\langle e,\sigma\rangle} \mid \forall a \in D_e.\, f(a) \in [\![\beta]\!](g[a/i]) \,\}.$$

They note that "there is a question about the correctness of the definition". Not only does this rule make an incorrect prediction below, there is no empirically correct rule with these types.

To derive (2) on the standard account, the rule (4) is invoked twice: once for *at most six people*$_j$ and once for *who*$_i$. The first time, the node β is t_j *read which book by him*$_i$, whose denotation

(5) $$[\![\beta]\!] = \lambda g.\, \{\, \text{`}g(j)\text{ read }p\text{'} \mid \text{`}p\text{ is a book by }g(i)\text{'} \,\}$$

has the type $\langle g, \langle t, t\rangle\rangle$. The output of Predicate Abstraction (over the index j) is of type $\langle g, \langle\langle e, t\rangle, t\rangle\rangle$:

(6) $$[\![\alpha]\!] = \lambda g.\, \{\, h \in D_{\langle e,t\rangle} \mid \forall y \in D_e.\, \exists p \in D_e.\, \text{`}p\text{ is a book by }g(i)\text{'} \wedge h(y) = \text{`}y\text{ read }p\text{'} \,\},$$

The second time, the node β is t_i *thought at most six people*$_j$ *read which book by him*$_i$ and denotes

(7) $$[\![\beta]\!] = \lambda g.\, \{\, \text{`}g(i)\text{ thought that, for at most six people }y, y\text{ read }f(y)\text{'} \mid f \in D_{\langle e,e\rangle} \wedge \forall y \in D_e.\, \text{`}f(y)\text{ is a book by }g(i)\text{'} \,\}.$$

The output of Predicate Abstraction (over the index i this time) is

(8) $$[\![\alpha]\!] = \lambda g.\, \{\, h \in D_{\langle e,t\rangle} \mid \forall x \in D_e.\, \exists f \in D_{\langle e,e\rangle}.\, \forall y' \in D_e.\, \text{`}f(y')\text{ is a book by }x\text{'} \wedge h(x) = \text{`}x\text{ thought that, for at most six people }y, y\text{ read }f(y)\text{'} \,\}.$$

The theory thus predicts and only predicts the following quasi-functional reading for (2).

(9) 'For which male $x \in D_e$ and which map $f \in D\langle e, \langle e, e\rangle\rangle$ from males x' and people y' to books by x' did x think that, for at most six people y, y read $f(x)(y)$?'

This prediction is incorrect on two counts. First, 'Chomsky thought at most six people y read the book by him that y criticized most fiercely' can be an answer to (9) but not to (2). This mismatch is because the first invocation of Predicate Abstraction yields (6) rather than the desired value $\lambda g. \{\, \lambda y_e.$ 'y read p' $\mid$ 'p is a book by $g(i)$' $\}$. As I will explain in the talk, it is an intuitive consequence of Reynolds's abstraction theorem—not an obscure technical fact—that this desired value cannot be obtained given the type of (5). Second, if John wrote no book, then (9) has no answer because there is no satisfactory f, whereas 'Chomsky thought at most six people read *Aspects*' is an answer to (2) even if not every man wrote a book. This mismatch is because the second invocation of Predicate Abstraction yields the type $\langle g, \langle\langle e, t\rangle, t\rangle\rangle$ rather than $\langle g, \langle e, \langle t, t\rangle\rangle\rangle$.

To produce the desired denotations, the meaning of t_j *read which book by him*$_i$ must be like $\lambda x_e. \{\, \lambda y_e.$ 'y read p' $\mid$ 'p is a book by x' $\}$, of type $\langle e, \langle\langle e, t\rangle, t\rangle\rangle$. The outer "$\langle e, \ldots\rangle$" in this type is bound by the index i, while the inner "$\langle e, \ldots\rangle$" is bound by the index j. In between the two layers of binding is a layer of alternatives "$\langle \ldots, t\rangle$". To analyze (2–3) properly, binding by i must take place outside—yet binding by j must take place inside—the layer of alternatives. As types of the form "$\langle g, \ldots\rangle$" indicate, this middle layer cannot be accommodated within the standard theory of binding, on which a single assignment function performs binding at all indices wholesale.

By contrast, a variable-free treatment of binding, such as Jacobson's proposal, provides the needed flexibility. We can add alternative sets to variable-free semantics by replacing function types $\langle \tau, \sigma\rangle$ with relation types $\langle \tau, \langle \sigma, t\rangle\rangle$ throughout (Shan 2001). Semantic combination proceeds pointwise, followed by a set union operation; for example, the Function Application rule becomes:

(10) If α is a branching node whose daughters are β and γ, where $[\![\beta]\!]$ has the type $\langle\langle \tau, \langle \sigma, t\rangle\rangle, t\rangle$ and $[\![\gamma]\!]$ has the type $\langle \tau, t\rangle$, then $[\![\alpha]\!]$ has the type $\langle \sigma, t\rangle$ and is defined by the equation

$$[\![\alpha]\!] = \{\, y \mid f \in [\![\beta]\!] \wedge x \in [\![\gamma]\!] \wedge y \in f(x) \,\}.$$

It is easy to reinterpret the λ-terms defining Jacobson's type-shift operators g, l, and z as manipulating relations rather than functions. For example, the Geach operator g, defined by $g(f)(v)(c) = f(v(c))$, now composes relations: formally, $g(F) = \{\, \lambda v. \{\lambda c. \{\, w \mid u \in v(c) \wedge w \in f(u) \,\}\} \mid f \in F \,\}$.

As is standard in Hamblin semantics, the *wh*-phrase *who* denotes the alternative set of all individuals. Less standardly, *which* relates properties to individuals satisfying them; in other words, *which* denotes the singleton set containing the identity function of type $\langle\langle e, t\rangle, \langle e, t\rangle\rangle$. These denotations generate the readings in (2–3). Moreover, variable-free accounts of phenomena like weak crossover carry over to this relational variant of variable-free binding, ruling out sentences like (11).

(11) *Which author of it$_i$ thought at most six people$_j$ read which paper$_i$?

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