Respective Answers to Coordinated Questions

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SALT-13
Seattle, Washington
May 9, 2003

1 Introduction

- As Munn (1998, 1999) observes, examples like (1a), coupled with pair-list answers such as (1b), appear to violate the identity condition on across-the-board (ATB) extraction:

(1) a. Where did Mary vacation and Bill decide to live?
 b. Mary vacationed in Paris and Bill decided to live in Toronto.

- To save the identity condition, he concludes that such cases should be analyzed as functional readings along the lines of Chierchia (1993).
- The schematic semantics for (1a):

(2) Which f: Mary vacationed in *f(Mary)* and Bill decided to live in *f(Bill)*?

- The LF representation:

(3) [Where]$_i$ did Mary$_x$ vacation t_i^x and Bill$_y$ decide t_i^y to live?

- However, there are several anomalies that arise in Munn's analysis:

1. It specifically predicts that pair-list answers are not available for examples with a conjoined VP (4a) because only one binder is available, whereas we find the answer in (4b) to be impeccable.

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(4) a. What did Bill eat and drink?
 b. He ate a hamburger and drank a coke.

Note that taking the properties to be the function arguments would require coindexing traces with verbs:

(5) [What]$_i$ did Bill eat$_x$ t_i^x and drink$_y$ t_i^y

2. Munn's non-identity ATB readings are unavailable with *unambiguously* singular NPs (cf. 1a & 4a):

(6) a. In what #city/cities did Mary vacation and Bill decide to live?
 b. Mary vacationed in Paris and Bill decided to live in Toronto.

This restriction is unexpected since it does not arise with other cases that have been successfully analyzed as pairlist readings:

(7) a. What relative does every boy love?
 b. Tom loves his mother, Fred loves his aunt...

- In this paper we:
  - Argue that the readings of examples like (1a) are not functional but instead instances of *respective* readings of the sort operative in (8):

  (8) Mary vacationed and Bill decided to live in Paris and Toronto (respectively). (cf. 1a)

  - Provide an analysis using the semantic machinery for such readings proposed by Gawron and Kehler (to appear).
  - Argue that the set of data he considers is not uniform; indeed one particular subclass of cases *are* functional

2 The Semantics of Respective Readings

2.1 The Nature of the Phenomenon

- The basic case:

(9) a. *Tolstoy and Dostoyevsky* wrote *Anna Karenina and The Idiot* respectively.
 b. *Tolstoy* wrote *Anna Karenina* and *Dostoyevsky* wrote *The Idiot*.

- A semantic phenomenon, not a syntactic one (Dalrymple and Kehler 1995, inter alia):

(10) Though the Trail Blazers won this series in six games from Phoenix, they were far from dominant. *Their margins of victory* were *2 points, 1 point, 6 points, and 3 points* respectively. (New York Times article)

- Exist independently of the adverb *respectively*:

(11) Though the Trail Blazers won this series in six games from Phoenix, they were far from dominant. *Their margins of victory* were *2 points, 1 point, 6 points, and 3 points.*

- Can involve groups of property-denoting expressions:

(12) Sue and Karen jog to school and drive to work (respectively).

(13) George and Martha respectively denounced and were denounced by the governor. (McCawley 1998)

(14) John and Mary sang loudly and softly (respectively)

(15) The Mondavi Woodbridge and Beringer Reserve wines are cheap and expensive (respectively).

2.2 Analysis

Property and Proposition Sums

- We therefore need a representation for groups of property-denoting and proposition-denoting expressions in which the subparts are retrievable
- Treat these as denoting SUMS (Link 1983), on analogy with conjunctions of individual-denoting expressions
- Provides a treatment for conjunction that is uniform for property-denoting, proposition-denoting, and individual-denoting expressions
  - The JOIN operation (written $\sqcup$ for properties/propositions and $\vee$ for individuals).
- Details of the lattice-theoretic construction appear in the appendix, as well as our type system given the need to move away from classic Montagovian denotations

- For each boolean type $\langle$ a, b $\rangle$:

$$\forall\alpha \in \mathrm{D_a},\ \beta_1\,\beta_2 \ldots \beta_n \in \mathrm{D_{\langle a,b\rangle}}$$
$$[[\beta_1 \sqcup \beta_2 \sqcup \ldots \sqcup \beta_n](\alpha) = \beta_1(\alpha) \sqcup \beta_2(\alpha) \sqcup \ldots \sqcup \beta_n(\alpha)]$$

Ways of Getting Property Sums

1. From the conjunction of property (and relation) denoting expressions

(16) a. jog and drive
b. jog $\sqcup$ drive

2. From sentential conjunction and lambda abstraction

(17) a. (the person) that John fired and Susan hired
b. λs[fired(John, s) $\sqcup$ hired(Susan, s)]

3. The distributivity operator (Link 1983, Roberts 1987)

(18) wrote Anna Karenina and War and Peace

(19) a. $\mathrm{Dist} = \lambda \mathrm{P} \lambda g \bigsqcup_{x \ \mathrm{atom}\sqsubseteq_i g} \mathrm{P}(x)$

b. $\mathrm{Dist}(\mathrm{wrote}) = \lambda g \bigsqcup_{x \ \mathrm{atom}\sqsubseteq_i g} \mathrm{wrote}(x)$

c. $\mathrm{Dist}(\mathrm{wrote})\ (\mathrm{AK} \vee \mathrm{WP}) = \bigsqcup_{x \ \mathrm{atom}\sqsubseteq_i \mathrm{AK}\vee\mathrm{WP}} \mathrm{wrote}(x) = \mathrm{wrote}(\mathrm{AK}) \sqcup \mathrm{wrote}(\mathrm{WP})$

Sequencing Functions

Model the context-dependent ordering among individuals in a group-denoting expression with pragmatically-supplied SEQUENCING FUNCTIONS:

(20) $f \in (\mathrm{U}^{\mathbf{I}})^{\mathbf{G}}$

In which we use:

- **U** for the set of (possibly atomic) entities of all types
- **G** for the set of entities of all types minus atoms (i.e., the set of sums of all types)
- **I** for the set of integers

A sequencing function f, then, is a **partial** function from $\mathbf{G}$ to an assignment function, where an assignment function is, in turn, a **partial** function from integers to entities.

(21) a. Sue and Karen jog and drive respectively.
b. Sue, Karen, and Bob jog, drive, and jog respectively.
c. # Sue, Karen, and Bob jog and drive respectively.

i	Group	
	$f(\mathrm{s} \vee \mathrm{k})(i)$	$f(\mathrm{jog} \sqcup \mathrm{drive})(i)$
1	s	jog
2	k	drive
3	$\uparrow$	$\uparrow$

Table 1: The sequencing function for example (21a), where $\mid f \mid = 2$.

i	Group	
	$f(\mathrm{s} \vee \mathrm{k} \vee \mathrm{b})(i)$	$f(\mathrm{jog} \sqcup \mathrm{drive} \sqcup \mathrm{jog})(i) = f(\mathrm{jog} \sqcup \mathrm{drive})(i)$
1	s	jog
2	k	drive
3	b	jog
4	$\uparrow$	$\uparrow$

Table 2: The sequencing function for example (21b), where $\mid f \mid = 3$.

Constraints on sequencing functions:

1. Cardinality: We require that for all $g \in \mathbf{G}$, f be defined for the same subset of $\mathbf{I}$. The cardinality of f is written as $\mid f \mid$.

2. Proper Subgroups: We require that, for each g, i, $f(g)(i)$ pick out a proper subpart of g. That is,

   (22) $f(g)(i) \sqsubset_i g$

3. Exhaustivity: Finally, we require that $f(g)$ be exhaustive, that is, that:

   (23) $\left(\bigsqcup_{i \leq |f|} f(g)(i) \right) = g$

The Respective Operator

(24) $\mathrm{Resp}_f = \lambda \mathrm{P} \lambda \mathrm{g} \bigsqcup_{i \leq |f|} [f(\mathrm{P})(i)](f(\mathrm{g})(i))$

(25) $\mathrm{Resp}_{f^2}(\mathrm{jog} \sqcup \mathrm{drive})(\mathrm{s} \vee \mathrm{k})$
$= \bigsqcup_{i \leq 2} [f_i(\mathrm{jog} \sqcup \mathrm{drive})](f_i(\mathrm{s} \vee \mathrm{k}))$
$= \mathrm{jog}(\mathrm{s}) \sqcup \mathrm{drive}(\mathrm{k})$

Serves as denotation of *respectively*, but can occur freely

An Example with the Distributivity Operator

(26) Tolstoy and Dostoyevsky wrote *Anna Karenina* and *The Idiot* respectively. (=9a)

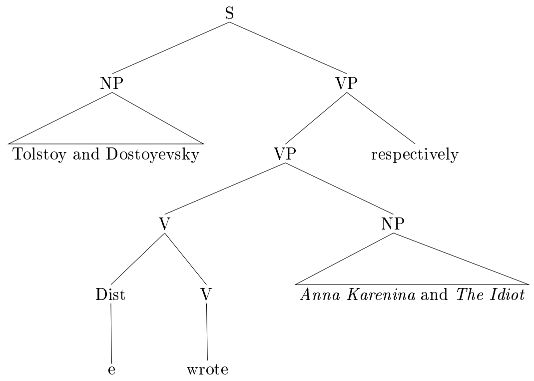

Figure 1: Analysis of (26)

The denotations of the nodes of the tree in (1) are shown in (27):

(27) a. $[\![$ [Dist wrote] Anna K and The Idiot $]\!]$
$= \mathrm{Dist\ write}(\mathrm{AK} \vee \mathrm{I})$
$= \mathrm{write}(\mathrm{AK}) \sqcup \mathrm{write}(\mathrm{I})$

b. $[\![$ [Dist wrote] Anna K and The Idiot respectively $]\!]$
$= \mathrm{Resp}_{f^2}[\mathrm{write}(\mathrm{AK}) \sqcup \mathrm{write}(\mathrm{I})]$

c. $[\![$ Tolstoy and Dostoyevsky [Dist wrote] Anna K and The Idiot respectively $]\!]$
$= \mathrm{Resp}_{f^2}[\mathrm{write}(\mathrm{AK}) \sqcup \mathrm{write}(\mathrm{I})](\mathrm{T} \vee \mathrm{D})$
$= \mathrm{write}(\mathrm{AK})(\mathrm{T}) \sqcup \mathrm{write}(\mathrm{I})(\mathrm{D})$

2.3 Interaction will Filler-Gap Dependencies

- Recall that conjunctions of gap-containing clauses yield property sums:

(28) a. (the person) that John fired and Susan hired (=17)
b. $\lambda s[\text{fired}(\text{J}, s) \sqcup \text{hired}(\text{S}, s)]$

- The analysis predicts that the respective operator can intervene between this sum and the sum containing the fillers to create non-identity ATB extraction with a variety of filler-gap constructions:

- Relative Clauses:

(29) I bought travel guides for Paris and London yesterday. They are the cities where Mary vacationed and Bill decided to live, respectively.

(30) the c cities(c),
$[\text{Resp}_f(\lambda x\,[\text{vacation}(\text{Mary}, x) \sqcup \text{decide-to-live-in}(\text{Bill}, x)])\ (c)]$

(31) The two most expensive cities in Europe, which are where Mary vacationed and Bill decided to live respectively, are very beautiful.

- Clefts:

(32) I bought travel guides for Paris and London yesterday. It was these cities where Mary vacationed and Bill decided to live, respectively.

(33) It was the two most expensive cities in Europe where Mary vacationed and Bill decided to live, respectively.

- Right-Node Raising:

(34) I bought travel guides for Paris and London yesterday. Mary vacationed, and Bill decided to live, in these two cities respectively.

(35) Mary vacationed, and Bill decided to live, in the two most expensive cities in Europe, respectively.

- Topicalization:

(36) I bought travel guides for Paris and London yesterday. Those two cities, Mary vacationed in and Bill decided to live in, respectively.

(37) The two most expensive cities in Europe, Mary vacationed in and Bill decided to live in, respectively.

- All of these are problematic for syntactic theories that impose an identity condition on gaps and their fillers.

- This issue generalizes to other types of predication relationships; consider a unification-based treatment of subcategorization for (38):

(38) Sue and Karen jog and drive respectively.

The index for *Sue and Karen* cannot be unified with the lexical subject role for either *jog* or *drive*.

3 Coordinated Questions

3.1 The Respective Analysis

- Munn's cases are another type of filler-gap dependency in which a respective operator can intervene:

(39) a. Where did Mary vacation and Bill decide to live? (=1a)
b. Paris and London (respectively).
c. Mary vacationed in Paris and Bill decided to live in London.

- Schematic semantics for (39):

(40) which X $\text{Resp}_f(\lambda \text{x}[\text{vacation}(\text{Mary})(x)] \ \sqcap$
$\lambda \text{x}[\text{decide-to-live-in}(\text{Bill})(x)])$ (X)

- Fine with plural, but not with singular, as predicted:

(41) a. In what cities/#city did Mary vacation and Bill decide to live?
b. Paris and London (respectively).
c. Mary vacationed in Paris and Bill decided to live in London.

- Analysis predicts felicitous cases with VP-conjunction:

(42) a. What did Bill eat and drink? (=4a)
b. what X $\text{Resp}_f(\lambda \text{x}[\text{eat}(\text{Bill})(\text{x})] \sqcap \lambda \text{x}[\text{drink}(\text{Bill})(\text{x})])$ (X)

- As well as NP-conjunction:

(43) a. What cities did Mary visit in Africa and Asia?
b. She visited Nairobi and Monrovia in Africa and Tokyo and Bangkok in Asia.

- Admittedly, the respective interpretation does not always seem to be as accessible as other possible readings:

(44) Which men and women do you like and love?

- But the reading is available with overt *respectively*:

(45) Which men and women do you like and love respectively?

- Other types of contextual clues can also help:

(46) A. Let's gossip. Which man does Bob like the most?
B. Fred.
A. Which woman does he love the most?
B. Sue.
A. OK, which man and woman does John like and love the most?
B. Bob and Wanda.

- Respective readings are intuitively more 'work', so contextual support or overt *respectively* may be necessary to make such readings preferred.

3.2 Another Look at Munn's Data

- We and Munn agree that number-ambiguous Wh-NPs are fine, although for different reasons:

(47) a. Who did Bill kill on Tuesday and Fred kill on Wednesday?
b. John killed Bruno and Bill killed Arno.

- Munn finds the singular (*man*) to be acceptable, we find only the plural (*men*) to be:

(48) a. What man did Bill kill on Tuesday and Fred kill on Wednesday? (vs. *men*)
b. John killed Bruno and Bill killed Arno. (Munn's judgment)

- Munn: "the data [i.e. 48] improve considerably if we explicitly mention the function in the *wh*-phrase itself":

(49) Which of his victims did John kill on Tuesday and Bill kill on Wednesday?

- Let's make the NP singular:

(50) a. Which victim on his list did John kill on Tuesday and Bill kill on Wednesday?
b. John killed Bruno and Bill killed Arno.
c. His brother. (with sloppy reading)

- As expected, VP-coordination is now bad (cf. 50):

(51) a. Which victim on his list did John maim on Tuesday and kill on Wednesday?
b. # He maimed Bruno on Tuesday and killed Arno on Wednesday.

- As well as our NP-coordination case (cf. 43):

(52) # Which inhabitant of its coast did John kill in Africa and Asia?

- Consider a variant of (50) with no pronoun:

(53) a. Which victim did John kill on Tuesday and Bill kill on Wednesday?
b. ?? John killed Bruno and Bill killed Arno.
c. ?? His brother.

- And a variant of (48) again, which has a non-relational noun only:

(54) a. Which man did John kill on Tuesday and Bill kill on Wednesday?
b. # John killed Bruno and Bill killed Arno.
c. # His brother.

- Functional relative clauses (Sharvit 1999):

(55) a. The picture of himself which every student hated annoyed his friends. (e.g., his passport photo)
b. The picture of his mother which every student hated annoyed his friends. (e.g., her driver's license photo)
c. The picture which every student hated annoyed his friends. (identity only?)

- Thus, the ability to get functional readings with singular NPs appears to display gradience:

relational nouns w/ pronouns > relational nouns > nonrelational nouns

- But the evidence remains that the plural cases Munn discusses are respective readings
  - Restrictions on functional readings do not exist
  - Exactly what one would expect given the other filler-gap constructions previously discussed
- A functional/respective hybrid example?

(56) Which of their relatives did John and Bill visit?

- Handled by a freely-occurring Resp operator that takes NP level scope (Gawron and Kehler 2002), as in (57):

(57) John and Bill visited their (respective) relatives.

4 Conclusion

- With one subclass of exceptions, Munn's examples are instances of respective readings, and not functional readings.
- Our analysis captures these readings, as well as those in a range of other filler-gap constructions, since Resp operators routinely intervene between constituent-based dependencies in the syntax and predicate-argument relations in the semantics.
- The machinery employed is independently necessary to simultaneously capture:
  - Examples in which the respective reading applies over one or more groups that are not specified with a coordinate structure.
  - Examples without *respectively*.
  - Examples in which the respective reading applies over one or more groups that denote relations (e.g., verbs, verb phrases, adjectives, adverbs).

Acknowledgments

We thank Chris Barker for comments on a previous version of this talk.

Appendix: Generalized Summing

Following Link, we assume a complete atomic semilattice on individuals. Here we review the basic idea of individual sums, to set up the development of higher order sums. We require:

(58) a. The $\sqsubseteq_i$ relation introduced above; $\sqsubseteq_i$ is transitive, reflexive, and antisymmetric.

b. For any subset S of E, we require the "sum" of the elements of S to be another element of E, written

$$\bigvee_{e \in s} e$$

We define this individual to be the supremum (or join or least upper bound or l.u.b.) of S with respect to $\sqsubseteq_i$. We also call such an individual an INDIVIDUAL SUM. Since E is a set such that the sum of any subset is in E, E is a COMPLETE JOIN SEMILATTICE with respect to $\sqsubseteq_i$. We write

$$a \vee b$$

for the supremum of a and b.

c. We define $\mathrm{A_E}$, a subset of E, to be the set of ATOMS and to consist of those elements a such that

$$\forall x[x \sqsubseteq_i a \longrightarrow x = a]$$

We write

$$a \text{ atom-}\sqsubseteq_i p$$

if and only if a is atomic and $a \sqsubseteq_i p$.

The next step is to assume a primitive set of propositions and assume a semilattice on these as well, corresponding to proposition conjunction. All the other semilattices on relations will be defined via morphisms into this lattice.

(59) a. Primitive set of propositions Π, as in Thomason (1980), Bealer (1982), Zalta (1983), Chierchia (1984), and Aczel (1989), for example.

b. A transitive, reflexive, antisymmetric ordering $\sqsubseteq_i$ on Π.

c. For any subset π of Π, we require the "sum" of the elements of π to be another element of Π, written

$$\bigsqcup_{p \ \text{atom}\sqsubseteq_i \pi} p$$

We require this proposition to be the supremum of π with respect to $\sqsubseteq_i$. We also call such a proposition a PROPOSITION SUM. Since Π is a set such that the sum of any subset is in Π, Π is a complete join semilattice with respect to $\sqsubseteq_i$. For notational convenience, we write

$$p_0 \sqcup p_1$$

for the supremum of p_0 and p_1. We reserve $\wedge$ for logical conjunction of formulae of type t.

d. We define A_Π, a subset of Π, to be the set of atoms and to consist of those elements a such that

$$\forall p[p \sqsubseteq_i a \longrightarrow p = a]$$

We write

$$a \text{ atom-}\sqsubseteq_i p$$

if and only if a is atomic and $a \sqsubseteq_i p$.

e. We will define truth in a possible world to give "conjunction semantics" for $p_0 \sqcup p_1$. Thus, assuming possible worlds to be sets of propositions, we will require of W, the set of possible worlds:

$$\forall w \in \mathrm{W}[p_0 \in w \wedge p_1 \in w \longleftrightarrow p_0 \sqcup p_1 \in w]$$

A consequence of this development is that ATOMIC PROPOSITIONS will not be very atomic looking. Atomic in the relevant sense just means not composed out of simpler propositions by summing ($\sqcup$). As such, all of the rather complex propositions in (60) are atomic:

(60) a. every(man)(walk)
b. believe(j)(happy(m))
c. $\neg$ [walk(j)]

We will assume relations are propositional functions:

(61) **Basic relations** will be functions from their argument types to Π, the set of propositions. The predicate $walk'$, for example, is a function from the set of entities E (following Link (1983)) to Π. Thus, in addition to the type t for truth values the type theory includes a type p for propositions.

The predicate $walk'$ is of type $\langle \mathrm{e}, \mathrm{p} \rangle$.

Prior to defining a join semilattice on relations, we define types and Boolean types, first syntactically:

(62) a. e is a type.
b. p is a type and is Boolean.
c. If a is a type and b is a type, then $\langle a, b \rangle$ is a type, and if b is a Boolean type, then $\langle a, b \rangle$ is a Boolean type.

The denotation space for these types will be:

(63) a. $\mathrm{D_p} = \Pi$
b. $\mathrm{D_e} = \mathrm{E}$
c. $\mathrm{D}_{\langle \mathrm{a,b} \rangle} = \mathrm{D_b}^{\mathrm{D_a}}$

Here are some types and syntactic categories in the proposed system:

Category	Montague's Term	Type	Examples
V, VP	IVP	$\langle$ e, p $\rangle$	walk
V	TVP	$\langle$ e, $\langle$ e, p $\rangle$ $\rangle$	devour
N	CN	$\langle$ e, p $\rangle$	man, men
Det	GQDET	$\langle$ $\langle$ e, p $\rangle$, $\langle$ $\langle$ e, p $\rangle$, p $\rangle$ $\rangle$	every, most
Det	SingDET	$\langle$ $\langle$ e, p $\rangle$, e $\rangle$	the, two

Note that the type of both CNs (common nouns) and IVPs (intransitive VPs) is $\langle$ e, p $\rangle$. Correspondingly, the type of a GQ (Generalized Quantifier) is $\langle$ $\langle$ e, p $\rangle$, p $\rangle$.

Finally we define the semilattice for relations, that is, for functions from entities to propositions, and for their inheritors up the hierarchy of types. For all Boolean types $\langle$ a, b $\rangle$:

(64) a. A transitive, reflexive, antisymmetric ordering $\sqsubseteq_i$ on $\mathrm{D}_{\langle \mathrm{a,b} \rangle}$.
b. For any subset S of $\mathrm{D}_{\langle \mathrm{a,b} \rangle}$, we require the "sum" of the elements of S to be another element of $\mathrm{D}_{\langle \mathrm{a,b} \rangle}$, written

$$\bigsqcup_{\mathrm{P} \ \text{atom}\sqsubseteq_i \mathrm{S}} \mathrm{P}$$

We define this individual to be the supremum of S with respect to $\sqsubseteq_i$. Such a sum is called a BOOLEAN SUM. We write

$$\mathrm{P} \sqcup \mathrm{Q}$$

for the supremum of P and Q.

c. We define $A_{\langle a,b\rangle}$, a subset of $D_{\langle a,b\rangle}$, to be the set of atoms of $D_{\langle a,b\rangle}$ and to consist of those elements Q such that

$$\forall P[P \sqsubseteq_i Q \longrightarrow P = Q]$$

We write

$$P \text{ atom-}\sqsubseteq_i Q$$

if and only if P is atomic and $P \sqsubseteq_i Q$.

d. **Boolean Reduction**: For each boolean type $\langle\, a,\ b\,\rangle$, we require of $\sqsubseteq_i$ that:

$$\forall \alpha \in D_a,\ \beta_1 \beta_2 \ldots \beta_n \in D_{\langle a,b\rangle}$$
$$[[\beta_1 \sqcup \beta_2 \sqcup \ldots \sqcup \beta_n](\alpha) = \beta_1(\alpha) \sqcup \beta_2(\alpha) \sqcup \ldots \sqcup \beta_n(\alpha)]$$

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