

# The (re-)emergence of representationalism in semantics

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The major challenge posed to all those seeking to explain semantic properties of natural language is the pervasive dependence on context for the way in which expressions are understood. This chapter surveys the emergence of formal models of semantics against the background of the new emphasis in linguistics during the 1950's of formal modelling of grammars, and then details the way in which formal semanticists have increasingly turned to tools of proof theory for formal languages as they have grappled with this challenge. As we shall see, the starting point for this modelling of context dependence involved fierce disagreement between the protagonists as to whether or not explanations of natural-language content required some form of semantic representation, a view which those working within formal semantics paradigms initially so effectively ridiculed that this alternative was barely aired at all within semantics for the last decades of the last century. Yet as formal tools have been increasingly refined in order to express this pervasive context-dependence, the disagreement that led early on to the setting-aside of representationalism in semantics as a respectable methodology has, as we shall see, got so transformed that the initially conflicting sets of assumptions are now hard to distinguish.

## **1 The point of departure: the 1960's**

During the sixties, with Chomsky's setting out of a theoretical framework for formal study of natural languages (Chomsky 1965), inquiry into the status of natural language semantics within natural-language grammars was inevitable. Two developments went almost hand in hand: the articulation of semantics as part of the Chomskian philosophy (Katz and Fodor 1962, Katz and Postal 1963, Katz 1972), to be closely followed by the extension of formal-language semantic tools to natural-language (Montague 1968, 1970a,b, 1973, all reprinted in Thomason ed. 1974).

## 1.1 The new Chomskian methodology

The Chomskian break-through in the exploration of grammars of natural language came from extending the methodology of grammar-writing for the familiar logics of propositional and predicate calculus to natural language. In these “formal languages”, constructed to enable formal modelling of logical reasoning, a stock of primitive expressions is defined, and from these by a small number of syntactic and semantic rules, an infinite set of strings can be licensed. Using these languages, the phenomenon of inference is defined by positing inference rules with concomitant semantics, the interaction of this small set of rules being able to express all and only the infinite set of valid inferences. Developing such a methodology for natural language (NL), Chomsky proposed that NL grammars be defined as a small number of rules inducing an infinite set of strings, with concept of wellformedness for a language then residing in whether or not the language is characterised by the given rule set. Grammars were to be evaluated by whether the set of rules that constituted such a grammar matched the right set of strings (observational adequacy), whether they did so in a principled way that was commensurate with capturing generalisations about the individual language (descriptive adequacy), or whether they did so relative to an overall theory of language capable of explaining the facts of language acquisition by a child exposed to any arbitrary language (explanatory adequacy). In this, he was universally followed. Whatever other cross-theory disagreements there might be, linguists agreed that there is no grounding of grammars directly in evidence from what is involved in producing a linguistic string or in parsing a linguistic string. Models of language were logically prior to any consideration of performance factors; and the data relevant to grammar construction had to be intuitions of grammaticality as made by individuals with capacity in the language. This early and universal commitment to complete separation of competence-based grammars from all performance considerations has been the underpinning to almost all linguistic theorising since then, though see Hawkins 1994, 2004 for an isolated exception (Higginbotham 1988 sets out a clear extension of this methodology to semantics). Ironically, it is developments in semantics which have led to the need to modify this stance as we shall see (Kamp 1981, Kamp and Reyle 1993); but it is only at the turn into the 21st century that this assumption is now being openly called into question (Kempson et al 2001, Cann et al 2005, Hamm et al 2006,, and also Phillips 1995, 2006).

Following up on the new Chomskian methodology, Katz and colleagues set out criteria of adequacy that a theory of natural-language semantics might be expected to provide: such a theory had to be able to express the relation between word meaning and sentence meaning as displayed by the compositionality of meaning for composite phrasal expressions; synonymy for all expressions which had the same meaning; entailment for all clausal expressions displaying a (possibly asymmetric relation of dependence of meaning); necessary truth for sentences which in virtue of their meaning are necessarily true; contradiction for sentences which are necessarily false in virtue of such meaning; and ambiguity for expressions with more than one distinct interpretation. The criterion was to devise rule specifications that get the right results in just the same spirit as the vehicle Chomsky had set out for syntacticians, with these rules being evaluable by their predictive success in yielding the requisite set of semantic relations/properties. Much of the focus was on exploring the “semantic representation” that should be assigned to words to provide a basis for predicting such entailment relations as *John killed Bill*, *Bill died*, or *John is a bachelor*, *John is an unmarried man*; and a supposedly universal set of “semantic markers”

- ADULT, HUMAN, CAUSE, BECOME and others - were posited as the basis out of which core lexical meanings were constructed by individual languages with so-called “distinguishers” providing language-particular idiosyncracies, which the child is said to possess innately. In those early specifications, no attempt was made to ground the proposed representations in a formal procedure for mapping from such constructs onto the objects/events which the natural language expression might be presumed to express (to provide a truth-theoretic grounding for such a characterisation).

## 1.2 Formal Languages: syntax, semantics and proof theory

In sharp contrast, defining a truth-theoretic grounding for natural language interpretation was the central focus of the Montague program. Montague advocated that by extending modal/temporal predicate logic systems with the lambda calculus to match the extra flexibility of natural language, each individual natural language could be seen as a formal language. As background to evaluating this claim, we provide a sketch of the syntax and semantics of the canonical formal language, predicate logic, and its attendant definitions of inference.

Predicate logic is definable as a language with lexicon, syntax and semantics (see Gamut 1991 for an exemplary introduction to predicate logic syntax, proof theory and semantics). There is a finite stock of primitive expressions, and a small set of operators licensed by the grammar – the connectives and the quantifiers:  $\wedge$ ,  $\vee$ ,  $\rightarrow$ ,  $\neg$ ,  $\forall$ ,  $\exists$ .<sup>1</sup> A finite number of syntactic rules defines the properties of these operators, mapping primitive expressions onto progressively more complex strings; and for each such bottom-up step of inducing greater complexity of structure, there is a corresponding semantic rule. There are a number of ways of defining such a semantics. In the Montague system, the semantics is defined with respect to a “model” where this is defined as (i) a set of stipulated individuals as the domain of discourse, (ii) appropriate assignment of base denotation for the primitive expressions from that set – individuals from the domain of discourse for names, sets of individuals from the domain of discourse for one-place predicate expressions, and so on. Semantic rules are then defined to map these assignments onto denotations for composite expressions. Such denotations are based exclusively on the basis of the assignments given to their parts and their mode of combination as defined by the syntax, yielding a truth value (1, 0 corresponding to True, False) for each propositional formula with respect to the model. There is a clear-cut restriction on the remit of such semantics, dictated by the design purpose of formal languages such as propositional and predicate calculus. Such logics are defined to provide the formal vehicle over which inference independent of subject matter can be defined. Accordingly, model-theoretic semantics for the expressions of the language take the denotation of terminal expressions as a primitive, without explanation: all that it provides is a formal way of expressing compositionality for the language, given an assumption of a stipulated language-denotation relation for the elementary expressions.

With such semantics defined, the relationships between propositional formulae are then them-

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<sup>1</sup>Technically, the lexicon contains solely predicate letters, individual constants, individual variables, and brackets, as the operators are introduced by the relevant syntactic rules, hence defined syncategorematically. However we approximate here, to bring out the parallelism with natural language.

selves definable. There are two co-extensive characterisations of inference for such systems. One, the more familiar to linguists, is the semantic characterisation: entailment for predicate-logic formulae is defined model-theoretically. A proposition  $\phi$  entails a distinct proposition  $\psi$  if in all models in which  $\phi$  is true  $\psi$  is true. Synonymy, or equivalence,  $\equiv$ , is when this relation is two-way; and a necessary truth is a propositional formula that is true in all models. The other characterisation is syntactic, i.e. proof-theoretic, with inference defined exclusively through the proof rules. A minimal body of proof rules is defined, and it is interaction between these rules which fully determines all and only the correct inferences expressible in the language. In a so-called natural deduction system (Fitch 1951, Prawitz 1965, Lemmon 1965), each operator has an associated introduction and elimination rule. Elimination rules map complex formulae onto simpler formulae: introduction rules map simpler formulae onto a more complex formula. For example, there is Conditional Elimination (classically called Modus Ponendo Ponens), which given premises of the form  $\phi$  and  $\phi \rightarrow \psi$  licenses the deduction of  $\psi$ ; there is Conditional Introduction, which, conversely, from the demonstration of a proof of  $\psi$  on the basis of some assumption  $\phi$  enables the assumption of  $\phi$  to be removed, and a weaker conclusion  $\phi \rightarrow \psi$  to be derived; there is  $\wedge$  Elimination licensing the move from  $P \wedge Q$  both to  $P$  and to  $Q$ , and  $\wedge$  Introduction licensing the inverse move from having established  $P$  and  $Q$  separately to the conclusion  $P \wedge Q$ . Universal Elimination licenses the inference of  $\forall x F(x)$  to  $F(a)$ , simplifying the predicate logic formula by removing the quantifying operator and replacing its variable with a constructed term. Universal Introduction enables the universal quantifier to be re-introduced into a formula replacing a corresponding formula containing a name, subject to certain restrictions. In rather different spirit, Existential Elimination involves a move from  $\exists x F(x)$  by assumption to  $F(a)$ , only licensing the return to the quantified assumption once some conclusion has been derived on the basis of satisfying a particular set of constraints, specifically that there must be nothing particular to the assumption of the name used in the assumption  $F(a)$  on which the derived conclusion depends. A sample proof, with annotations as metalevel commentary detailing the rules used, illustrates the characteristic pattern of these proofs: early steps of the proof involve eliminating the quantificational operators and the structure they impose, revealing the propositional structure simpliciter with names in place of variables; central steps of inference (here just one) involve propositional calculus steps; late steps of the proof may then re-introduce the quantificational structure with suitable quantifier-variable binding.

$\forall x(F(x) \rightarrow G(x)), \forall x.F(x) \vdash \forall x.G(x)$

1.  $\forall x(F(x) \rightarrow G(x))$  Assumption
2.  $\forall x.F(x)$  Assumption
3.  $F(a) \rightarrow G(a)$  Universal-Elim, 1
4.  $F(a)$  Universal-Elim, 2.
5.  $G(a)$  Modus Ponens 3,4
6.  $\forall x.G(x)$  Universal-Intro, 5

These rules provide a full characterisation of the phenomenon of inference itself, in that the interaction of these yields all and only the requisite inference relations as valid proofs of the system, with semantic definitions grounding the syntactic rules appropriately.

Bringing back into the picture the consideration relevant to linguists of how to use such formal

languages as a point of departure for modelling natural languages, what is striking about the association of inferences over names as part of the proof-theoretic characterisation of predicate logic is that these constructed so-called “arbitrary names” display a pattern remarkably similar to quantifying expressions of natural language. The vast majority of natural languages include quantified expressions as a mere subclass of syntactic expressions of an individual-denoting type:<sup>2</sup> NO natural language displays the predicate-logic structural property of having quantificational operators structurally defined as propositional operators, mapping sentence-sized structures into further sentence-sized structures. In some sense then that we might seek to exploit, quantifying expressions in natural language can be seen as closer to the PROOF constructs used in the explication of quantifying forms of inference than they are to the predicate logic language itself, that is the constructs used to model the dynamics of inferential action. As preliminary confirmation of this, there is tantalising parallelism between the so-called epsilon calculus (Hilbert and Bernays 1938) and natural languages. The epsilon calculus constitutes the formal study of arbitrary names manipulated in predicate logic proofs. This logic is a conservative extension of predicate logic, which means that exactly the same theorems are provable, though in making explicit properties of the arbitrary names that are only implicit in predicate logic, it is more expressive. With this extra expressivity, the defined name that corresponds to the arbitrary names of predicate logic proofs, the so-called epsilon term, has to carry a record of the mode of combination of the propositional formula within which it occurs:

$$\exists xF(x) \equiv F(\epsilon xF(x))$$

That is, the formula on the right hand side of the equivalence sign is a predicate-argument sequence and within the argument of this sequence, there is a required second token of the predicate  $F$  as the restrictor for that argument term ( $\epsilon$  is the variable-binding term operator that is the analogue of the existential quantifier). The effect is that the term itself replicates the content of the overall formula. If we now add a second conjunct to the predicate-logic formula above, in so doing creating the predicate-logic analogue to an existential assertion of natural language:

$$\exists F(x) \wedge G(x)$$

we see how with each increased step of complexity, the corresponding epsilon-term analogue becomes more complex, because, by definition, the name itself reflects the containing formula:

$$\exists xF(x) \wedge G(x) \equiv (F(\epsilon xF(x) \wedge G(x)) \wedge G(\epsilon xF(x) \wedge G(x)))$$

As we shall see in section 4, it turns out that this internal complexity to the epsilon terms corresponds directly to one well-known use of natural language pronouns, the so-called E-type pronouns (Evans 1980). In these uses, the pronoun has in some sense to pick up on the whole content of some previous propositional formula, despite acting as a naming device. So there is intrinsic interest in exploring links between natural language construal and epsilon terms (see Heusinger 1997, Kempson et al 2001, Kempson and Meyer-Viol 2004, Heusinger and Kempson (ed.) 2004). There is also, more generally, as we shall see in section 6 a growth of interest in exploring links between natural language interpretation processes and proof-theoretic characterisations of inference. However, the correspondence between the debate in logic of the relationship between proof-theoretic and model-theoretic forms of explanation and the debate in natural semantics as to whether representations of content are essential to natural-language explanation

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<sup>2</sup>Straits Salish might be an isolated example ( see Jelinek 1992), but the fact that even putative counter-examples are so rare buttresses the strength of the observation about natural language in general.

is not straightforward; and, as we shall see, interest in proof-theoretic methodologies has arisen from two quite different sources.

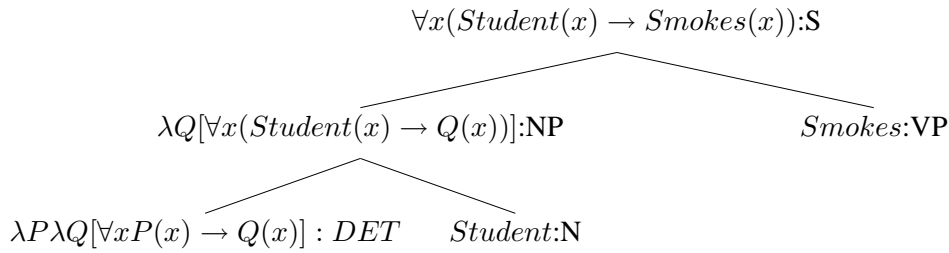
## 2 Natural language as a formal language: formal semantics

Avenues of research that explore structural concepts in semantics have only opened up relatively recently. From the late 70's and for the remainder of the twentieth century, natural-language research went in the semantic direction, driven by the Montague program of research which set its face against all psychologism or any form of representationalism in semantics. The force of Montague's program was to show by the combination of modal predicate logic with the lambda calculus, that predicate logic insights about existential and universal quantification can be preserved as the basis for a semantics for natural language expressions, despite the apparent disharmony between syntactic properties of natural language quantifiers as determiners and syntactic properties of predicate logic quantifiers: famously, one of Montague's paper bears the title "English as a formal language" (see Thomason ed. 1974). The critical new tool was the lambda calculus.

The lambda calculus is a logic with a function operator,  $\lambda$ , which binds variables in some open formula to yield a function from the type of the variable onto the type of the formula. For example  $F(x)$ , an open predicate-logic formula, can be used as the basis for constructing the function  $\lambda x[F(x)]$ , where the lambda-term is identical in content to the one-place predicate expression  $F$ . Thus, the formula  $\lambda xF(x)$  makes explicit the functional nature of the predicate term  $F$ , as does its logical type  $\langle e, t \rangle$  (equivalently  $e \rightarrow t$ ): any such expression is a function mapping individual-denoting expressions onto propositional formulae. As Montague so elegantly demonstrated (see Thomason ed. 1974), all that is then needed to yield a concept of compositionality of semantics for natural language strings, is to take the predicate logic analogue for any natural-language quantification-containing sentence, and define whatever processes of abstraction are needed over the predicate-expressions in the agreed predicate-logic representation of content to yield a match with requirements independently needed by the natural language expressions making up that sentence. So for example, on the assumption that  $\forall x(student(x) \rightarrow smoke(x))$  is indeed an appropriate point of departure for formulating the semantic content of *Every student smokes*, two steps of abstraction can be applied to the predicate logic formula, replacing the two predicate constants with appropriately typed variables and lambda operator to yield a term which can combine first with the term *Student* (to form a noun-phrase meaning) and then with the term *Smokes* (as a verb-phrase meaning) to yield back the predicate logic formula:

$$\lambda P \lambda Q [\forall x P(x) \rightarrow Q(x)] (Student) (Smokes)$$

This might be schematically represented as a tree structure with parallel syntactic and semantic labelling to bring out the parallelism between the lambda terms and NL syntactic categories, adopting conservative assumptions about what these should be:



The consequence of this view is that noun phrases in natural language are not analysed as individual-denoting expressions of type  $e$  (for individual), but as higher-type expressions ( $e \rightarrow t \rightarrow t$ ) expressions. Since the lower-type expression is derivable from the higher-type expression, such a lifting was taken to be fully justified by the reinstatement of syntactic and semantic parallelism for natural language expressions that it makes possible. This gave rise to the generalised quantifier theory of natural language quantification (see Barwise and Cooper 1981 and many others since). The surprising result is the required assumption that the content attributable to the VP is semantically the argument (despite whatever linguistic arguments there might be that the verb is the syntactic head in its containing phrase), and the subject expresses the functor that applies to it, mapping it into a propositional content, so semantic considerations and syntactic considerations appear no longer to coincide. At least, the verb no longer semantically constitutes the functional head of the sentence.

This methodology of defining suitable lambda terms that in combination can express the same content as some appropriate predicate-logic formula was extended across the broad array of natural-language structures. Hence the demonstrable claim that the formal semantic method captures a concept of compositionality for natural language sentences while retaining predicate-logic insights into the content to be ascribed, a formal analysis which also provides a basis for characterisations of entailment, synonymy, etc. With syntactic and semantic characterisations of formal languages defined in strictly separate vocabulary, albeit in tandem, the Montague methodology for natural languages necessarily imposes separation of syntactic and semantic characterisations of natural language strings, the latter being defined exclusively in terms of combinatorial operations on denotational contents, with any intermediate form of representation being for convenience of exegesis only. Montague indeed explicitly demonstrated that the mapping onto intermediate (intensional) logical forms in articulating model-theoretic meanings was eliminable.

There was little concern with the concept of meaning to be assigned to elementary expressions: these are simple model-specific stipulations. However, this did not mean that relationships between word meanings could not be expressed: any dependence there might be between expressions was outlined as definable by imposing constraints on possible denotations. For example, the verb *be* (under its construal as expressing identity), was defined to show how extensions of its arguments could be defined to ensure their identity across all possible worlds), and, conversely, the verbs *look for* and *find* were taken as examples where the two verbs must be defined to ensure that they NOT be assigned equivalent forms of denotational content (see Thomason ed. 1974).

### 3 The Demolition of the Katzian program

As it happened, the Montague proposal and the Katz proposals were being aired pretty much at the same time, and the very much more elegant model-theoretical characterisation swept the board. Indeed at the time, Lewis was dismissive of any representationalist program for semantics, and in a famously acid critique of the Katz' program for semantics (Lewis 1972), he declared that the Katzian representationalist program was empty of content since it did not provide what he called "real semantics", this being a treatment of truth conditions for natural language sentences. This critique was extremely influential; and the possibility of developing alternative proof-theoretic or other representationalist bases for characterising NL semantics was simply jettisoned without further consideration.<sup>3</sup>

At that time, there were in any case what were taken to be good additional reasons for not seeking to develop a proof-theoretic alternative to the model-theoretic program, principal amongst these being that for any one semantic characterisation, there are a large number of alternative proof systems for predicate and propositional calculus. Amongst the many variant proof-theoretic methods for predicate-logic proof systems, Fitch-style natural deduction is invariably informally cited as the closest to the observable procedural nature of natural language reasoning (Fitch 1951, Prawitz 1965, Lemmon 1965, Gabbay 1991). If consideration of external factors such as psycholinguistic plausibility had been taken as a legitimate criterion for determining selection between alternative candidate proof systems, this scepticism with respect to the feasibility of a proof-theoretic basis for natural language semantics might not have been so widespread. However, until the turn of this century, such inclusion of performance-related considerations was, and largely still is, deemed to be wholly illegitimate. There was very general agreement that there was no basis for selecting amongst putative proof-theoretic alternatives to the model-theoretic program, and hence that the only way to advance study of natural language semantics was to articulate some model-theoretic or equivalent mode of presentation. Subsequently a broad range of empirical results seemed to confirm this view, since the model-theoretic tools provided a sophisticated vocabulary for describing a very broad range of denotational meanings associated with natural language expressions: generalised quantifiers, modality, questions, relative clauses, etc, etc. In consequence, there was also very general acceptance of the view that the vocabularies for syntactic and semantic generalisations had to be disjoint (see Swart 1998, Chierchia & McConnell-Ginet 2000, Cann 1993 for textbook introductions), with all syntax-semantics correspondences having to be explicitly defined. Indeed the assumption of the separation of levels within the grammar has spawned a further paradigm of fruitful formal results: see in particular the glue logic results explored in LFG in applying linear logic to the articulation of the syntax-semantics interface within LFG Dalrymple (ed.) 1999). However, as we shall see, representationalist assumptions have been progressively re-emerging, for a number of rather different reasons, and amongst these are a group of researchers seeking to fulfil the Katz-style desideratum of providing appropriate predictions of entailment/consequence relations between natural-language sentences with a strictly

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<sup>3</sup>Some linguists have persisted with articulating representationalist forms of lexical analysis without providing formal-semantic underpinnings, relying on linguistic/computational/psycho-linguistic forms of justification alone (Jackendoff 2002, Pustejovsky 1995, Pinker 1994); but these have by and large not been taken seriously by semanticists.

proof-theoretic methodology (see Szabolsci 2005, Stabler 2005).

#### **4 The Challenge of context-dependence**

Despite the dismissal in the seventies of ANY form of representationalism within a formal-semantic characterisation of interpretation, it was known rightaway that the model-theoretic stance as a program for natural language semantics within the grammar isn't problem-free. One major problem is that natural language construal is very generally dependent on context, so that, at the very least, a truth-theoretic program for defining the semantics of natural-language expressions themselves has to be defined relative to some concept of context. The pervasiveness of this was not taken to be of great significance by some, and in Lewis 1972, the only provision that is made for the problem of context-dependence is the stipulation of an addition to the model of an open-ended set of "indices" indicating objects in the utterance context. Nevertheless, the problem posed by context was recognised as a challenge to be met; and an early attempt to meet it while sustaining the overall Montague conception of denotational semantics was proposed by Barwise and Perry (1983), with the articulation of situation semantics, for which an enriched semantic ontology was proposed to include situations and an array of partial semantic constructs (called variously "resource situations", 'infons', etc.) with sentence meanings requiring "anchoring" in such situations in order to constitute contents with context-determined values. Inference relations were then defined in terms of relations between situations, with speakers being said to be "attuned" to such relations between situations (see the subsequent exchange between Fodor and Barwise on such direct interpretation of natural language strings (Barwise 1987, Fodor 1988, Barwise 1989 (part II)). Notably, for all the enrichment of the ontology, the concept of denotational content defined over natural-language strings was retained.

Since then it has become increasingly evident that not only is the reliance on context of natural language construal systematic and pervasive, but if the concept of context is to fulfil its role of providing an adequate basis from which context-seeking forms of interpretations can be explained, this has to be richly structured in ways which reflect how information is projected for some given sentence-string, in ways that have no necessary ontological counterpart. Moreover, again reflecting the dynamics of language use, the concept of context has to be defined so as to allow perpetual update, with the interpretation of each expression, once established, itself becoming part of the context relative to which a subsequent string is to be construed. So problems of structure and incrementality matching the dynamics of language processing arise in all discussions of context-dependence, even within methodologies which remain neutral about general cognitive commitments of the model defined.

In due course, we shall see this emergent representationalism in connection with ellipsis; but recognition of the extent of the problem first emerged in attempts to provide principled explanations for the phenomenon of pronoun construal. Amongst the earliest observations, it was pointed out that pronouns can be interpreted either anaphorically, indexically or as a bound-variable. For example in (1), the pronoun is subject to apparent indexical construal (functioning like a name as referring to some intended object in some sense recoverable from the context):

(1) She is tired.

There are also bound-variable construals of the same pronoun such as (2) in which the pronoun is construed like a predicate-logic variable as having its interpretation determined by some antecedent quantifying expression, hence not from the context:

(2) Every woman student is panicking she is inadequate.

Yet Kamp and others showed (Evans 1980, Kamp 1981, Kamp and Reyle 1993) that there are further problems, in that the phenomenon of anaphoric dependence is not restrictable to the domain provided by any one natural-language sentence as reflected in some analogue of predicate-logic semantics. For there are in addition uses of that same pronoun in which it picks up its interpretation from a quantified expression across a sentential boundary:

(3) A woman student left. She had been panicking about whether she was going to pass.

If natural languages followed predicate-logic patterns directly, not only would we apparently be forced to posit ambiguity as between indexical and bound-variable uses of pronouns, but one would thus be confronted with puzzles that don't fall into either classification. One should not indeed expect such anaphoric connectedness, for the scope of the quantifier extends only over the sentence within which it is contained. So this type of pronoun has to be understood as giving rise to a term denoting some arbitrary witness of the preceding propositional formula, viz a name arbitrarily denoting some randomly picked individual having the properties of being a student, female, and having left. And this is where the proof-theoretic characterisation of names becomes relevant, for such natural-language construal is directly analogous to that of the epsilon terms underpinning the arbitrary names of natural deduction proofs, apparently carrying a history of the compilation of content from the sentence providing the antecedent (see Heusinger 1997 for related exploration of the applicability of the epsilon calculus). But this just adds to the problem; for now we appear to have three different bases of interpretation for one and the same pronoun. At the very least, there seems to be systematic ambiguity according as a pronoun is understood as indexical, as a bound variable, or as an epsilon term (a so-called E-type pronoun). Moreover, as Partee pointed out early on (1973), tense specifications display all the hallmarks of anaphora construal, able to be interpreted either anaphorically, indexically or as a bound-variable, indeed with E-type effects as well, so the phenomenon of apparent ambiguity clearly is not specific to pronouns.

## **5 Answers to the Context Challenge**

### **5.1 Discourse Representation Theory**

Discourse Representation Theory (Kamp 1981, Kamp and Reyle 1993) was the first formal articulation of a response to the challenge of modelling anaphoric dependence in a way that enables

its various uses to be integrated. Sentences of natural language were said to be interpreted by a construction algorithm for interpretation which takes the syntactic structure of a string as input and maps this by successive constructional steps onto a structured representation called a Discourse Representation Structure (DRS), which constitutes a partial model for the interpretation of the natural language string. These partial models are defined as containing named entities (“discourse referents”) introduced from natural-language expressions, with predicates taking these as arguments, and the sentence relative to which such a partial model is defined is said to be true as long as there is at least one embedding of the model so constructed into the overall model. Importantly such Discourse Representation Structures are taken to be the same kind of construct as the model itself: note the embeddability of the DRS into the total model as the condition for its truth. So for example, for a simple sentence-sequence such as:

(4) John loves a woman. She is French.

principles for building discourse representation structure, the so-called construction algorithm, induce a DRS for the interpretation of the first sentence in which a discourse referent is entered into the discourse model corresponding to the name and the quantifying expression, also entering a set of predicates/relations corresponding to the verb and noun.

x,y
<b>John</b> =x <b>loves</b> (x)( y) <b>woman</b> (y)

Such a DRS might then be extended by additional sentences as part of the algorithm defined for Discourse Representation Structure construction, continuing the process of defining the overall “discourse” by applying the algorithm to the second sentence, so that the initial DRS is extended to an expanded DRS:

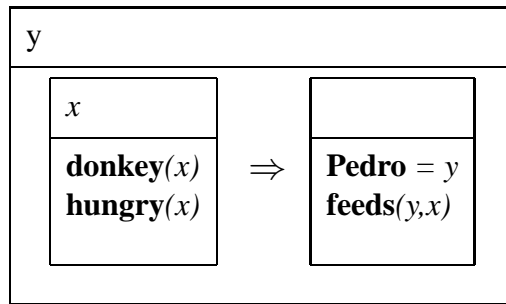
x,y,z
<b>John</b> =x <b>loves</b> (x)( y) <b>woman</b> (y) z = y <b>French</b> (y)

In such a process, definite NPs and pronouns require that the referent entered into the DRS be identical to some discourse referent already introduced: the whole DRS can then be evaluated by its embedding into the overall model. Any such resulting partial model is true if and only if there is at least one embedding of that partial model within the overall model.

This illustrative DRS is simple, but the construction of such DRS’s may be complex, with one DRS nested inside another, reflecting dependencies between them. A classic example is the

presentation of conditionals, for which the antecedent is said to induce the construction of a sub-DRS, the consequent another, with the truth-rule for the pair being that every embedding of the DRS corresponding to the antecedent clause must be extendible to a DRS containing also the specifications provided by the consequent clause (see Kadmon 2001 for an introduction). So for (5), the following complex nested structure has to be posited:

(5) If a donkey is hungry, Pedro feeds it.



The indefinite having only local scope involves entering a discourse referent into the most local structure: the name Pedro, being constant across worlds, involves nesting directly into the model, and is entered into the top box. The nested DRS is true if and only if for every world in which there is a donkey that is hungry, this is also a world in which Pedro feeds that donkey; and the whole DRS is true if there is at least one embedding into the overall model that makes that complex nested dependency true.

An immediate bonus for this approach is that the so-called E-type pronouns fall into exactly the same characterisation as more obvious cases of co-reference: all that is revised is the domain across which some associated quantifying expression can be seen to bind. It is notable in this account that there is no structural reflex of the syntactic properties of the individual quantifying determiner: indeed this formalism was among the first to come to grips with the name-like properties of such quantified formulae (see also Fine 1984, 1985). It might of course seem that such a construction process is obliterating the difference between names, quantifying expressions, and anaphoric expressions, since all lead to the construction of discourse referents in a DRS. But, as we've seen, these expressions are distinguished by differences in the construction process. Proper names are discourse referents which are directly nested in the model, hence for any DRS in the "top box", the least embedded level. Indefinite NPs are said to lead to the introduction of a new discourse referent, that is one not already entered into the DRS; conversely definite NPs and pronouns are required to introduce a discourse referent to be identified with a discourse referent already so introduced. By means such as this, the burden of explanation for natural language expressions is split: some aspect of their content is characterised by the mode of construction of the intervening DRS, some of it by the embeddability conditions of that structure into the overall model.

The particular significance of DRT lies in the Janus-faced properties of the constructs defined. On the one hand, this intervening level is a partial model, defined as true if and only if it is embeddable in the overall model (hence essentially the same type of construct). On the other hand,

the process of its progressive accumulation involves mechanisms for building this intervening construct; and Kamp argues (Kamp & Reyle 1993 and elsewhere) that the specific structural properties of the DRS are necessary to defining the appropriate antecedent-pronoun relation (a pronoun can only be construed by a discourse referent at the same or higher level in the discourse representation structure), hence such a level constitutes an essential intermediary between the natural-language string and the denotations to be assigned the natural-language expressions.

A further significance of the shift in perspective initiated by Kamp's work is the reflection in the model of the dynamics of HOW interpretation is progressively built up, by defining a progressive build-up of the DRS. This is an implicit rejection of the severe methodology whereby no reflex of performance should be included in any specification of aspects of natural-language competence, for the construction algorithm for building DRS's yields a formal reflection of the sentence-by-sentence accumulation of content in a discourse (hence the term "Discourse Representation Theory" ).<sup>4</sup>

## 5.2 Dynamic Predicate Logic

This formulation by Kamp of anaphoric resolution in terms of discourse-representations sparked immediate response from proponents of the model-theoretic tradition, in particular Groenendijk and Stokhof 1991, who argued that the intervening construct of DRT was on the one hand unnecessary, and on the other hand was illicit in making compositionality of natural-language expressions definable not directly over the natural language string but only via this intermediate structure. Part of their riposte to Kamp involved positing a new Dynamic Predicate Logic (DPL) with two variables for each quantifier and a new attendant semantics, so that one of these variables gets closed off in ways familiar from predicate-logic binding, but the second remains open, defined to be bindable by a quantifying mechanism introduced as part of the semantic combinatorix associated with some preceding string, hence obtaining cross-sentential anaphoric binding without any ancillary level of representation as invoked in DRT. The semantics for such partially closed propositional formulae then involves a semantics defined in terms of update to variable assignments. In consequence, both the logic and its attendant semantics is new. Nevertheless, such a view is directly commensurate with the stringently model-theoretic view of context-dependent interpretation for natural language sentences provided by eg Stalnaker 1971, 1999, Heim 1982: in these systems, progressive accumulation of interpretation across sequences of sentences in a discourse is seen exclusively in terms of intersections of sets of possible worlds progressively established, or rather, to reflect the additional complexity of formulae containing unbound variables, intersection of sets of pairs of worlds and assignments of values to variables (see Heim 1982 where this is set out in detail for NL).

Since then there has been continuing debate as to whether any intervening level of representation is justified over and above whatever syntactic levels are posited to explain syntactic properties of

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<sup>4</sup>An explicitly proof-theoretic characterisation of NL quantification was urged by Hintikka 1974, but in adopting tableaux systems to represent putative assignments of content to quantifying expressions, with their hunt-for-counterexamples methodology, the Hintikka system failed to correspond to incremental NL processing in the way that buttresses the plausibility of DRT as a model of interpretation matching the incrementality of NL interpretation; and the Hintikka system has not achieved centre-stage as a competitive alternative.

natural language expressions. Examples such as (6)-(7) have been central to the debate (Kamp 1996, Partee 1996, Dekker 1997):

- (6) Nine of the ten marbles are in the bag. It is under the sofa.
- (7) One of the ten marbles isn't in the bag. It is under the sofa.

According to the DRT account, the reason why the pronoun *it* cannot successfully be used with the interpretation that it picks up on the one marble not in the bag in (6) is because such an entity is only inferrable from information given by expressions in the previous sentence: no REPRESENTATION of any term denoting such an entity in (6) has been made available by the construction process projecting a discourse representation structure on the basis of which the truth conditions of the previous sentence are compiled. So though in all models validating the truth of (6) there must be a marble not in the bag described, there cannot be a successful act of reference to such an individual by the pronoun. By way of contrast, in (7), despite its being true in all the same models that (6) is true, it is because the term denoting the marble not in the bag is specifically introduced, anaphoric resolution is successful. Hence it is argued, the presence of an intermediate level of representation is essential, for purely linguistic reasons.

### 5.3 The pervasiveness of context-dependence

Notwithstanding the inconclusiveness of some of the debates in this area, Kamp's early DRT insight (Kamp 1981) that anaphora resolution was part of the construction algorithm for building up interpretation was set aside in the face of the charge that DRT could not provide a properly compositional account of natural language semantics, and in Kamp and Reyle 1993, an alternative generalised-quantifier account of natural language quantification was provided to reinstate compositionality of content over the natural language string within the general DRT framework (see also Eijk and Kamp 1997), even though positing an intermediate level of representation.

Despite great advances made by DRT in enriching the perspectives formal semantics could bring to modelling natural language interpretation, the broader issue of how to model context dependence continues to raise serious challenges to model-theoretic accounts of natural-language content, for the different modes of interpretation available for pronouns extends far beyond a single syntactic category. Definite NPs, demonstrative NPs, tense, etc can all be analysed by at least a three-way ambiguity between indexical, bound-variable and E-type forms of construal,<sup>5</sup> and this ambiguity, if not reducible to some general principle, requires that the language be presumed to contain more than one such expression, with discrete expression-denotation pairings. But this ambiguity is a direct consequence of the assumption that an articulation of meaning of an expression is to be given in terms of its systematic contribution to truth conditions of the sentences in which it occurs, and arguably no more than that. Such distinct uses of pronouns do indeed need to be expressed as contributing different truth conditions, whether as variable, as name, or as some analogue of an epsilon term; but the very fact that this ambiguity occurs in all

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<sup>5</sup>The anaphoric properties of tense were first noted by Partee 1973.

context-dependent expressions in all languages indicates that something systematic is going on: this pattern is wholly unlike the accidental homonymy proto-typical of lexical ambiguity (see Kempson et al 2001 chapter 1).

Furthermore, it is the phenomenon of context-dependence – its centrality to natural language construal and its total non-existence in formal language interpretation – which lies at the heart of the difference between the two types of system. In a formal language, by definition, there is no articulation of context and how interpretation is built up relative to that, for the phenomenon under study is that of inference. Natural languages are however not systems that are purpose-built as designed by the humans that use them, and context-dependence is essential to the success of natural language as an economic vehicle for expressing arbitrarily rich pieces of information relative to arbitrarily varying contexts. Evidence for this conclusion has been piling up over some time from work done not only in semantics but also in the neighbouring disciplines of philosophy of language and pragmatics. The gap between intrinsic content of words and their interpretation in use had been emphasised by Austin (1961) and Grice (papers collected in Grice 1989) amongst others, a problem that has been more recently taken up by pragmatists, in particular by Sperber and Wilson (1986/1995), whose relevance theory centres on the claim that the content of natural-language expressions systematically under-determines the information recoverable from their use in utterances. But the very fact that context is essential to natural language construal imposes an additional condition of adequacy specific to natural-language theorising: a formal characterisation needs to be provided both of the input which an individual natural-language expression provides to the interpretation process and of the context with which that input has to interact, so that the result of their interaction can be explained in a principled way. Answers to the problem of analysing context cannot be expected to come from formal language semantics. Rather we need some basis for formulating specifications that under-determine any assigned content. Given the needed emphasis on underspecification, on what it means to be part-way through a process whereby some content is specifiable only as output, it is natural to think in terms of representations, or, at least, in terms of constraints on assignment of content, and this is now becoming common-place amongst linguists (Reyle 1993, Koller et al 2002, Copestake 2005). Indeed Hamm, van Lambalgen and Kamp, following up on van Lambalgen and Hamm 2005 have argued explicitly such linguistically motivated semantics-internal representations have to be construed within a broadly computational, hence representationalist theory of mind (van Lambalgen and Hamm 2005, Hamm et al 2006).

## **6 The Shift towards Proof-Theoretic perspectives**

The shift towards more representational modes of explanation is not restricted to anaphora resolution. Following up on an independent logical proof of the isomorphism of the lambda calculus and type deduction of intuitionistic logic through the assumption of propositions as types, (The Curry Howard isomorphism), the fine structure of how compositionality of content for natural language expressions is built up can be elegantly represented, making use of such lambda-calculus intuitionistic-logic isomorphism (see Morrill 1994, Carpenter 1997).

## 6.1 The Curry-Howard Isomorphism

The Curry Howard isomorphism is displayed in proofs of type deduction in which propositions are types, and in which a labelling system is defined that demonstrates how that proof type as conclusion can be derived. The language of the labels defining this record is none other than the lambda calculus, with functional application in the labels corresponding directly to type deduction on the formula side. In the natural language application, reflecting this result, the compositionality of context expressible through functional application defined over lambda terms is representable as a step of natural deduction over labelled propositional formulae, with functional application on the labels and modus ponens on the typed formula. This is achieved by taking the logical type of the expression as representing some propositional formula,  $t, e, e \rightarrow t, e \rightarrow (e \rightarrow t)$ , all different propositional units, with contents attributable to underlying tokens of these types as a label for the given token. For example, a two-place predicate representable as  $\lambda x \lambda y[see(x)(y)]$  of type  $\langle e, \langle e, t \rangle \rangle$  can be stated as a label to a typed formula:

$$\lambda x \lambda y[see(x)(y)] : e \rightarrow (e \rightarrow t)$$

This, when combined with a formula

$$Mary : e$$

yields as output:

$$\lambda y[see(Mary)(y)] : e \rightarrow t$$

And this in its turn when paired with

$$John : e$$

yields as output by one further step of simultaneous functional application and Conditional Elimination:

$$see(Mary)(John) : t$$

It is notable that, in this application, proof-theoretic methods are used as a formal tool for modelling increase of information, even while providing a characterisation of inference (which is a decrease of information).

## 6.2 Labelled Natural Deduction in Type-Logical Grammar

This very general method for using the fine structure of natural deduction as a means of representing natural language compositionality has had very wide applicability (Dalrymple et al. 1991, Morrill 1994, etc. etc.), in particular in categorial grammar. In categorial grammar, following Lambek 1958, natural languages are defined as logics with attendant proof results definable. In the original Lambek system syntactic categories are defined as logical types with two order-sensitive connectives,  $\backslash, /$  reflecting order of expressions, eg.  $S, N \backslash S$ ;<sup>6</sup> but subsequently richer systems have been developed with infix operators  $\downarrow \uparrow$  on the semantic side, and

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<sup>6</sup>Following Morrill 1994, I take  $N \backslash S$  to represent an operator combining with a category of type N to its left to yield a sentence category, type N being of NP type).

a so-called “wrap” ( $W$ ) on the string side licensing permutation of expressions.<sup>7</sup> In such systems, quantifying determiners such as *every* can be defined as generalized quantifiers of type  $((S \uparrow N) \downarrow S)/CN$  (informally, a term that combines with a nominal restrictor to its right to yield a term that combines with a predicate term to yield a sentence ).

The properties of such type-assignments and accompanying proof-results can be defined as a logic with any suitable proof system; and in Morrill 1994 an explicitly natural-deduction style was used, as displayed in the following derivation for a quantifier containing sentence bringing out its scope potential. The proof for (8) sets out the types of individual expressions, combining them by labelled deduction when possible (*every* and *man* are combined at a very early step.<sup>8</sup> There is however a subproof constructing an assumption associated with the position in the string the quantifying expression has to bind, an assumption which gets discharged later to create an abstract that can combine with the construal assigned to *every man*, all very much in the manner of a predicate-logic natural-deduction proof:

(8) Every man walks.

1	$every - \lambda P \lambda Q \forall z (P(z) \rightarrow Q(z)) : ((S \uparrow N) \downarrow S)/CN$	
2	$man - man : CN$	
3	$walks - walk : N \setminus S$	
4	$every + man - (\lambda P \lambda Q \forall z [P(z) \rightarrow Q(z)](man) : (S \uparrow N) \downarrow S$	/Elim 1,2
5	$every + man - (\lambda Q \forall z [man(z) \rightarrow Q(z)] : (S \uparrow N) \downarrow S$	=4
6	$a - x : N$	Assumption
7	$a + walks - (walk x) : S$	\ Elim. 3,6
8	$\epsilon + a + walks - (walk x) : S$	= 7
9	$((\epsilon, walks)W a) - (walk x) : S$	=8
10	$(\epsilon, walks) - \lambda x (walk x) : S \uparrow N$	\uparrow Insertion 6,9
11	$((\epsilon, walks)W every + man) -$ $(\lambda Q \forall z [man(z) \rightarrow Q(z)] \lambda x (walk x)) : S$	\downarrow Elim. 5,10
12	$\epsilon + every + man + walks - \forall z [man(z) \rightarrow walk z] : S$	=11
13	$every + man + walks - \forall z [man(z) \rightarrow walk(z)] : S$	= 12

Steps (1)-(3) set out the elementary types. Steps (4)-(5) set out the combination of determiner and noun by labelled type deduction, displaying the Curry-Howard type isomorphism, with type-logical deduction on the syntactic categories, functional application on their labels. At step (6) the constructed assumption is introduced, with subsequent compilation of clausal content relative to that assumption, step (7). At step (8) the empty element,  $\epsilon$ , is introduced into the phonological

<sup>7</sup>Additional modal operators have also been defined as a means of determining further constraints on combinatorial license available to natural languages (see in particular Moortgat 1997, Morrill 1990, Vermaat 2005).

<sup>8</sup>The proof is taken from Morrill 1994 chapter 4 section 3.2. The specifics of the operations on the prosodic string involve permutation, a so-called *Wrap* operation (following Bach 1979) with the composite prosodic/semantic/deductive operations ensuring that some constructed assumption can be appropriately positioned through permutation operations to enable the corresponding lambda term to be constructed at the requisite point of quantifying in to ensure suitable scope construals for quantified expressions. In this proof,  $W$  represents the wrap operation,  $\epsilon$  the empty string, to enable the wrap rule to apply possibly vacuously, this being a basis for obtaining a maximally general characterisation of the combinatorial properties of the quantifying determiner simultaneously in the prosodic string and the semantic operations.

sequence, at step (9) permutation over the string places that empty element in argument position of the string while isolating by Wrap the constructed name, thereby preparing for the appropriate abstraction to remove the assumption of that constructed name (line 10). The process of  $\uparrow$ -Elimination, which involves functional application plus type-deduction at line (11) is defined to involve, in the string dimension, the introduction of a second Wrap operator to ensure that the effect in the string is to wrap the string, which is paired with the created abstract, around the quantifying expression. The result is that the quantifier expression arrives at exactly the position the constructed assumption had started out at, while in the formula, standard steps of reduction yield the requisite suitably-bound predicate-logic formula as the content suitably paired with *Every man walks*. Indeed, the specifics of both  $\uparrow$  introduction and  $\downarrow$  Elimination rules are set up in such a way that they will have this effect. The detailed motivation of these rules need not concern us here: rather, the significance of this application of a natural-deduction proof methodology is lack of any representationalist assumptions in adopting it. Morrill emphasises that use of such methodology doesn't involve any commitment to representationalism as such: the natural deduction format is intended ONLY as an elegant display of how sequences of words, prosodic sequences, are paired with combinatorial operations, and NO further structure is assumed for the paired prosodic and semantic devices taken as a composite labelling for the type-deduction operations.<sup>9</sup> Nevertheless, subsequent work in categorial grammar both him and others has involved further development of natural-language grammars as logics, enabling results about properties of natural-language grammars to be formally deducible (see Moortgat 1996, Stabler 2005, Areces and Bernardi 2004, Merenciano and Morrill 2003, Morrill and 2005)

### 6.3 Type-Theory with Records

Work by Morrill, Moortgat and colleagues has been broadly in such a type-logical tradition. Ranta however, defined a full proof-theoretic analogue of the Montague program following intuitionistic type theory (Ranta 1994),<sup>10</sup> with furthermore the Martin-Löf ontology that all aspects of proofs must be explicitly represented (Martin-Löf 1984). (Remember how in natural deduction proofs (section 1), the metalevel annotations vary very considerably in how explicit they are, and characteristically do not, for example, record dependencies between arbitrary names as they are set up - indeed the Morrill notation is only partially explicit in this respect.) The Martin-Löf methodology to the contrary requires that all such dependencies are recorded, and duly labelled; and Ranta used this to formulate analyses modelling naphora resolution, and from this to establish a structural concept of context.

The Martin-Löf system reflects the following assumptions:

- (a) propositions constitute judgements, and a labelled proposition is to be taken as an assertion of a proof of that proposition;
- (b) such labels, being a history of how the conclusion is derived, constitute the context for a proof of that proposition,

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<sup>9</sup>In more recent work, Morrill argues that Linear Logic labelling can be used as a direct reflection of processing complexity in the build-up of interpretation (Morrill and Gavarró 2004).

<sup>10</sup>Intuitionistic logic contains only the conditional as connective.

(c) dependencies between propositions can be defined, and must be reflected in the labelling. This leads to increase of structure both in the proposition as represented and the label. Intuitively, if  $\alpha_1 : T_1$  where  $\alpha_1$  labels  $T_1$ , and  $\alpha_2$  labels  $T_2$  where  $T_2$  is dependent on  $\alpha_1$ , then this dependency is to be made explicit as  $\alpha_2 : T(\alpha_1)$ .

Collections of such labelled formulae effectively take the form of an AVM,<sup>11</sup> in which one structure can be assigned as value to a given input. Relative to the Martin-Löf methodology all such pairings are labelled. Richly structured labels can thus be built up for any given deductive step reflecting the particular level of granularity required in the explanation. This notation, as Ranta and others following him have explored, can be applied in linguistic modelling, both to representation of semantic values and to syntax. Ranta developed a semantics for natural-language grammar formalism (TTG) using this general type-theoretic methodology. One of the results reported in Ranta 1994 is a proof-theoretic, hence syntactic, concept of context for natural-language construal, the incremental accumulation of labels providing a record of derivation steps. Ranta indeed used this as a basis for articulating pronoun construal (Ranta 1994). This was a new move for categorial-grammar formalisms that had otherwise paid little attention to anaphora; and Ranta and others following him have shown how, with the attendant Martin-Löf concept of dependent types, a fully explicit account of generalized quantifiers emerges as a consequence, from which an account of anaphora resolution follows that incorporates E-type pronouns as a sub-type. The account is similar in its range to that of DRT, but strictly proof-theoretic (see Pitek 1998, Ahn 1999, Fernando 2002).<sup>12</sup> Despite the advocacy of a Martin-Löf methodology as applied to natural language semantics, the TTR framework should not be presumed to involve any commitment to representationalist assumptions in the sense of mentalism. To the contrary, the presentation of a proof-theoretic methodology was adopted purely as a needed basis for a fully explicit characterisation of the fine structure of how natural-language content is built up.

In Cooper 2006, the Ranta framework is taken a step further, yielding the Type Theory with Records framework (TTR). Cooper uses the concepts of records and record-types is used to set out a general framework for modelling both context-dependent interpretation and the intrinsic underspecification that natural-language expressions themselves contribute to the interpretation process. I give merely the flavour of this here. Echoing the DRT formulation, the interpretation to be assigned the sentence *A man owns a donkey* is set out as taking the form of the record type (Cooper 2005):<sup>13</sup>

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<sup>11</sup>Attribute Value Matrices are a core notation made use of in HPSG, so a means of unifying syntactic and semantic displays, at least in format; and they are used in TTR to bring together HPSG and record-type syntax and semantics respectively.

<sup>12</sup>Such dependency-labelling has properties like that of epsilon terms of the epsilon calculus, since the terms that constitute the labels to the derived types express the history of the mode of combination, in the same manner as does the history-reflecting internal structure of epsilon terms.

<sup>13</sup>It should be noted that what are characterised as variables in these formulations, as labels to proof-terms, do not correspond straightforwardly to predicate-logic-like variables, for variables in predicate logic have no life independent of the quantifier relative to which they are defined. These to the contrary have a life entirely independent of any quantifier. Rather they are more like arbitrary names, expressing dependencies between one term and another, whose semantics has to be defined as a choice function. Here these are used as the basis for characterising indefinite quantification. Analogous model-theoretic accounts of indefinite quantification exist in which choice functions are posited to achieve analogous results without any such representational proof-theoretic interface (eg Winter 1997, Kratzer this volume (CHECK), and papers in Heusinger and Kempson 2004), but without this interface, the positing of such functions is a stipulation of added complexity in what is otherwise a purely model-theoretic form of

$$\left[ \begin{array}{l} x : Ind \\ c_1 : man(x) \\ y : Ind \\ c_2 : donkey(y) \\ c_3 : own(x, y) \end{array} \right]$$

$x, y$  are variables of individual-type,

$c_1$  is of the type of proof that  $x$  is a man, (hence a proof that is dependent on some proof of  $x$

$c_2$  is of the type of proof that  $y$  is a donkey, ...

A record of that record type would be some instantiation of variables eg :

$$\left[ \begin{array}{l} x = a \\ c_1 = p_1 \\ y = b \\ c_2 = p_2 \\ c_3 = p_3 \end{array} \right]$$

$p_1$  a proof of ‘man( $a$ )’,

$p_2$  a proof of ‘donkey( $y$ )’,

and so on.

The record represents some situation that provides values that make some record-type true. It is thus the concept of record-type that corresponds to the concept of sentence meaning, in abstraction from any given context/record; and a general concept of sentence-meaning is defined as a mapping from records to record-types.

This is a proof-theoretic re-presentation of the situation-theory concepts of infon (= situation-type) and situation (see Cooper 2005), given the representation both of a situation in the form of a record, and some abstraction from it in the form of a record-type. The parallel with a DRS is also deliberate, with the concept of pairing of record-type with a record, paralleling the pairing of a DRS with its attendant embeddability condition that the DRS be true if and only if it is embeddable into the overall model. The difference between the two forms of representation lies primarily in the grounding of records and record-types in proof-theoretic rather than model-theoretic underpinnings. Again it should be stressed that such a move is entirely neutral with respect to any assumption of psychological grounding of such representations: indeed Cooper himself prefers a construal of such records in set-theoretic terms (see Cooper 2004). Nevertheless, there is an immediate advantage to making the move from a model-theoretic concept of context into a proof-theoretic one. The proof-theoretic concept of context is richer, allowing arbitrary levels of nesting of records;<sup>14</sup> and this opens up the potential for exploring novel analyses of presuppositional phenomena in these terms.

This articulation of record theory with types as a basis for natural language semantics leaves open the link with the syntactic algebra to be defined. In Ranta’s own development of TTG (Ranta

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explanation.

<sup>14</sup>Variables have to be indexed to keep track of where they have been introduced, as Cooper (2005) notes, providing an irreducibly representationalist flavour.

1994), the primary concern was to develop proof-theoretic foundations for Montague Grammar, and, as in Montague's system, the status of syntax was relatively weak: areas of natural-language syntax where there appears to be mismatch between syntactic and semantic characterisation were set aside as mere sugaring, not needing principled formulation. Labelling systems for logical inference can however be used more generally (see Gabbay 1991 for a general formal characterisation of labelled deductive systems); and in recent work, Cooper and colleagues have extended the concept of records and record-types yet further to incorporate full details of linguistic signs (with phonological, and syntactic information as well as semantic) so that the labelling methodology of proof theory is extended to the full range of grammar-internal statements, pairing together TTR with HPSG.

In TTR put together with HPSG, such proof-theoretic methodologies have been used to combine syntactic and semantic information in a neutral AVM format. Proof-theoretic methodologies have also been used to map syntactic onto semantic information while retaining their independence within Lexical Functionist Grammar, with assumptions of Linear Logic being used to define a “glue language” articulating the interface between syntactic and semantic representations providing fine structure for articulating quantifier construal variation while sustaining an independent (and multi-level) concept of syntax (see Dalrymple 2009 ed. for a representative set of papers).<sup>15</sup> Others advocating explicitly representationalist models of content that bring together formal, computational and semantic considerations are Hamm and van Lambalgen 2004, Hamm et al 2006.

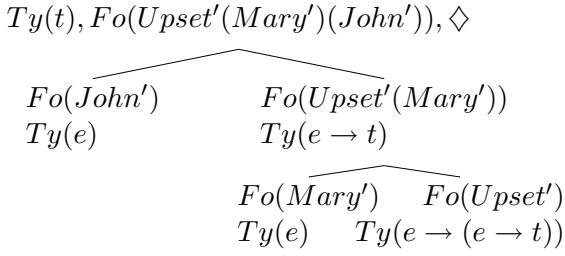
#### 6.4 Dynamic Syntax: Parsing Dynamics as a basis for syntax

Further still along the representationalist cline is the so-called Dynamic Syntax approach (Kempson et al 2001, Cann et al 2005); and in this theory, the advocacy of mentalism becomes explicit. Dynamic Syntax models the dynamics of how interpretation is incrementally built up following the dynamics of parsing, with progressively richer representations of content constructed as the words are processed relative to context. What is radical about Dynamic Syntax is that this model of the stepwise way in which interpretation is built up in context during a parse is seen as syntax: indeed the claim is that this is ALL that is needed for explaining natural-language syntax (Kempson et al 2001, Cann et al 2005). The general methodology is to adopt a representationalist stance vis a vis content (Fodor 1983) using constructs such as the logical types  $e$ ,  $e \rightarrow t$  familiar in formal semantics, but then to represent predicate-argument structures in a tree format, treat them as the basis for syntax, and furthermore to add the assumption that concepts of underspecification and update should be extended from semantics/pragmatics into syntax. The concept of progressive update of partial tree-representations of content totally replaces the semantically blind syntactic specifications characteristic of such formalisms as Minimalism (Chomsky 1995) and HPSG (Sag et al 2002) (see Kempson et al 2001, Cann et al 2005, Purver et al 2006 for formal details). Trees in this system reflect representations of predicate-argument content, with propositional formula for a completed tree at the root, sub-terms of that formula its dominated nodes, so the resulting interpretation for a string such as *John upset Mary* would, schematically,

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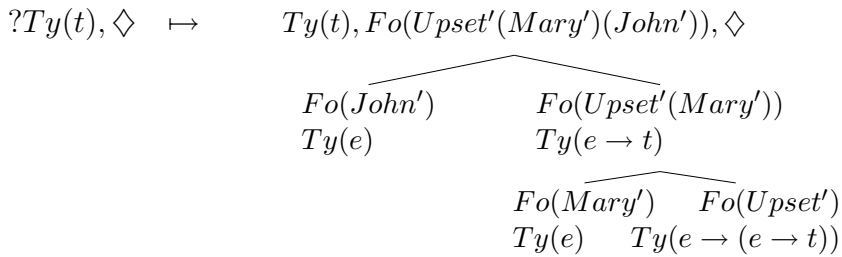
<sup>15</sup>Linear logic articulates a concept of linear-dependence into the proof steps by defining connectives relative to the constraint that assumptions can never be used more than once.

be:



The substance of the syntactic system however lies in the growth process onto such a tree. The general process of parsing is seen as starting from an initial one-node tree simply stating the goal of the interpretation process which is to establish some propositional formula (the tree representation to the left of the  $\mapsto$  in (9)) and then, using both parse input and information from context, to progressively build up some propositional formula (the tree representation to the right of the  $\mapsto$  in (9)). In all cases, the output is a fully decorated tree whose topnode is a representation of some proposition expressed with its associated type specification; and each node in a completed tree has a concept formula, e.g.  $Fo(John')$  representing some individual John, and an indication of what semantic type that concept is ( $Fo$  for *Formula*). The primitive types are types  $e$  and  $t$  as in formal semantics but construed syntactically as in the Curry-Howard isomorphism, with labelled type-deduction determining the decorations on non-terminal nodes.<sup>16</sup> There is invariably one node under development in any partial tree, as indicated by the pointer  $\diamond$ . So a parse process for (9) would constitute a transition across partial trees, the substance of this transition turning on how the growth relation  $\mapsto$  is to be defined:<sup>17</sup>

(9) John upset Mary.



Parsing *John upset Mary*

The concept of *requirement*  $?X$  for any decoration  $X$  is central. Decorations on nodes such as  $?Ty(t)$ ,  $?Ty(e)$ ,  $?Ty(e \rightarrow t)$  etc. express requirements to construct formulae of the appropriate type on the nodes so decorated, and these requirements drive the subsequent tree-construction process. The general dynamics is to unfold a tree structure imposing such requirements by a combination of general rules for tree growth and lexical actions contributing concepts and other aspects of structure, and then compositionally to determine the combination of those concepts

<sup>16</sup>There are other types, but the list is highly restricted. Unlike categorial grammar formalisms (see eg Morrill 1994), there is no recursive definition of types, no type-lifting or composition of functions.

<sup>17</sup>Here and elsewhere in the development of DS to date, a highly simplified account of proper names is assumed, with no attempt to address the substantial issues in addressing the context-sensitivity of linguistic names.

in a strictly bottom-up fashion using labelled type-deduction in the style of the Curry-Howard isomorphism to yield the overall interpretation, leaving no requirements outstanding. Indeed a string is said to be wellformed if and only if there is at least one derivation involving monotonic growth of partial trees which is licensed by computational (general), lexical and pragmatic actions following the sequence of words given that yields a complete tree with no requirements outstanding.

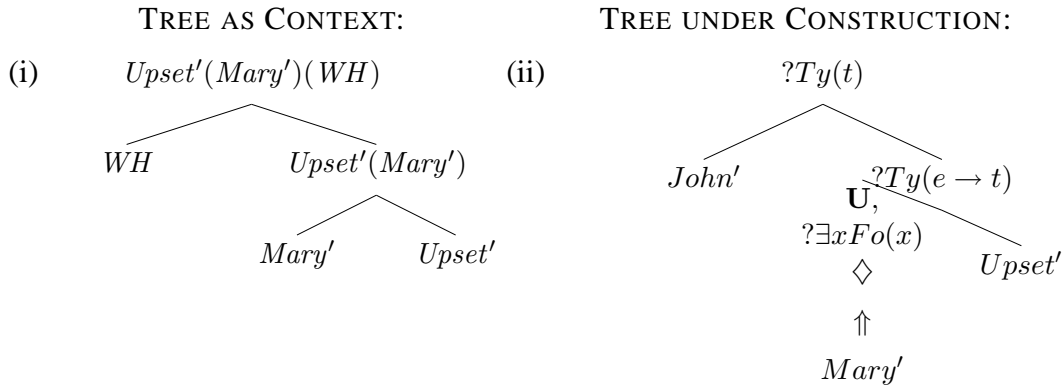
The concept of requirement and its mode of resolution underpins a range of syntactic generalisations. Just as the concept of tree growth is central, so too is the concept of procedure for mapping one partial tree to another. Individual transitions from partial tree to partial tree are all defined as *procedures* for tree growth.<sup>18</sup> This applies both to general constraints on tree growth (hence the syntactic rules of the system) and to specific tree update actions constituting the lexical content of words. So the intrinsic contribution which a word makes to utterance interpretation is invariably more than just a specification of some concept: it is a sequence of actions developing a sub-part of a tree, possibly building new nodes, and assigning them decorations such as formula and a type specifications.

Of the various attendant concepts of underspecification, two are of particular importance, that associated with anaphoric expressions and that associated with left-peripheral expressions, in other frameworks “extracted” from some clause-internal position. Anaphoric expressions are defined as adding to a node in a tree a place-holding metavariable of a given type as a provisional formula value: but this interim value is seen as having to be replaced by some fixed value which the immediate context makes available. The update for the associated metavariable is driven by the requirement  $?\exists x Fo(x)$  which accompanies it, a requirement which has to be satisfied either by selection of a value from context or from the construction process, with reflexive pronouns requiring the provision of such an update from within a minimal predicate-argument domain, pronouns from outside that domain. Thus on the assumption (to be justified in section x.x) that context too is represented in exactly similar terms - as a record of previous parse states containing trees and actions, the resolution of anaphora is taken to be defined over representations, selecting some representation of appropriate type out of the structure provided by the context:

(10) Q: Who upset Mary?      Ans: John upset her.

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<sup>18</sup>The formal system underpinning the partial trees that are constructed is a logic of finite trees (LOFT: Blackburn and Meyer-Viol 1994). There are two basic modalities,  $\langle \downarrow \rangle$  and  $\langle \uparrow \rangle$ , such that  $\langle \downarrow \rangle \alpha$  holds at a node if  $\alpha$  holds at its daughter, and the inverse,  $\langle \uparrow \rangle \alpha$ , holds at a node if  $\alpha$  holds at its mother. Kleene \* operators are also defined over these relations, so that  $\langle \uparrow_* \rangle Tn(a)$  is a decoration on a node, indicating that somewhere dominating it is the node  $Tn(a)$  (a standard tree-theoretic characterisation of ‘dominate’, used in LFG to express *functional uncertainty* see Kaplan and Zaenen 1988). The procedures in terms of which the tree growth processes are defined then involve such actions as  $make(\langle \downarrow \rangle)$ ,  $go(\langle \downarrow \rangle)$ ,  $put(Fo(\alpha))$ ,  $make(\langle \downarrow_* \rangle)$ , et.



The parsing of *John upset her* in (ii) of (10) involves substitution of the term *Mary'* as this is a formula of appropriate type provided by the context of having parsed the string *Who upset Mary*. Indeed such a selection must be made as otherwise the requirement on provision of a fixed formula value,  $?\exists x Fo(x)$ , will not be satisfied, and no wellformed outcome derived. This yields ambiguity of construal correctly without having to specify ambiguity in the content of the word itself, this ambiguity arising whenever the context makes available more than one possible substituent for the metavariable which the encoded actions of the pronoun provide. The observation which this formal account reflects is that though anaphoric expressions play an essential role in the process of interpretation, by analysis contributing to the monotonic tree growth process like all other words, they do not introduce a fully specified concept. Hence the flexibility of how their interpretation is assigned while nevertheless meeting the condition of conforming to a strictly incremental account of the processing of the words.

This is a relatively uncontroversial approach to anaphora construal, equivalent to formulations in many other frameworks (notably DRT). The emphasis on underspecification intrinsic to natural-language construal is however pushed considerably further than this in Dynamic Syntax. Given a system in which interpretation is defined in terms of tree growth, all aspects of that growth process are expected to allow for systemic underspecification involving update articulated as part of that process, with structural underspecification and tree-growth included as one type of update. Making this assumption concrete provides a basis for providing a new perspective on many core syntactic phenomena. Long-distance dependency, the central instance of movement within transformational grammars, is defined as involving introduction of an UNDERSPECIFIED structural relation whose value must be provided from the construction process.<sup>19</sup>

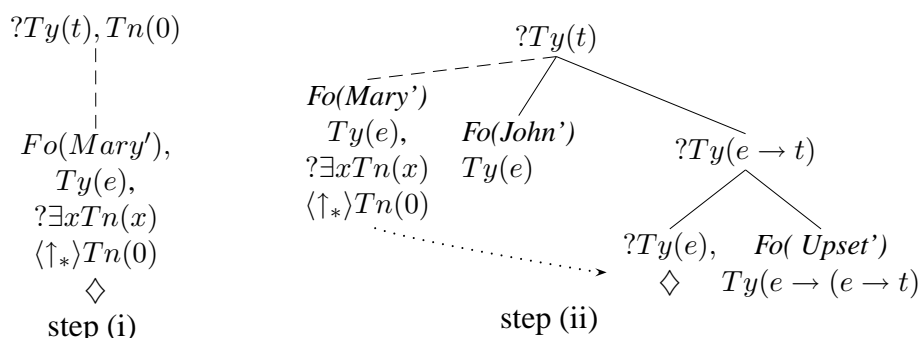
(11) *Mary, John upset.*

In (11), for example, the word *Mary* is construed as providing a term to be used in deriving the resulting logical form, but the node which it decorates does not have its relation within the overall

<sup>19</sup>See 3.1 for an argument that the type of fragment ellipsis argued by Stainton 2004 to be intransigent for syntactic explanations of ellipsis, constitutes a context-provided enrichment of such a relation, allowing that such underspecification of structure might be updated from context.

structure yet fixed. Formally the construction of a new node within in a partial tree is licensed from some node requiring a propositional type, with that relation being characterised only as that of domination (weakly specified tree relations are indicated by a dashed line: this is step (i) of (12)). Accompanying the under-specified tree relation is a requirement for a fixed treenode position:  $?\exists xTn(x)$ . The update to this relatively weak tree-relation becomes possible only once having parsed the verb (this is the unification step (ii) of (12)), an action which satisfies both type and structure update requirements:

(12) Parsing *Mary, John upset*:



This process, like the substitution operation associated with pronoun construal feeds into the ongoing process of creating some completed tree, in this case by subsequent steps of labelled type deduction.<sup>20</sup> We then expect this process of structural update to interact with the process of anaphora construal, and a number of syntactic effects fall out in consequence - expletive pronouns as in *It is likely that Ruth is wrong*, resumptive pronouns as in *This is the man who I wish HE would take over as Department head rather than Bill*, among others (see Cann et al 2005). Even case specifications, an uncontentionally syntactic phenomenon, can be analysed in terms of constraints on tree growth, at least for the structurally transparent forms of case. For example,  $?(\uparrow)Ty(e \rightarrow t)$  is the requirement associated with accusative case, notably definable over the emergent tree, determining that the node being decorated by the case-marked expression must, in the output, be immediately dominated by a mother node whose formula is of type  $t$ .

There is more to be said of course to cover the full diversity of types of structure: relative clauses, coordination, adjuncts etc will all need addressing: the DS framework involves the projection of pairs of trees to express such compound structures. There is also the full account of quantification, and how the epsilon calculus can provide an adequate basis for this. However, this sketch is sufficient to see the shift in ontology into a Fodorian representationalist stance: on this view, natural languages are denotationally interpretable only via a mapping onto constructs in an intermediate logical system. And, since compositionality of denotational content is defined over the

<sup>20</sup>It might seem that all such talk of (partial) trees as representations of content could not in principle simultaneously serve as both a syntactic explanation and a basis for semantic interpretation, because of the problems posed by quantification, known to necessitate a globally defined process expressing scope dependencies between quantifying expressions. However, quantified expressions are taken to map onto epsilon terms, hence of type  $e$  (for details of how an account of scope dependencies can be compatible with an incremental perspective on NL construal, see Kempson et al 2001 ch.7).

resulting trees, it is the incrementality of projection of word meaning and the attendant monotonicity of the tree growth process which is the only analogue to compositionality that can be defined for the sequence of words making up any such uttered sentence.

## **7 Ellipsis: a window on context?**

Looking back over the unfolding of different perspectives on the phenomenon of context-dependence, we see how there has been an inexorable shift into taking some form of representationalism for granted: it is indeed striking in reflecting on this narrative, how after a long period in which articulating representationalist views risked either being ignored or ridiculed, advocacy of representationalism as a basis for explaining natural language semantics has now become legitimised. This shift towards representationalism is strongly buttressed by ellipsis, which has become one focus of attention in current research on context. Indeed it was the challenge of capturing the range of ellipsis data that has been the primary motivation for the incorporation of sign-based information in the articulation of record-types (Ginzburg and Cooper 2004). The significance of ellipsis as evidence for the concept of context lies in the pretheoretic observation that ellipsis constitutes a heterogeneous bunch of phenomena where, in some sense to be explained, whole phrases can be omitted because the context in which the expression is uttered **DIRECTLY** provides what is needed to understand what is overtly only a fragment. In searching for an appropriate formulation of context for natural-language construal, ellipsis thus promises to provide a good source of data.

### **7.1 Ellipsis: Syntax vs Semantics?**

In the study of ellipsis, as with anaphora resolution, the debate has centred on the problems of structure-dependence, and putative ambiguity. The primary debate has been taken to be whether the mode of construal has to be structure-dependent, hence as involving mappings from representation to representation (where this is presumed to be the remit of syntax: Fiengo and May 1994), or whether the requisite range of construals is definable using only model-theoretically definable constructs direct from the input natural language string onto propositional contents (for a range of different views, see Lappin and Benmamoun 1999). Ambiguity of the input string by assigning it more than one syntactic structure is very generally presumed (Merchant 2002, Stanley 2000, along with many others), a stance which simply assumes that ellipsis is not a unitary phenomenon. Yet, given that ellipsis is a universal phenomenon, with broadly similar cross-linguistic forms of construal despite syntactic variability, there is the challenge of whether the ambiguity can be characterised in terms of systematic underspecification of content that the expressions themselves provide, with their more elaborate construal made possible by what is provided in context (Purver et al 2006). A theory of context here, as elsewhere, is seriously needed.

Until very recently, no standard formalism could make available a unitary account of ellipsis. The problem turns on such diversity as (13)-(17):

(13) John washed his socks and Bill did so too

(13) raises the challenge that, even on a single construal of the first conjunct as ‘John washed John’s socks’, the sentence is ambiguous according to whether Bill washed John’s socks (the “strict” interpretation) or his own (the “sloppy” interpretation) (see Dalrymple et al 1991 for extended discussion): this availability of both strict and sloppy interpretations of elliptical forms is universal. (14) poses a different and very English-specific challenge, so-called antecedent-contained ellipsis, in which the ellipsis site is reconstructed from within a single sentential sequence, threatening circularity for any simple copy analysis to the VP itself (Hornstein 1996):<sup>21</sup>

(14) John interviewed everyone Bill did

Then there is (15), known since Ross 1967 as Stripping, again a very general cross-linguistic phenomenon, differing across languages only in what provides the license for such construal:

(15) John wanted Ann to visit Bill in hospital; and Sue too.

This is ambiguous according to whether the construal of the fragment *Sue too* involves some process of substitution, replacing the interpretation provided by any one of the three NPs in the construal of the first conjunct with that made available by the fragment. There are also other constructions such as Sluicing and Gapping, which both involve general cross-linguistic properties, yet language-particular idiosyncracies (Merchant 2002, Neijt 1980, Steedman 2000):

(16) John interviewed a friend of mine; and he didn’t say who.

(17) John interviewed Bush, and Harry, Clinton.

The question is whether any sense can be made of the intuition that in each case it is the context being used that provides the interpretation of the second conjunct, despite the rather different modes of construal. Advocates of syntactic accounts of ellipsis would give a negative answer, on the grounds that these involve discrete syntactic analyses with a phonological filter which simply deletes all but the (single) fragment expression in the second conjunct upon the mapping of syntax into phonology, preserving semantic properties (Fiengo and May 1994, Stanley 2000, amongst others). On this view, context plays no essential role: the phenomenon is simply that of a set of unrelated structures (each notably separately named), warranting grammar-internal specification of discrete structures, all of which happen to result in deletion of portions of the induced tree. An alternative semantic account of ellipsis has been proposed to cover some of these cases (Dalrymple et al 1991, and others following). In Dalrymple et al, a higher-order abstraction operation on the denotation content of the first conjunct is defined to yield an interpretation which

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<sup>21</sup>Its restriction to English rests on specific properties of English auxiliaries as licensing ellipsis, which many languages do not.

can be unified with the content presented by the fragment in the second conjunct to yield the requisite interpretation. This semantic account of ellipsis faces the problem that different modes of construal are subject to different syntactic constraints, a matter which points contrarily to a syntactic account, for at least some cases. In particular, the higher-order unification account is poorly adapted to providing an account of the antecedent-contained ellipsis presented in (14), for that account relies on some composite denotational content (of type *t*) over which to define some higher-order abstraction as input to construal of the fragment which this structure does not, on the face of it, provide. Indeed, all fragments that are incrementally construed as part of the process of constructing sentence-interpretations are problematic:

- (18) John is coming to visit me, in London, and my mother in Cyprus, as part of a round-the-world trip.

On the other hand, syntactic analyses of ellipsis are ill-equipped to handle apparently indexical bases of construal for ellipsis (Stainton 2004):

- (19) A (stepping out of the lift): McWhirters, please?  
B: Second on the left.

And so the debate goes on. The challenge of providing an integrated basis to ellipsis might seem to be illusory.

## 7.2 Ellipsis, context, and dialogue-modelling

Most recently the debate about ellipsis has taken on new significance, because successful modelling dialogue has been set out by Pickering and Garrod 2004 as a pre-requisite on theoretical explanations of language given the centrality of conversational dialogue as constituting the core language data. Dialogue exchanges are indeed a rich source of ellipsis data; and the hunt is on for a concept of context which is itself rich enough to provide a unitary basis for the various divergent forms of ellipsis and ellipsis construal, of which the hardest challenge is posed by so-called “split utterances” :<sup>22</sup>

- (20) A: We’re going to ..  
B: Tathersham.  
A To see my brother.  
C: Has he asked you to?
- (21) A. They X-rayed me, and took a urine sample, took a blood sample.  
A: Er, the doctor  
B: Chorlton?  
A: Chorlton, mhm, he examined me, erm, he, he said now they were on about a slight [shadow] on my heart.

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<sup>22</sup>Example (21) is taken from the BNC, file KNY (sentences 315–317).

These fragments have multiple uses - as extensions, clarifications, acknowledgements - all of them in some way depending on context. The challenge has become one of seeing such elliptical fragments in a perspective that absorbs the apparently heterogeneous syntactically discrete operations that ellipsis construal can give rise to. There is good reason to think this is the right way to go. Like anaphora, ellipsis construal is not a language-specific phenomenon. All languages make extensive use of ellipsis, and presume on its dependence on context for its construal. Languages differ over the points at which elliptical strategies can be made use of: the *do so too* phenomenon of English is indeed idiosyncratic to the language and doesn't carry over readily from language to language. However, the phenomenon of bare expressions construed on the basis of what context makes available is an extremely general phenomenon, displayed in some form or other in all languages. Just as with anaphora, any approach which simply stipulates heterogeneity, with accompanying claims of ambiguity, gives every appearance of simply failing to meet the challenge which ellipsis poses. We want an account of ellipsis which involves articulation of context in a sufficiently representational and structured way to allow the rich divergent effects and the individual variation across languages, while nevertheless allowing an integrated basis from which the diversity can be predicted in a principled way.

Two approaches to dialogue are indicative of the new representationalist research directions being explored. On the one hand, there is the sign-based approach of Ginzburg and Cooper already alluded to in connection with the proof-theoretic paradigm for natural language semantics advocated by Ranta. Cooper and colleagues have developed a dialogue system GODIS (Larsson 2002, Cooper et al 2003, Cooper and Larsson forthcoming) to match the extension of Ranta 1994 defining record types as labels to type deduction; and this is now further extended to incorporate a representation of how the projected content might be realised as a structured natural-language string (Ginzburg and Cooper 2004). This enrichment of Ranta's 1994 system is essentially representational; and Ginzburg and Cooper argue for such recursively-complex form of labelling on the basis that a fragment expression may take a morphological form, eg a case specification, that necessitates a particular syntactic environment, a restriction only stateable in the syntactic vocabulary of the grammar formalism, and not as a semantic restriction. Nevertheless, the underlying syntactic/semantic interpretation mechanisms and the associated dialogue context-update mechanisms are essentially sentence-based, with fragments treated as schematic sentential forms with underspecified propositional contents (hence of propositional type). In consequence, the framework therefore has, as yet, a limited capacity for reflecting incrementality at any sub-sentential level as displayed by (20)-(21).

### **7.3 Ellipsis construal in Dynamic Syntax**

Dynamic Syntax is the other competitor in this arena; and, as we shall now see, the action-directed representationalist perspective seems to have the leading edge in providing an integrated account of the context-dependence that ellipsis construal displays, while nevertheless characterising the diverse effects that elliptical forms give rise to.

**Use of context-provided formulae** We have already seen that anaphoric processes induce substitution of some conceptual representation provided from context; and elliptical phenomena, too, demonstrate the ability by language-users to pick up on terms as made available from some previous parse process, re-using a predicate formula by a simple substitution process. This is illustrated with the anaphoric use of VP ellipsis, via the assumption that auxiliaries, like pronouns, in having an anaphoric role, project a meta-variable, a predicate place-holding device. The basis for enriching that meta-variable is assumed to be made available in the immediate context got from parsing previous strings directly following the pattern of pronouns: the hearer chooses some term of predicate type from that context. The result is the so-called strict reading of ellipsis:

(22) Q: Who upset Mary?  
Ans: John did.

In this case, the construal of the ellipsis site is modelled here as a process of substitution, but this is equivalent to assigning it some fixed content, so equally analysable model-theoretically.

**Use of context-provided actions** It might be counter-argued that ellipsis phenomena can't be analysed as invariably having their construal directly determined by what is available in context, since linguistic forms can in some sense be re-used to yield a NEW interpretation rather than simply matching that provided by the context. There are the sloppy ellipsis construals, where such re-use of the content of some preceding utterance leads to a DISTINCT interpretation for the fragment:

(23) Q: Who hit himself?  
Ans: John did. Bill, too.

In these cases, it might seem that there has to be a coercion operation ON the context to create the appropriate predicate. Sloppy ellipsis construal, that is, has been taken to warrant an abstraction process, here a retraction of content from that provided by the immediate context to establish a predicate for combining with the content of the fragment (Dalrymple et al 1991):

$$\lambda x[\text{Hit}'(x, x)]$$

This is the basis for the highly influential account of VP ellipsis set out by Dalrymple et al 1991, and pursued in different forms by others since, using a process of predicate abstraction and higher-order unification.

Despite the power of higher-order unification and its applicability to an extremely broad array of cases, such a device, defined as it is in the semantic algebra and without reference to details of syntactic structure, cannot reflect any sensitivity to syntactic constraints. Seen from a dynamic perspective, such a solution has putative disadvantage of being non-monotonic: the information content presented by the context has to have something removed, abstracted out, to yield the content that is applicable to complete the presented fragment. Being non-monotonic, this form

of analysis would be surprising in the DS framework, running, as it does, against the assumption otherwise monotonic growth of interpretation. There is however a simple alternative, given this dynamic structural perspective, which is to define context in such a way that the actions used in establishing that construal of the first utterance themselves form part of the context, and so can be re-used just as structure can be. In connection with (23), amongst the actions so reiterated from the context is the projection of a metavariable (as part of the actions associated with *his*) to be identified as before from the subject argument, which in the new context provided by the just parsed subject expression *John* will give rise to a new predicate ‘upset John’s mother’.<sup>23</sup> Taking this example as illustrative of a general pattern, sloppy construals of ellipsis can be seen as evidence that the inventory of what context makes available should be extended to include sequences of actions. Context, with this extension, is defined as a sequence of previous parse states, hence triples of a sequence of words, some (partial) structure and a sequence of actions used to build up that structure.

A first bonus of this analysis is that no reshuffling of syntactic or morphological features is needed to preserve some requisite concept of linguistic identity (of the kind argued for by Fiengo and May 1994 and adopted by many others):

(24) John has washed his socks and so has Sue.

(25) A: You’re sitting on my chair.  
B: No I’m not.

To interpret examples such as (24)-(25) with appropriate ‘sloppy’ interpretation, the elliptical fragment is simply parsed using some sequence of actions culled from the context which can yield a propositional interpretation when applied to the input which the fragment provides. Actions from context will have the distinguishing property of only being available as a record of previously parsed/produced utterances; so the report that at least some forms of ellipsis construal require a linguistic antecedent (Hankamer and Sag 1976) is matched in the analysis by those cases which make use of context-provided actions. So the Dynamic-Syntax-style of account directly reflects the intuition that ellipsis involves reconstruction from context in essentially the same way as anaphora, despite its tighter association with what is traditionally thought to be a grammar-internal process of syntax, without forcing identity of denotational content between the elliptical form and its antecedent. Both anaphora and ellipsis construal involve a concept of context that provides a record of formulae, structure and actions,<sup>24</sup> A second bonus is the way the account reflects the common observation that construal of ellipsis involves meeting a parallelism constraint, the interpretation of the ellipsis site having to match that of the antecedent. In

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<sup>23</sup>See Cann et al 2005 for extensive justification, and Purver et al 2007 for a detailed specification of how such re-application of actions yields parallel results in the new context, including the interaction of ellipsis and quantification. The actions to be selected are constrained to be those which given the input will yield a propositional type. That is, no further parse from new input is allowed.

<sup>24</sup>Pronoun construal that involves re-use of actions provided by context is given by the paycheck examples of Karttunen 1968:

(i) John puts his paycheck in the bank, but Bill keeps it under his bed.

this framework, unlike all others, the parallelism is an immediate consequence of the account provided, ensured by re-use of actions.<sup>25</sup>

As these examples have illustrated, accounts of ellipsis that cover the full range of construals for elliptical forms, inexorably incorporate consideration of dialogue. While this is not an uncontentious move, it is notable that an action-based account of natural-language construal can extend seamlessly to dialogue phenomena, in which structure-building is distributed across more than one interlocutor. One central type of case is the pairing of a question with a fragment as answer, as in (26):<sup>26</sup>

(26) Q: Who did John upset?  
Ans: Himself.

In these, given that in DS the syntactic mechanism is nothing more than growth of semantic representation, it is the just-provided interpretation of the question which, in being a predicate-argument structure, can be taken as the context for interpreting the answer. Furthermore, the reflexive in (26) can be interpreted as providing the update for that very structure, with its antecedent term provided by having parsed the word *John* given within it. So again, though by a different mechanism, the context directly provides a basis from which the elliptical fragment is construed.<sup>27</sup> This type of elliptical construction can also in principle be formulated in model-theoretic terms, though fragment answers would in principle be analysed as essentially propositional (see Groenendijk and Stokhof 1997, Ginzburg and Sag 2001), hence in rather different terms than the interpretation of (one subtype of) VP ellipsis. But it is notable, nonetheless, that the representationalist account has the bonus of continuing to directly reflect the intuition that context itself provides the basis for interpretation of the elliptical fragment.

### 7.3.1 Production in Dynamic Syntax: Towards a Dialogue Model

In characterising such exchanges, it is essential to have a characterisation not merely of language understanding, but also of language production. Despite the parsing-directed stance of DS, this turns out to be unproblematic. The production mechanism, in being grounded in the grammar formalism, can be seen to follow the very same steps as in parsing, with the additional restriction that every licensed parse transition must subsume the selected so-called goal tree representing the interpretation to be conveyed in the sense that there is a possible extension from the selected parse tree to the given goal tree (see Purver et al 2006, and also Purver and Otsuka 2003). Like every other cognitive activity, production is context-dependent: rather than having to engage in

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<sup>25</sup>Very generally, parallelism is stipulated as a filter on licensed interpretations for ellipsis, taken to be an external, unanalysed restriction: see Kehler (2002), Dalrymple et al (1991), among others.

<sup>26</sup>We assume here an account of *wh* expressions as providing a particularised metavariable that acts as a placeholder for the answer at the appropriate node see Kempson et al 2001 ch.5 for detailed arguments.

<sup>27</sup>In similar style, with case defined as a filter on update, any case-matching requirements displayed by elliptical fragments in language with rich case-morphology such as German can be expressed as constraints on tree growth, so that even the data taken by Ginzburg and Cooper to warrant the AVM-style enrichment of record-types to include interpretation about morphological properties of the string is expressible in tree-growth terms.

incremental search in the lexicon, word by word, for some putative selection, the producer, as a first pass, searches the context for possible update formula, structure or actions. This account will immediately extend to ellipsis. We expect in the linearisation process mapping some propositional structure onto a string of words that, if the speaker CAN make use of formulae, structure or actions which have already been established in context, relative to the constraint that such actions lead to an update that subsumes their goal tree, they will do so. This leads us to expect high frequency of elliptical constructions in language use in context both in parsing and production as a major cost-saving device.

The split-utterance phenomenon as in (20), repeated here, now fall into place:

- (20) A: We're going to ..  
B: Tathersham.  
A To see my brother.  
C: Has he asked you to?

This phenomenon is anticipated in the DS account (Purver et al 2006). Whether parsing or producing some string, the same tree is being constructed by an individual hearer/speaker because, in either task, the parsing procedure is central. If then before completion, the hearer can leap to the conclusion of what is being said, he can take up the actions he has so far used as a parser and continue from them to complete a tree that matches what he now sees as his goal tree. Equally, the speaker can shift into being a parser, as she, too, has just used a sequence of actions to construct whatever partial tree she has so far taken to match her goal tree. On this view, this is merely a shift from PROVIDING the input for updating some partial structure, to analysing some PROVIDED input with which to update that very same partial structure. Unlike in other frameworks, the phenomenon of apparently shared utterances is strikingly natural. Apart from the abduction step of anticipation made by the interrupting interlocutor, nothing new needs to be added; and even this is no more than establishing the proposition expressed as quickly as possible, hence optimising its relevance (Sperber and Wilson 1986, 1995).

The significance of this account of such individually incomplete utterances is its essential invocation of structure, indeed of actions that induce such structure. Finally we have a concept of context that is rich enough to provide a unified basis for modelling ALL elliptical fragments: fragments are interpreted providing whatever terms, structure or actions that context makes available. A model-theoretic characterisation of content provides no obvious basis for explaining this last type of fragment: analysing all strings as being assigned as interpretation a function from string to denotational content, with the add-on of some model-theoretically defined concept of context and context-update, simply doesn't provide the fine structure needed to characterise how exchange of speaker/hearer roles can be made at any point. So even in so far as other types of ellipsis can be modelled, albeit in heterogeneous ways, such accounts remain incomplete. In general, grammar-formalisms defined as constraints on strings given phonological, syntactic and semantic specification, do not provide a good basis for analysing split utterances. The remit of explanation is the set of sentential strings, and fragments are only included by being said to be incomplete sentences that can be assigned some propositional form of construal from context.

Any application of such a grammar to define parsing and production models needs special mechanisms to explain why, on the one hand, fragments only partially parsed/produced can nevertheless be extended by that very same person switching into the other role as though that had been their role all along, and on the other hand why a fragment can be apparently completed by picking up on some partial structure as though, conversely, their newly adopted role is what they had previously been engaged in. It is only a grammar formalism in which the concept of syntax itself is articulated as actions inducing incremental growth of semantically grounded structure (so that both parsing and production manipulate the same tree-growth processes) which is able straightforwardly to capture the split-utterance phenomena and provide an integrated basis for capturing ellipsis as a phenomenon of context-dependence. And this in its turn demands assumptions of representationalism in the explanation of interpretation for natural-language strings.

## 8 Summary

Both the Dynamic Syntax framework and the Cooper-Ginzburg system (together with other developments using the GODIS system) share a commitment to modelling dialogue as part of the remit a natural-language system should be expected to explain. Indeed, they are amongst the very few frameworks able to respond to the Pickering and Garrod (2004) challenge that grammar formalisms should be evaluated by how well they can express the patterns displayed in conversational dialogue. This is signally not possible for most other frameworks: given the use-neutral nature of conventional grammar formalisms, the fluency with which participants switch between speaker and hearer roles remains problematic (see Kempson et al forthcoming for discussion). The more general significance of the GODIS and DS frameworks is the indication they provide of the continuing influence of DRT in having initiated a shift into positing more structural modes of representation to reflect the dynamics of how interpretation is built up. Looking back across the window of time from the first emergence of formal semantics to the current attempts to model the richness of ongoing human conversational dialogue (see Partee 1996 for a more model-theoretic form of reflection), this progressive re-emergence of structural approaches to natural language construal is striking. There is an increasingly prevailing sense that, if we are to get the right answer to the concept of content for natural language expressions qua expressions, we have to get to grips with the fact that expressions of natural language are vehicles for constructing content, able to project different contents in different contexts.

The detailed answers to the questions raised by anaphora, ellipsis and dialogue modelling are likely to remain active areas of current research for some time. The dispute between representationalist and denotational accounts of content hasn't gone away as an outmoded and long-since resolved controversy. Yet it has been transformed into an entirely different debate from that which was held in the mid-seventies, one that is now focussed on how to model the human capacity to interpret fragments in context, in conjunction with other participants in a dialogue. And with this bringing together of competence and performance considerations, both proof-theoretic and mentalist assumptions of the centrality of representations can be re-evaluated in a way that leads to a re-opening of the debate about the psychological status of representations in semantic explication. And it is this exploration which is opening up new possibilities for our understanding of the nature of natural language and of linguistic competence (Cann et al 2005, Hamm et al

2006, Cann et al forthcoming, Kempson et al forthcoming).

## 9 Bibliography

- Ahn, R. 1999. Agents, Objects and Information-modelling: the Dynamics of Interaction. Ph.D Tilburg University.
- Austin, J.L. 1961. *How to Do Things with Words*. Oxford: Clarendon Press.
- Areces, D. and R. Bernardi, 2004. Analyzing the Core of Categorical Grammar. *Journal of Logic, Language and Information* 13 (2): 121-137.
- Bach, E. 1979 Control in Montague grammar. *Linguistic Inquiry* 10, 515–31.
- Baldrige, J. 2002. *Lexically Specified Derivational Control in Combinatory Categorical Grammar*. Ph. D. thesis, University of Edinburgh.
- Barwise, J. 1987. Unburdening the language of thought. *Mind and Language*. reprinted in Barwise 1989.
- Barwise, J. 1989. *The Situation in Logic*. Stanford: CSLI Press.
- Barwise, J. & Cooper, R. 1981. Generalized quantifiers and natural language. *Linguistics & Philosophy* 4, 159–219.
- Barwise & Perry, 1981. *Situations and Attitudes*. Cambridge MA: MIT Press.
- Blackburn, P. and Meyer-Viol, W. 1994. Linguistic logic and finite trees. *Bulletin of the Interest Group of Pure and Applied Logics* 2, 2–39.
- Cann, R. 1993. Introduction to Formal Semantics. Cambridge: Cambridge University Press.
- Cann, R., Kempson, R. and Marten, L. 2005 *Dynamics of Language*. Oxford: Elsevier.
- Cann, R. Kempson, R & Purver M. forthcoming. Context, wellformedness and the dynamics of dialogue. *Research on Language and Computation* 5.
- Carpenter, R. 1997 *Type-Logical Semantics*. MIT Press.
- Chierchia, G.& McConnell-Ginet, S. 2000. *Meaning and Grammar* (2nd edition). MIT Press. Cambridge MA.
- Chomsky, N. 1965. *Aspects of the theory of Syntax* MIT Press.
- Chomsky, N. 1995. *The Minimalist Program*. Cambridge MA: MIT Press.
- Cooper, R. 2005. Austinian truth, attitudes and type theory. *Research on Language and Computation*, 3.
- Cooper, R. 2006. Records and record types in semantic theory. *Journal of Logic and Computation*.
- Cooper, R. 2004. Dynamic generalized quantifiers and hypothetical contexts. *Ursus Philosophicus*. festschrift for Björn Haglund.
- Cooper, R. and Larsson, S. forthcoming Accommodation and reaccommodation in dialogue. In Bäuerle, Ryele and Zimmermann (eds.) *Presuppositions and Discourse*. Amsterdam: Elsevier.
- Cooper, R., S. Ericson, S. Larsson, I. Lewin 2003. An information state update approach to collaborative negotiation. In Kunlein, Rieser and Zeevat (eds.) *Perspectives on Dialogue in the new Millennium*. John Benjamins, 271-287.
- Copestake, A et al 2005. Minimal Recursion Semantics: An introduction, *Journal of Research on Language and Computation*, 3(2-3), 281-332.
- Curry, H. and Feyes, R. 1958. *Combinatory Logic*. Amsterdam. North-Holland.
- Dalrymple M. Shieber, S. and Pereira, F. 1991. Ellipsis and higher-order unification. *Linguistics*

*and Philosophy* 14. 399-452.

Dekker, P. 1999. Coreference and representationalism. ms. Amsterdam.

Dowty, D. Wall, R. & Peters, S. 1981. *Introduction to Montague Semantics*. Reidel: Dordrecht.

Eijk, J. van & Kamp, H. 1997. Representing discourse in context. In van Benthem and ter Meulen, A. (eds.) *Handbook of Logic and Language*, pp. 179-239, Elsevier: Amsterdam.

Ericsson, S. 2005. Information enriched constituents in dialogue. Ph.D Goteborg.

Erk, K. Koller, A. and Niehren, J. .2004? Processing Underspecified Semantic Descriptions in the Constraint Language for Lambda Structures. *Journal of Language & Computation*.

Evans, G. 1980. Pronouns. *Linguistic Inquiry* 11. 337–62.

Fernando, T. 2000. Between proofs and models: presuppositions. ms.

Fernando, T. 2002. Three processes in natural language interpretation (In *Reflections on the Foundations of Mathematics: Essays in Honor of Solomon Feferman*, W. Sieg, R. Sommer and C. Talcott, eds., Association for Symbolic Logic, *LNiL 15*, Natick, Massachusetts, pp 208-227.

Fiengo, R. & May, R. 1994. *Indices and Identity* MIT Press.

Fine, K. 1984 *Reasoning with Arbitrary Objects Aristotelian Monograph Series*.

Fine, K. 1985. Natural deduction and arbitrary objects. *Journal of Philosophical Logic* 14, 57–107.

Ginzburg, J. forthcoming. *Semantics for Interaction in Dialogue* CSLI Press.

Fitch, F. 1951. *Symbolic Logic*. New York:

Fodor, J.A. 1983. *The Modularity of Mind*. Cambridge MA: MIT Press.

Fodor, J.A. 1988. A situated grandmother. *Mind and Language* 2, 64–81.

Gabbay, D. 1991 *Labelled Deductive Systems*. Oxford: Oxford University Press.

Gamut, L.T.F. 1991. *Logic, Language and Meaning*.. University of Chicago Press.

Ginzburg, J. and Cooper, R. 2004. Clarification, Ellipsis, and the Nature of Contextual Updates, *Linguistics and Philosophy* 27, 297-365.

Ginzburg, J. and Sag, I. 2002. *English Questions: Syntax and Semantics* . Stanford: CSLI Press.

Grice, H.P. 1989. *Studies in the Way of Words*. Cambridge Mass: Harvard University Press.

Groenendijk & Stockhof. 1991. Dynamic predicate logic. *Linguistics and Philosophy*.

Groenendijk, J. & Stockhof, M. 1997. Questions. *Handbook of logic and language*, ed. by J. Van Benthem and A Ter Meulen, 1055-1124. Cambridge, MA: MIT Press.

Hamm,F. & Lambalgen, M. van, 2004. *The Proper Treatment of Events*, Routledge, London.

Hamm, F., Kamp,H & Lambalgen, M. van. 2006. There is no opposition between formal and cognitive semantics, *Theoretical Linguistics* 32:1-40.

Hankamer, J. and Sag, I. 1976. Deep and surface anaphora. *Linguistic Inquiry* 7, 391–428.

Hardt, D. 1993. *Verb Phrase Ellipsis: Form, Meaning, and Processing*, Ph.D.thesis, University of Pennsylvania.

Heim, I. 1982. The Semantics of Definite and Indefinite NPs. UMass Amherst Ph.D.

Heusinger, K. von. 1997. Definite descriptions and choice functions. In Akama, S. (ed.) *Logic, Language and Computation*, 61-92. Dordrecht: Kluwer.

Higginbotham, J. 1988. Contexts, models and meanings. In Kempson, R. (ed.) *Mental Representations*, pp. 29–48. Cambridge University Press.

Hintikka, J. 1974 Quantifiers vs quantification theory. *Linguistic Inquiry* 5, 153-177.

Hoffman, B. 1996. Integrating "free" word order syntax and information structure. Ph.D University of Pennsylvania

Hornstein, N. 1996 An argument for minimalism: the case of antecedent-contained deletion. *Linguistic Inquiry* 25, 455-480.

- Jackendoff, R. 2002. *Foundations of Language*. MIT Press.
- Kadmon, N. 2001. *Formal Pragmatics*. Oxford: Blackwell.
- Kamp, H. 1981 A theory of truth and semantic representation. In Groenendijk, J. Janssen, T. and Stokhof, M. *Formal Methods in the Study of Language* 277-322. Amsterdam: Mathematisch Centrum.
- Kamp, H. 1996. Discourse Representation Theory and Dynamic Semantics: representational and nonrepresentational accounts of anaphora. ms. Stuttgart.
- Kamp, H. & Reyle, U. 1993 *From Discourse to Logic*. Dordrecht: Kluwer
- Kaplan, R. & Zaenen, A. 1989. Long-distance dependency, constituent structure and functional uncertainty. In Baltin, M. and Kroch, A. (ds.) *Alternative conceptions of phrase structure*, pp. 17–42. Chicago: University of Chicago Press.
- Karttunen, L. 1968. Discourse referents. *Syntax and Semantics 7: Notes from the Linguistic Underground* (ed. J. McCawley, pp. 363–385. New York: Academic Press.
- Katz, J.J. 1972 *Semantic Theory*. New York: Harper and Row.
- Katz, J. J. & Postal, P. 1963. *An Integrated Theory of Linguistic Description*. MIT Press.
- Katz, J.J. & Fodor, J.A. 1962 *The Structure of a Semantic Theory*. MIT Press
- Kempson, R. Meyer-Viol, W. and Gabbay, D. 2001. *Dynamic Syntax: The Flow of Language Understanding*. Oxford: Blackwell.
- Kempson, R. & Meyer-Viol, W. 2004. The dynamics of scope. In Reimer, M. & Bezuidenhout, A. 2005. *Descriptions and Beyond*. Oxford: Oxford University Press.
- Kempson, R. Cann, R & Purver, M. forthcoming. Talking and Listening: Dialogue and the semantics/pragmatics interface. In Hackl, M. & Thornton, R. (eds.) *Asserting, Meaning and Implying* Oxford University Press.
- Kratzer, A. this volume
- Lambek, J. 1958. The Mathematics of Sentence Structure, *American Mathematical Monthly* 65, 154-170.
- Lappin, S. & Benmamoun, E. (eds. 1999) *Fragments*: Oxford: Oxford University Press.
- Larsson, S. 2002. *Issue-based Dialogue Management*. Ph.D Göteborg University.
- Lemmon, E.J. 1965. *Beginning Logic*. Nelson University Paperbacks. Chapman & Hall.
- Lewis, D. 1970. General semantics. *Synthese* 122, 18– 67. repr. In Harman and Davidson, D. (eds.) (1972) *Formal Semantics of Natural Language*. Dordrecht: Reidel.
- Martin-Löf, M. 1984. *Intuitionistic Type Theory.*, Bibliopolis, Naples.
- Merchant, J. 2002. *The Syntax of Silence*. Oxford: Oxford University Press.
- Merenciano and Morrill 2003. Generation as natural deduction on labelled proofnets. ms.
- Montague, R. 1968. Pragmatics. In Thomason (ed.) *Formal Philosophy: selected papers of Richard Montague*, pp. 95–118. Yale University press.
- Montague, R. 1970a Universal Grammar. In Thomason (ed.) *Formal Philosophy: selected papers of Richard Montague*, pp. 222-246. Yale University press.
- Montague, R. 1970b English as a formal language. In Thomason (ed.) *Formal Philosophy: selected papers of Richard Montague*, pp. 188-221. Yale University press.
- Montague, R. 1973. The proper treatment of quantification in ordinary English. In Hintikka, K.J.J., Moravcsik, J.M.E., and Suppes, P. (eds.) *Approaches to Natural Language*, pp. 221-242. Dordrecht: Reidel. Reprinted in Montague (1974), pp. 247-270.
- Moortgat, M. 2007. Categorical type logics. In van Benthem J. & ter Meulen, A. eds. *Handbook of Logic and Linguistics*, pp. 93-178. Amsterdam: Elsevier.

- Morrill, G. 1990. Intensionality and boundedness. *Linguistics and Philosophy* 13, 699–726.
- Morrill, G. 1994. *Type Logical Grammar*. Dordrecht: Foris.
- Morrill, G. and Gavarró, A. 2004.
- Neijt, A. van. 1980. *Gapping: A Contribution to Sentence Grammar*. Dordrecht: Foris.
- Partee, B.H. 1973 Some structural analogies between tenses and pronouns in English. *The Journal of Philosophy* 70, 601-609.
- Partee, B.H. 1996. The development of formal semantics in linguistic theory. in Lappin, S. (ed.) *The Handbook of Contemporary Semantic Theory*, pp. 11–38. Oxford: Blackwell.
- Pinker S. 1994. *The Language Instinct*. MIT Press.
- Piwek, P. 1998. Logic, Information and Conversation. Ph.D Technical University Eindhoven.
- Prawitz, D. 1965. *Natural Deduction: A Prof-Theoretical Study*. Uppsala: Almqvist and Wiksell.
- Purver, M. 2006. CLARIE: Handling Clarification Requests in a Dialogue System. *Research on Language and Computation* 4(2-3), pages 259-288, 2006.
- Purver, M. Cann, R. & Kempson, R. 2006. Grammars as parsers: the dialogue challenge. *Research on Language and Computation* 4.
- Purver, M. & Otsuka, M. 2003. Incremental Generation by Incremental Parsing: Tactical Generation in Dynamic Syntax. In Proceedings of the 9th European Workshop on Natural Language Generation (ENLG-2003), pages 79-86, Association for Computational Linguistics, Budapest, Hungary, April 2003.
- Pustejovsky, J. 1995. *The Generative Lexicon*. Cambridge, MA: MIT Press.
- Ranta, A. 1994. *Type-Theoretic Grammar*. Oxford: Clarendon.
- Reyle, U. 1993. Dealing with ambiguities by underspecification: construction, representation and deduction. *Journal of Semantics* 10, 123-79.
- Ross, H. 1967. *Constraints on Variables in Syntax*. Ph.D MIT.
- Sag, I. Wasow, T. & Bender, E. 2002. *Head Phrase Structure Grammar: An Introduction* (2nd editn). CSLI Press.
- Sperber, D. & Wilson, D. 1986/1995. *Relevance: Cognition and Communication*. Oxford: Blackwell.
- Stainton, R. 2004. The Pragmatics of Non-Sentences. *Handbook of Pragmatics*. L. Horn, and G. Ward. Oxford: Blackwell. 266-287.
- Stalnaker, R. 1970. Pragmatics *Synthese* 22. reprinted in Stalnaker 1999
- Stalnaker, R. 1999 *Context and Content*. Oxford: Oxford University Press.
- Stanley, J. 2000 Context and logical form. *Linguistics and Philosophy* 23: 391-434.
- Steedman, M. 1996. *Surface Structure and Interpretation*. Cambridge MA: MIT Press.
- Steedman, M. 2000. *The Syntactic Process*. Cambridge MA: MIT Press.
- Swart, H. de. 1998. *Introduction to Natural Language Semantics*. Stanford: CSLI Press.
- Thomason, R. (ed.) 1974 *Formal Philosophy: Selected Papers of Richard Montague*. New Haven: Yale University Press.
- Vermaat, W. 2006. *The Logic of Variation*. Ph.D. University of Utrecht.
- Winter, Y. 1997. Choice functions and the scopal semantics of indefinites. *Linguistics and Philosophy* 20, 399–467.