The Dynamics of Sense and Implicature: Anaphora, “Presupposition,” and CIs

Scott Martin
scott@ling.ohio-state.edu
http://www.ling.ohio-state.edu/~scott/

Natural Language Understanding Laboratory
Nuance Communications

Construction of Meaning Workshop
Stanford Linguistics Department
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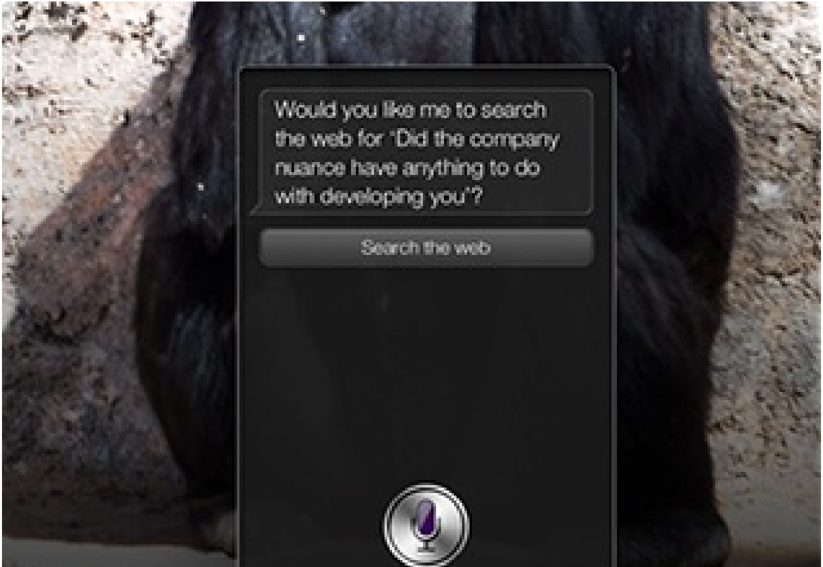
A Bit about Me

- I finished up my Ph.D. thesis at Ohio State this past summer, advised by Carl Pollard and Craige Roberts
- I'm interested in logical/mathematical approaches to language, especially semantics and pragmatics, and applications to natural language processing (paraphrase alignment, generation)
- Currently I'm a research scientist at Nuance's recently established natural language understanding laboratory in Sunnyvale
- I also have a background in languages, philosophy, and software engineering

What's Happening at Nuance?

We're trying to go from this ...



What's Happening at Nuance?

To this:

What's Really Happening at Nuance?

- We're building conversational user agents that are intelligent
- This of course means using big data and machine learning techniques
- But we're also trying to leverage (what I'll call) *smart data*: morphology, syntax, semantics, discourse analysis, parsing, reasoning, AI techniques, …

My Thesis in a Nutshell

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- This new characterization leads to a generalized account of contextual felicity

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- My dissertation work is about a new approach to semantics and pragmatics based on a novel way of characterizing meaning that has some old roots
- This new characterization leads to a generalized account of contextual felicity
- I also give an explicit formal account of some English data based on this new taxonomy, encoded in a discourse semantics that captures both anaphora and Potts's (2005) "CIs"
- Its central feature is that foreground and background meaning are computed in parallel, and it is designed with computational applications in mind

Outline

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Sense and Implicature

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- Senses are targeted by the semantic *operators* negation (*not*), modals (*might*, *maybe*), question words (*who/what/when/where/how*, *Did* ...), conditionals (*If* ..., *then* ...)
- But implicatures are not targeted by these operators: they are **persistent**

Spotting Implicatures I

One test for implicatures is embedding in the scope of an operator.

(1) Maybe the woman bought a ticket. (anaphora)

a. $\not\rightsquigarrow$ The woman bought a ticket.

b. $\rightsquigarrow$ *The woman* has a retrievable antecedent.

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(3) Did Kim quit smoking? (aspectual)

a. $\not\rightsquigarrow$ Kim used to smoke.

(similarly for *continue*, *start*, *stop*, *switch to*; achievements (*graduate*, *win*); "factives" (*know*, *realize*, *regret*))

Spotting Implicatures II

Another test for implicatures is direct acceptance/denial.

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a. No. $\not\rightsquigarrow$ Lance is from Texas.

b. Yes/No. $\rightsquigarrow$ Lance is a cyclist.

(6) Kim quit smoking.

a. Yes, that's true. $\rightsquigarrow$ Kim used to smoke.

b. No. $\rightsquigarrow$ Kim did not quit smoking.

c. No, she's never smoked in her life. $\not\rightsquigarrow$ Kim used to smoke.

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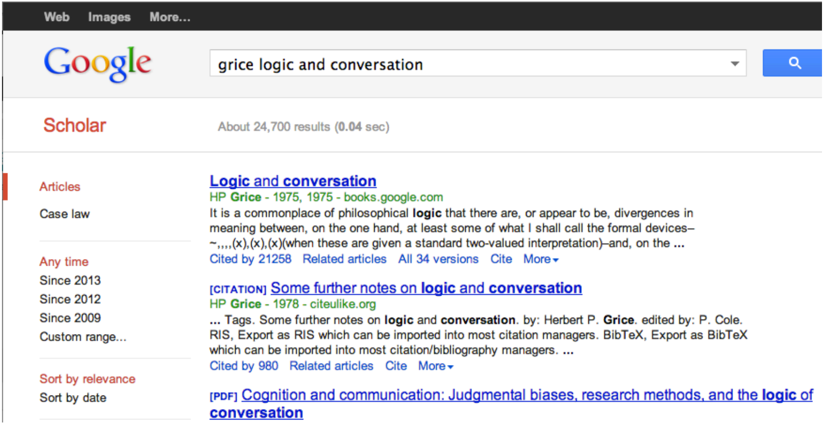
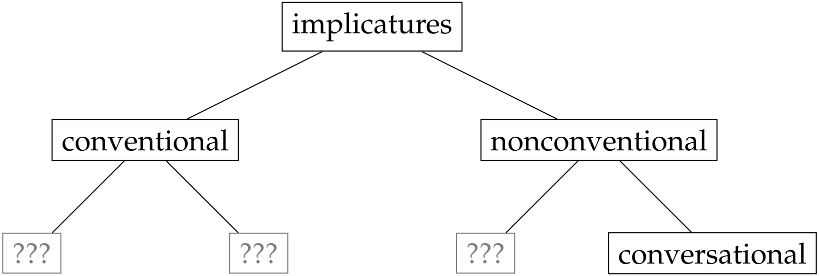


"Gricean Implicature" II

But what about the others? Grice didn't say too much about those...



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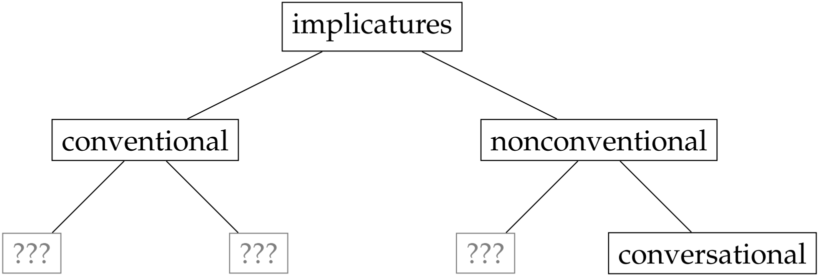

I’ll argue that implicatures can be characterized based on two criteria:

1. Whether their persistence is *conventionally signaled*, and
2. Whether they must be *speaker commitments*, a cross-cutting distinction

Conventional Implicature: Anaphora and "CIs"

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But the non-anaphoric conventional implicatures do not:

(8) I'm a big Obama supporter. But my tea party neighbor thinks that Obama, who's totally a Kenyan pinko in charge of secret terrorist camp in the ravine behind his house, will destroy the country. (cf. Amaral et al., 2007; Harris and Potts, 2009)

Nonconventional Implicatures I: Achievements

Nonconventional implicatures can sometimes persist. A case in point is the preparatory phase associated with *achievements*.

- In (9), the speaker is committed to Lance's having participated in the Tour:

(9) Lance won the Tour de France.

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- In (9), the speaker is committed to Lance's having participated in the Tour:

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- But in (10), it can't be the speaker's commitment:

(10) Lance didn't enter last year's Tour de France, but Kim is convinced that he won it.

And the implication that Lance participated does not persist.

Nonconventional Implicatures II: Aspectuals

A second case is the *aspectuals*.

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  (12) I wonder why Kim is so sluggish lately. Maybe she switched to decaf, or something.

- And just as for the achievements, aspectuals do not have to be speaker commitments:

  (13) Kim never drank caffeinated coffee, but Robin believes that Kim switched to decaf.

Nonconventional Implicatures III: "Factives"

So-called "factives" also exhibit similar behavior.

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- They can also be non-speaker commitments:

(16) The Riemann hypothesis remains a mysterious, unsolved conjecture in mathematics, but Louie just knows it is true.

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(18) Lance, a cyclist, is from Texas. # Lance is not a cyclist.

- And similarly for the nonconventional implicatures:

(19) # Kim never smoked in her life, and then she stopped smoking.

What About Accommodating those "Presuppositions"?

- Members of the class of nonconventional implicatures (achievements, aspectuals, factives) are characterized as potentially, but not necessarily, giving rise to entailments
- As a result, there is no place in this taxonomy for a notion of *presupposition* separate from *anaphora*—i.e., *presupposition* and *anaphora* are synonyms

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- This taxonomy is at odds with theories that construe achievements, aspectuals, and factives as presuppositions that require accommodation when they contain new information
- In my proposal, accommodation really is a repair strategy, triggered e.g. when a definite is used without a retrievable antecedent

Infelicity and Commitment Variability

- (The threat of) infelicity is a factor in determining speaker vs. non-speaker commitment, as in (10), repeated from above:

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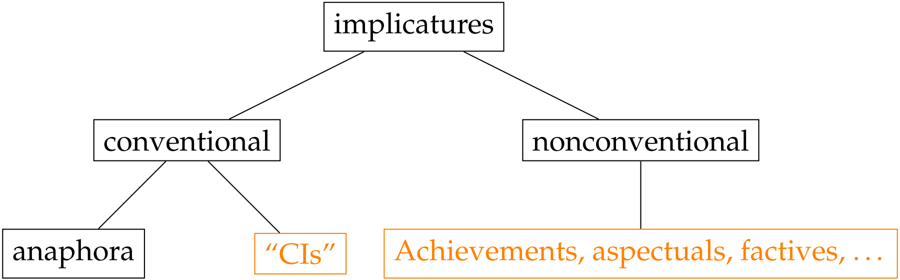
Taxonomy of Nonconversational Implicatures

A Grice-inspired taxonomy of implicature, leaving out the conversational implicatures (which are nonconventional):



(Here, implicatures with variable commitment status are highlighted.)

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- It is both *compositional* and *dynamic*: utterances both update the context and depend on it for their own interpretation
- The goal of most dynamic theories is to model anaphora; DyCG aims at implicatures more generally
- It is most similar to the compositional dynamic theories advanced by Beaver (2001) and de Groote (2006)

DyCG Basics

- Adopting Curry's (1961) distinction between abstract and concrete syntax, DyCG is built upon three logics:

  Concrete syntax
  : models word order: An instantiation of (simple) type theory with a single nonlogical type s, of strings, that has a concatenation operator with a two-sided identity (the empty string)

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  Semantics models meaning in context: A dependent type theory with the nonlogical types e (entities), p (propositions), ω (natural numbers)

- It shares the abstract/concrete strategy with de Groote's (2001) *Abstract Categorial Grammars* and Muskens's (2007) *Lambda Grammars*

DyCG Grammar Rules

The grammar is a system for deriving *signs*, which, ignoring concrete syntax, are pairs of the form

$$A\,;b : B\ ,$$

where A is a formula of abstract syntax, b a term of the semantics, and B a semantic type.

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where A is a formula of abstract syntax, b a term of the semantics, and B a semantic type. There are only four rules:

$$\vdash A\,;b : B \quad \text{(Entry)}$$

$$A\,;x : B \vdash A\,;x : B \quad \text{(Trace)}$$

$$\frac{\Gamma, A\,;x : B \vdash C\,;d : D}{\Gamma \vdash A \multimap C\,;(\lambda_x d) : B \rightarrow D}\ \text{(Extract)}$$

$$\frac{\Gamma \vdash A \multimap B\,;f : C \rightarrow D \qquad \Delta \vdash A\,;c : C}{\Gamma, \Delta \vdash B\,;(f\,c) : D}\ \text{(Combine)}$$

The Underlying Static Semantics I

- The underlying static semantics assumes that:
  1. There is a type w of worlds, and
  2. For every meaning type A, there is some function $@_A : A \to \mathrm{w} \to \mathrm{Ext}(A)$, that takes each inhabitant of A to its extension $\mathrm{Ext}(A)$ at a given world

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- But it is *agnostic* about how $@_{\mathrm{p}}$ is defined, following Plummer and Pollard (2012)
- In particular, this means there is no need to define an extensional fragment

The Underlying Static Semantics II

- The static semantics also axiomatizes these connectives and quantifiers to behave as expected:

$\mathsf{entails} : \mathrm{p} \to \mathrm{p} \to \mathrm{t}$	(entailment)
$\mathsf{true} : \mathrm{p}$	(a necessary truth)
$\mathsf{false} : \mathrm{p}$	(a necessary falsehood)
$\mathsf{not} : \mathrm{p} \to \mathrm{p}$	(negation)
$\mathsf{and} : \mathrm{p} \to \mathrm{p} \to \mathrm{p}$	(conjunction)
$\mathsf{implies} : \mathrm{p} \to \mathrm{p} \to \mathrm{p}$	(implication)
$\mathsf{or} : \mathrm{p} \to \mathrm{p} \to \mathrm{p}$	(disjunction)
$\mathsf{forall} : (A \to \mathrm{p}) \to \mathrm{p}$	(universal quantifier)
$\mathsf{exists} : (A \to \mathrm{p}) \to \mathrm{p}$	(existential quantifier)

Contexts

- A DyCG **context** is a function from an *n*-ary vector of entities to a proposition.
- The type of *n*-contexts is

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  where the type e^n is the type of vectors of n entities
- For example, the following is a 2-context:

$$\vdash \lambda_{x,y}.(\textsf{cyclist}\, x) \textsf{ and } (\textsf{bike}\, y) \textsf{ and } (\textsf{ride}\, y\, x) : \mathrm{c}_2$$

- The type c_n shows how dependent types are used in DyCG: an n-context requires n entities to produce a proposition

Contents

- Meanings of declarative utterances are modeled as **contents**, functions from contexts to pairs of contexts
- The type k_n is the type of contents that introduce n discourse referents:

$$\mathrm{k}_n =_{\mathrm{def}} \mathrm{c}_m \rightarrow (\mathrm{c}_{m+n} \times \mathrm{c}_{m+n})$$

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- Inspired by Karttunen and Peters (1979), the first component represents the sense of the expression, and the second its implicature
- For example, *It's raining* would get the content

$$\vdash \lambda_c. \langle \lambda_{\mathbf{x}^{|c|}}.\mathsf{rain}, \lambda_{\mathbf{x}^{|c|}}.\mathsf{true} \rangle : \mathrm{k}_0$$

Dynamic Properties

- Static properties are made dynamic by replacing their entity arguments with vector coordinates
- For example, the unary property cyclist : e → p and binary relation ride : e → e → p are dynamicized as

$$\text{CYCLIST} = \lambda_n \lambda_c . \langle \lambda_{\mathbf{x}^{|c|}} . (\textsf{cyclist}\, \mathbf{x}_n), \lambda_{\mathbf{x}^{|c|}} . \textsf{true} \rangle : \omega \rightarrow \mathrm{k}_0 \ ,$$

and

$$\text{RIDE} = \lambda_{mn} \lambda_c \, \langle \lambda_{\mathbf{x}^{|c|}} . (\textsf{ride}\, \mathbf{x}_m\, \mathbf{x}_n), \lambda_{\mathbf{x}^{|c|}} . \textsf{true} \rangle : \omega \rightarrow \omega \rightarrow \mathrm{k}_0$$

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- The *context change* function $\mathsf{cc} : \mathrm{k}_n \to \mathrm{u}_n$ does the promotion by collapsing the sense and implicature content together:
$$\mathsf{cc} =_{\mathrm{def}} \lambda_{kc}\lambda_{\mathbf{x}^{|c|},\mathbf{y}^{|k|}}.(c\,\mathbf{x}) \text{ and } (k\,c)^{\mathrm{s}}\,\mathbf{x},\mathbf{y} \text{ and } (k\,c)^{\mathrm{i}}\,\mathbf{x},\mathbf{y}\ ,$$
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- For example, for some $n : \omega$,

$$\vdash \mathsf{cc}\,(\textsc{cyclist}\,n) = \lambda_c\lambda_{\mathbf{x}^{|c|}}.(c\,\mathbf{x})\ \mathsf{and}\ (\mathsf{cyclist}\,\mathbf{x}_n)\ \mathsf{and}\ \mathsf{true} : \mathrm{u}_0$$

Dynamic Connectives I: Conjunction

- The dynamic conjunction of two contents $\textsc{and} : \mathrm{k}_m \to \mathrm{k}_n \to \mathrm{k}_{m+n}$ passes to the second conjunct the context updated by the first conjunct:

$$\textsc{and} =_{\mathrm{def}} \lambda_{hkc} \left\langle \lambda_{\mathbf{x}^{|c|},\mathbf{y}^{|h|},\mathbf{z}^{|k|}} . (h\,c)^{\mathrm{s}}\,\mathbf{x},\mathbf{y} \text{ and } (k\,(\mathsf{cc}\,h\,c))^{\mathrm{s}}\,\mathbf{x},\mathbf{y},\mathbf{z}, \right.$$
$$\left. \lambda_{\mathbf{x}^{|c|},\mathbf{y}^{|h|},\mathbf{z}^{|k|}} . (h\,c)^{\mathrm{i}}\,\mathbf{x},\mathbf{y} \text{ and } (k\,(\mathsf{cc}\,h\,c))^{\mathrm{i}}\,\mathbf{x},\mathbf{y},\mathbf{z} \right\rangle$$

- This seems pretty involved, but it just conjoins the two contents in a way that keeps sense and implicature separate

Dynamic Connectives I: Conjunction

- The dynamic conjunction of two contents $\text{AND} : \mathrm{k}_m \to \mathrm{k}_n \to \mathrm{k}_{m+n}$ passes to the second conjunct the context updated by the first conjunct:

$$\text{AND} =_{\text{def}} \lambda_{hkc} \left\langle \lambda_{\mathbf{x}^{|c|},\mathbf{y}^{|h|},\mathbf{z}^{|k|}} . (h\,c)^{\text{s}}\,\mathbf{x},\mathbf{y} \text{ and } (k\,(\mathsf{cc}\,h\,c))^{\text{s}}\,\mathbf{x},\mathbf{y},\mathbf{z}, \right.$$
$$\left. \lambda_{\mathbf{x}^{|c|},\mathbf{y}^{|h|},\mathbf{z}^{|k|}} . (h\,c)^{\text{i}}\,\mathbf{x},\mathbf{y} \text{ and } (k\,(\mathsf{cc}\,h\,c))^{\text{i}}\,\mathbf{x},\mathbf{y},\mathbf{z} \right\rangle$$

- This seems pretty involved, but it just conjoins the two contents in a way that keeps sense and implicature separate
- Example: for natural numbers m and n,

$$\vdash (\text{CYCLIST}\,m)\ \text{AND}\ (\text{RIDE}\,n\,m)$$
$$\equiv \lambda_c . \langle \lambda_{\mathbf{x}^{|c|}} . (\mathsf{cyclist}\,\mathbf{x}_m) \text{ and } (\mathsf{ride}\,\mathbf{x}_n\,\mathbf{x}_m), \lambda_{\mathbf{x}^{|c|}} . \mathsf{true} \rangle : \mathrm{k}_0$$

Dynamic Connectives II: Existential "Quantifier"

- The dynamic existential "quantifier" EXISTS : $(\omega \to \mathrm{k}_n) \to \mathrm{k}_{n+1}$ doesn't really do any quantifying:

$$\text{EXISTS} =_{\text{def}} \lambda_{Dc}.D\ |c|\ c^{+}$$

Here, c^{+} is the context just like c but with an extra vector coordinate.

Dynamic Connectives II: Existential “Quantifier”

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Here, c^+ is the context just like c but with an extra vector coordinate.

- Example:

$$\vdash \textsc{exists}\,\textsc{cyclist} = \lambda_c. \left\langle \lambda_{\mathbf{x}^{|c|},y}.(\mathsf{cyclist}\,y), \lambda_{\mathbf{x}^{|c|},y}.\mathsf{true} \right\rangle$$

Dynamic Connectives III: Negation

- Dynamic negation $\textsc{not} : \mathrm{k}_n \to \mathrm{k}_0$ not only negates, it also 'traps' any discourse referents introduced in its scope:

$$\textsc{not} =_{\mathrm{def}} \lambda_{kc}.\left\langle \lambda_{\mathbf{x}^{|c|}}.\textsf{not exists}_{\mathbf{y}^{|k|}}.(k\,c)^{\mathrm{s}}\,\mathbf{x},\mathbf{y},\ \lambda_{\mathbf{x}^{|c|}}.\textsf{exists}_{\mathbf{y}^{|k|}}.(k\,c)^{\mathrm{i}}\,\mathbf{x},\mathbf{y}\right\rangle$$

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- Example:

$$\begin{aligned}&\vdash \textsc{not}\,(\textsc{exists}\,\textsc{cyclist})\\ &= \lambda_c\,\langle \lambda_{\mathbf{x}^{|c|}}.\mathsf{not\ exists}_y.(\mathsf{cyclist}\,y), \lambda_{\mathbf{x}^{|c|}}.\mathsf{exists}_y.\mathsf{true}\rangle\\ &\equiv \lambda_c\,\langle \lambda_{\mathbf{x}^{|c|}}.\mathsf{not\ exists\ cyclist}, \lambda_{\mathbf{x}^{|c|}}.\mathsf{true}\rangle : \mathrm{k}_0\end{aligned}$$

Defining a Dynamic Semantics

- With conjunction, the existential, and negation defined, the other connectives can be defined in terms of them:

$$\text{IMPLIES} =_{\text{def}} \lambda_{hk}.\text{NOT}\,(h \text{ AND } (\text{NOT}\, k)) : \mathrm{k}_m \to \mathrm{k}_n \to \mathrm{k}_0$$

$$\text{OR} =_{\text{def}} \lambda_{hk}.\text{NOT}\,((\text{NOT}\, h) \text{ AND } (\text{NOT}\, k)) : \mathrm{k}_m \to \mathrm{k}_n \to \mathrm{k}_0$$

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- Then the dynamic generalized determiners are in turn defined in terms of these:

$$\text{A} =_{\text{def}} \lambda_{DE}.\text{EXISTS}_n.((D\,n) \text{ AND } (E\,n))$$
$$\text{EVERY} =_{\text{def}} \lambda_{DE}.\text{FORALL}_n.((D\,n) \text{ IMPLIES } (E\,n))$$

Outline

Preliminaries

- Anaphora uses the dynamic generalized determiner

$$\textsc{the} =_{\text{def}} \lambda_{DEc}.\left\langle (E\,(\mathsf{the}\,D\,c)\,c)^{\mathrm{s}}, \lambda_{\mathbf{x}^{|c|}}.(((D\ \textsc{that}\ E)\,(\mathsf{the}\,D\,c)\,c)^{\mathrm{i}}\,\mathbf{x})\ \mathsf{and}\ \mathsf{exists!}_{n:\omega_{|c|}}.(c\ \mathsf{k\text{-}entails}\ (D\,n))\right\rangle$$

- For example, *The cyclist rides* is modeled by

$$\begin{aligned}&\vdash \textsc{the cyclist ride}\\ &\equiv \lambda_c.\left\langle \lambda_{\mathbf{x}^{|c|}}.(\mathsf{ride}\,\mathbf{x}_{(\mathsf{the}\,\textsc{cyclist}\,c)}),\right.\\ &\qquad \left.\lambda_{\mathbf{x}^{|c|}}.\mathsf{exists!}_{n:\omega_{|c|}}.(c\ \mathsf{k\text{-}entails}\ (\textsc{cyclist}\,n))\right\rangle : \mathrm{k}_0\end{aligned}$$

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- Pronouns and other definites can be defined in terms of THE:

$$\begin{aligned} \textsc{it} &=_{\text{def}} \textsc{the nonhuman} \\ \textsc{lance} &=_{\text{def}} \textsc{the named-lance} \end{aligned}$$

Donkey Anaphora

Instances of 'donkey anaphora' are captured, for example

(22) Every cyclist that owns a bike$_i$ rides it$_i$

is modeled as

$$\vdash \text{EVERY}(\text{CYCLIST THAT } \lambda_n.\text{A BIKE}_m.(\text{OWN}\, m\, n))\ \lambda_n.\text{IT}_m.(\text{RIDE}\, m\, n)$$
$$= \text{FORALL}_n.(((\text{CYCLIST}\, n) \text{ AND EXISTS}_m.(\text{BIKE}\, m) \text{ AND } (\text{OWN}\, m\, n))$$
$$\text{IMPLIES IT}_m.(\text{RIDE}\, m\, n))$$

This has the sense

$$\lambda_{\mathbf{x}^{|c|}}.\text{not exists}_{y,z}.(\text{cyclist}\, y) \text{ and } (\text{bike}\, z) \text{ and } (\text{own}\, z\, y) \text{ and not } (\text{ride}\, z\, y)$$

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But note that the scope has the implicature

$$\lambda_{\mathbf{x}^{|c|}}.\text{exists}_{m:\omega_{|c|}}.(c \text{ k-entails } (\text{NONHUMAN } m))$$

Preliminaries

- The *merge* function $\Uparrow : (\omega \to \mathrm{k}_n) \to (\omega \to \mathrm{k}_n)$ turns sense content into implicature content

$$\Uparrow =_{\text{def}} \lambda_{Dnc}.\left\langle \lambda_{\mathbf{x}^{|c|},\mathbf{y}^{|D\,n|}}.\textsf{true}, \lambda_{\mathbf{x}^{|c|},\mathbf{y}^{|D\,n|}}.(D\,n)^{\mathrm{s}}\,\mathbf{x},\mathbf{y}\ \textsf{and}\ (D\,n)^{\mathrm{i}}\,\mathbf{x},\mathbf{y}\right\rangle$$

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- For example, merging a predicativized version of *a cyclist* gives

$$\vdash \Uparrow(\textsc{pred}\,(\textsc{a cyclist}))$$
$$\equiv \lambda_{nc}.\left\langle \lambda_{\mathbf{x}^{|c|}}.\textsf{true}, \lambda_{\mathbf{x}^{|c|}}.\textsf{exists}_y.(\textsf{cyclist}\,y)\ \textsf{and}\ (y\ \textsf{equals}\ \mathbf{x}_n)\right\rangle$$

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- Then the comma intonation is defined in terms of $\Uparrow$, as

$$\textsc{comma} =_{\text{def}} \lambda_{DQE}.Q\,((\Uparrow D)\ \textsc{that}\ E)$$

Basic Example with a Nominal Appositive

- As a basic example,

(23) Lance, a cyclist, is from Texas.

gets modeled as

$$\vdash (\textsc{comma}\ (\textsc{pred a cyclist})\ \textsc{lance})\ \textsc{from-texas}$$
$$= \textsc{lance}\ ((\Uparrow \textsc{pred a cyclist})\ \textsc{that from-texas})$$
$$= \textsc{the named-lance}\ ((\Uparrow \textsc{pred a cyclist})\ \textsc{that from-texas})$$

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  $$= \text{THE NAMED-LANCE}\ ((\Uparrow \text{PRED A CYCLIST})\ \text{THAT FROM-TEXAS})$$

- The sense is that Lance is from Texas:

  $$\lambda_{\mathbf{x}^{|c|}}.(\text{from-texas}\ \mathbf{x}_{(\text{the NAMED-LANCE}\ c)})$$

  and the implicature contains the information that he is a cyclist:

  $$\lambda_{\mathbf{x}^{|c|}}.\text{exists}_y.(\text{cyclist}\ y)\ \text{and}\ (y\ \text{equals}\ \mathbf{x}_{(\text{the NAMED-LANCE}\ c)})$$

Negated Nominal Appositive

- A negated version of (23),

(24) It's not true that Lance, a cyclist, is from Texas.

is given the semantics

$$\vdash \text{NOT}\left(\left(\text{COMMA}\left(\text{PRED A CYCLIST}\right) \text{LANCE}\right) \text{FROM-TEXAS}\right)$$

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  $$\vdash \text{NOT}\left(\left(\text{COMMA}\left(\text{PRED A CYCLIST}\right)\text{LANCE}\right)\text{FROM-TEXAS}\right)$$

- Here, the implicature is the same as before:

  $$\lambda_{\mathbf{x}^{|c|}}.\mathsf{exists}_y.(\mathsf{cyclist}\,y)\ \mathsf{and}\ (y\ \mathsf{equals}\ \mathbf{x}_{(\mathsf{the}\,\text{NAMED-LANCE}\,c)})$$

  but the sense is negated:

  $$\lambda_{\mathbf{x}^{|c|}}.\mathsf{not}\,(\mathsf{from\text{-}texas}\,\mathbf{x}_{(\mathsf{the}\,\text{NAMED-LANCE}\,c)})$$

Treatment of Supplements

- This approach can account for non-restrictive relatives, *as*-parentheticals, 'stacked' appositives, and utterance-final appositives:

  (25) Lance, who's a cyclist, is from Texas.

  (26) Lance, as a cyclist, rides every day.

  (27) Lance, a cyclist, a real go-getter, rides every day.

  (28) Kim met Lance, a cyclist.

- A similar treatment is given to expressives, like

  (29) Lance entered the Tour de France, and the damn doper won it.

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- It also allows implicature content to interact with the sense content

Sense/Implicature Interaction

- Sometimes sense and implicature interact, as in

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- This gets the semantics

$$\vdash (\textsc{comma}\ (\textsc{pred a}\ (\textsc{cyclist that}\ \lambda_n.\textsc{a bike}_m.\textsc{have}\ m\, n))\ \textsc{lance})$$
$$\lambda_n.\textsc{it}_m.\textsc{ride}\ m\, n$$

and so *rides it$_i$* is passed a context containing

$$\lambda_{\mathbf{x}^{|c|}}.\mathsf{exists}_{y,z}.(\mathsf{cyclist}\ y)\ \mathsf{and}\ (\mathsf{bike}\ z)\ \mathsf{and}\ (\mathsf{have}\ z\, y)\ \mathsf{and}$$
$$(y\ \mathsf{equals}\ \mathbf{x}_{(\mathsf{the}\ \textsc{named-lance}\ c)})$$

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- The anaphora works out, but we have to resort to implementing Roberts's (2003) *weak familiarity*

A Problem: Quantified Supplements

- DyCG does fine with examples like

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- DyCG does fine with examples like

(31) Some cyclist, a doper, won the Tour de France.

- But for supplements in the scope of quantifiers like

(32) # No cyclist, a doper, won the Tour de France.

It still gives the implicature

$$\lambda_{\mathbf{x}^{|c|}}.\mathsf{exists}_{y,z}.(\mathsf{doper}\,y)\ \mathsf{and}\ (y\ \mathsf{equals}\ z)$$

A Solution?

- Nouwen (2007) tries to solve this by requiring quantifiers to introduce plural antecedents, since examples like

  (33) Every climber, all experienced adventurers, made it to the summit

  are fine

- But this approach doesn't seem to extend to

  (34) No Tibetan Buddhist$_i$ believes that the Dalai Lama, his$_i$ spiritual mentor, would ever bow to Chinese pressure tactics.

Outline

Taking Stock

Some positives:

- A re-examination of the Gricean picture of implicatures leads to a unified account of anaphora and other implicatures
- The formal theory is both compositional and dynamic, extending some ideas originally due to Heim (1982) and Karttunen and Peters (1979)
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- Weak familiarity is hard to formalize
- I haven't said anything about how to model speaker vs. non-speaker commitments

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Any ideas?

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Axioms for the Static Semantics I

The *extension type* of a meaning type A is denoted $\mathrm{Ext}(A)$.

$$\begin{aligned}
\mathrm{Ext}(1) &=_{\mathrm{def}} 1 \\
\mathrm{Ext}(\mathrm{e}) &=_{\mathrm{def}} \mathrm{e} \\
\mathrm{Ext}(\mathrm{p}) &=_{\mathrm{def}} \mathrm{t} \\
\mathrm{Ext}(A \to B) &=_{\mathrm{def}} A \to \mathrm{Ext}(B) \\
\mathrm{Ext}(A \times B) &=_{\mathrm{def}} \mathrm{Ext}(A) \times \mathrm{Ext}(B)
\end{aligned}$$

The extension functions @ are written infix, similarly to phenogrammatical concatenation, and are subject to the following axioms.

$$\begin{aligned}
&\vdash \forall_{w:\mathrm{w}}.(* \,@_1\, w) = * \\
&\vdash \forall_{x:\mathrm{e}}\forall_{w:\mathrm{w}}.(x \,@_{\mathrm{e}}\, w) = x \\
&\vdash \forall_{f:A\to B}\forall_{w:\mathrm{w}}.(f \,@_{A\to B}\, w) = \lambda_{x:A}.(f\,x) \,@_{A\to B}\, w \\
&\vdash \forall_{c:A\times B}\forall_{w:\mathrm{w}}.(c \,@_{A\times B}\, w) = \langle(\pi_1 c) \,@_A\, w, (\pi_2 c) \,@_B\, w\rangle
\end{aligned}$$

Axioms for the Static Semantics II

$$\vdash \forall_{p:\mathrm{p}} \forall_{q:\mathrm{p}} . (p \; \textsf{entails} \; q) \Leftrightarrow \forall_{w:\mathrm{w}} . ((p \; @ \; w) \Rightarrow (q \; @ \; w))$$

$$\vdash \forall_{w:\mathrm{w}} . \textsf{true} \; @ \; w$$

$$\vdash \forall_{w:\mathrm{w}} . \neg(\textsf{false} \; @ \; w)$$

$$\vdash \forall_{p:\mathrm{p}} \forall_{w:\mathrm{w}} . ((\textsf{not} \; p) \; @ \; w) \Leftrightarrow \neg(p \; @ \; w)$$

$$\vdash \forall_{p:\mathrm{p}} \forall_{q:\mathrm{p}} \forall_{w:\mathrm{w}} . ((p \; \textsf{and} \; q) \; @ \; w) \Leftrightarrow ((p \; @ \; w) \wedge (q \; @ \; w))$$

$$\vdash \forall_{p:\mathrm{p}} \forall_{q:\mathrm{p}} \forall_{w:\mathrm{w}} . ((p \; \textsf{implies} \; q) \; @ \; w) \Leftrightarrow ((p \; @ \; w) \Rightarrow (q \; @ \; w))$$

$$\vdash \forall_{p:\mathrm{p}} \forall_{q:\mathrm{p}} \forall_{w:\mathrm{w}} . ((p \; \textsf{or} \; q) \; @ \; w) \Leftrightarrow ((p \; @ \; w) \vee (q \; @ \; w))$$

$$\vdash \forall_{P:A \to \mathrm{p}} \forall_{w:\mathrm{w}} . ((\textsf{forall} \; P) \; @ \; w) \Leftrightarrow \forall_{x:A} . ((P \, x) \; @ \; w)$$

$$\vdash \forall_{P:A \to \mathrm{p}} \forall_{w:\mathrm{w}} . ((\textsf{exists} \; P) \; @ \; w) \Leftrightarrow \exists_{x:A} . ((P \, x) \; @ \; w)$$

Contextual Entailment

$\vdash \forall_{p:\mathrm{p}}\forall_{q:\mathrm{p}}\forall_{w:\mathrm{w}}.(p \;\textsf{Entails}\; q) \mathbin{@} w \Leftrightarrow (p \;\textsf{entails}\; q)$

$\textsf{c-entails} =_{\mathrm{def}} \lambda_{c:\mathrm{c}}\lambda_{d:\mathrm{c}_{\geq |c|}}.\textsf{forall}_{\mathbf{x}^{|c|}}.(c\,\mathbf{x}) \;\textsf{Entails exists}_{\mathbf{y}^{|d|-|c|}}.(d\,\mathbf{x},\mathbf{y})$

$\textsf{k-entails} =_{\mathrm{def}} \lambda_{c:\mathrm{c}}\lambda_{k:\mathrm{k}}.c \;\textsf{c-entails}\; (\textsf{cc}\,k\,c)$

Definitions for Anaphora

$$\text{the} =_{\text{def}} \lambda_{D:\omega\rightarrow \mathrm{k}_m} \lambda_{c:\mathrm{c}} \imath_{n:\omega_{|c|}} . c \text{ k-entails } (D\, n)$$

$$\text{pro} =_{\text{def}} \lambda_{D:\omega\rightarrow \mathrm{k}_m} \lambda_{c:\mathrm{c}} \imath_{n:\omega_{|c|}} . c \text{ k-cons } (D\, n)$$

Additional Dynamic Definitions

$$\text{THAT} =_{\text{def}} \lambda_{DEn}.(D\,n) \text{ AND } (E\,n)$$

$$\text{PRED} =_{\text{def}} \lambda_{Qn}.\text{NOT}\,(\text{NOT}\,(Q_m.m \text{ EQUALS } n))$$