Embedded implicatures, compositional uncertainty, and pragmatic reasoning

The pragmateurs

November 2, 2014

1 Overview

(1) Grice (1975) defined conversational implicatures as social, cognitively complex meanings that discourse participants create jointly in interaction. Call accounts like these **interactional**.

(2) Recent approaches are framed in opposition to this conception, especially for scalar implicatures (SIs). For example, Chierchia et al. (2012) write, "the facts suggest that SIs are not pragmatic in nature but arise, instead, as a consequence of semantic or syntactic mechanisms". Call these **grammar-driven** accounts.

(3) It is widely assumed that the existence of semantically embedded implicatures would undermine interactional accounts and support grammar-driven ones. The reasoning seems to be that interactional accounts are necessarily 'post-semantic' and therefore unable to model pragmatic effects that need to contribute in some sense to the core semantic content.

(4) Many instances of apparently embedded implicatures have been shown to have straightforward Gricean/interactional accounts (Russell 2006; Geurts 2009; Chemla and Spector 2011). However, occurrences of scalar terms in the scope of non-monotone quantifiers remain recalcitrant on this view because they do not involve the entailment relations needed for standard Gricean pragmatic enrichment to deliver the right results. Chemla and Spector (2011) present evidence that pragmatic enrichment occurs in these contexts.

(5) We reproduce, to a large extent, the results of Chemla and Spector (2011) concerning the interpretations of scalar terms in the scope of monotone and non-monotone quantifiers. However, our experiments involve more items with less irrelevant information. We need not invoke auxiliary assumptions about how 'number of readings' relates to perceived salience. We also explore how these results relate to explicit exhaustification of the scalar term and to prosodic focus.

(6) However, we reject the notion that these facts point to the irrelevance of interactional accounts and towards the supremacy of grammar-driven ones. When communicating, people are interacting with grammar. So one would assume a priori that interaction and grammar are both relevant.

(7) In addition, the 'post-semantic' qualities of Gricean accounts are simply not aligned with one of the major findings of psycholinguistics: people are greedy online interpreters, venturing and revising hypotheses incrementally, drawing not only only subtle linguistics facts but also broader social and contextual ones.

(8) It is arguably the case that CFS agree with us despite their more oppositional position. CFS model the contextual variability of implicatures as ambiguities in the mapping from surface to logical form: certain arrangements of covert exhaustification operators lead to implicature-rich interpretations, and others do not. We still have to ask under which circumstances speakers will intend to use these operators and under which circumstances listeners will perceive them. These are questions of social cognition.

(9) CFS concede that "aspects of the Gricean picture are sound and effective". And, in summarizing their account, they make explicit the role that Gricean pragmatics must play in helping discourse participants to coordinate on the right logical forms: "one can capture the correlation with various contextual considerations, under the standard assumption (discussed in the very beginning of this paper) that such considerations enter into the choice between competing representations (those that contain the operator and those that do not)."

(10) We propose a model that embraces the compositional insights of CFS. However, rather than leaving the task of disambiguation (logical form selection) outside of the model, we bring it in and make predictions about it, seeking to retain the best aspects of interactional accounts. This shows that grammar-driven and interactional accounts are not really in opposition, but rather offer complementary insights. Grammar-driven accounts have helped to reveal that linguistic conventions (including intricate semantic operations) play a role in implicature calculation, and interactional accounts have made progress in explaining how those conventions work in context to yield conversational implicatures. Our model does both of these things.

2 Background conversational implicature

(11) Meta-note: I'm not sure how much we actually want to say here. It might be best to just introduce the facts for scalar implicatures. The reason is that the model we propose does not reify 'conversational implicature' as

a specific category. It doesn't try to reconstruct the maxims, it doesn't try to align with the Gricean characterization/definition, and it doesn't allow us to cleanly separate implicature inferences from others coming from priors, costs, and other contextual facts. I regard all these things as major strengths of the model. But they do compel us to shift the emphasis away from Grice and towards the empirical phenomena.

3 CFS's grammar-driven model

(12) This section briefly reviews the grammar-driven model of CFS.

(13) There are two central pieces to CFS's account: a generally available function *ALT* that maps denotations to their alternatives, and a covert exhaustification operator O.

(14) For *ALT*, the relevant notion of alternative is familiar from theories of questions and focus (Groenendijk and Stokhof 1984; Rooth 1985, 1992): we can assume, as a default, that the alternatives for a meaning t are some subset of the items in the same type-theoretic denotation domain as t. One can also imagine variants of this proposal in which *ALT* operates over lexical items, rather than denotations, but the denotational view will suffice here.

(15) The function *ALT* is part of context-dependent semantics: the discourse participants need to coordinate on it just as they need to coordinate on the meanings of deictic or discourse-bound pronouns, ellipsis sites, evaluation standards, and the like.

(16) The basic exhaustification operator is given in def. 17 (Spector 2007; Fox 2007, 2009; Magri 2009; Chierchia et al. 2012). (This is not the operator that those authors ultimately favor, since it requires some implicit restrictions on allowable *ALT* functions in order to get the right inferences. The final version has the same form as def. 17 but further restricts *ALT* to alternatives that are **innocently excludable**.)

(17) $O_{ALT}(p) = p \wedge \forall q \in ALT : (p \not\sqsubseteq q) \sqsubseteq \neg q$

(18) The O operator maps a meaning p to one that entails p but excludes all of the expressions that p does not entail. When dealing with truth-functional expressions, we can regard $\sqsubseteq$ as entailment, but the definition should be thought of as broad enough to include any kind of partial ordering, which Hirschberg (1985: §4) shows to be needed to capture the full range of 'scalar' implicatures.

(19) Part of the case for a grammar-driven view is that it uses pieces of semantic theory that are independently useful. In particular, exhaustification is at the heart of Groenendijk and Stokhof's (1984) theory of questions and their answers (see also McCarthy 1980). The above operator is a

common proposal for the meaning of *only* (for discussion: Rooth 1996; Büring and Hartmann 2001; Beaver and Clark 2008). Schulz and van Rooij (2006) use exhaustification for implicature calculation (see also de Jager and van Rooij 2007). The approach of CFS is directly inspired by those of Sauerland (2001), Spector (2007), and Fox (2007, 2009). (For critical discussion, see Alonso-Ovalle 2008 and Gajewski 2012.)

(20) The proposal can then be summarized easily: O operators can appear anywhere in the logical form of a sentence, perhaps subject to additional restrictions and general preferences (see CFS: §4.6).

(21) The following is a simple illustration involving truth-functional expressions. The summary is that if we assume the alternative set for *or* ($\vee$) contains just *and* ($\wedge$), then exhaustification of *or* yields an exclusive disjunction ($\overline{\vee}$).

a.

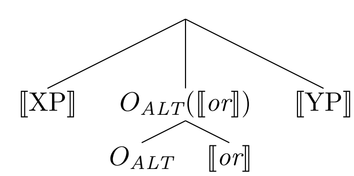
	p	q	$p \wedge q$	$p \vee q$	$p \overline{\vee} q$
w_1	T	T	T	T	F
w_2	T	F	F	T	T
w_3	F	T	F	T	T
w_4	F	F	F	F	F
	$\{w_1, w_2\}$	$\{w_1, w_3\}$	$\{w_1\}$	$\{w_1, w_2, w_3\}$	$\{w_2, w_3\}$

b. $ALT(\{w_1, w_2, w_3\}) = \{\{w_1\}\}$

c. $$\begin{aligned} O_{ALT}(\{w_1, w_2, w_3\}) &= \{w_1, w_2, w_3\} \cap (W - \{w_1\}) \\ &= \{w_1, w_2, w_3\} \cap \{w_2, w_3, w_4\} \\ &= \{w_2, w_3\} \end{aligned}$$

(22) With the above, we can have syntactic constituents like (23), which encodes a pragmatically enriched disjunction like (21c). This constituent is predicted to have the basic morphosemantic distribution of any other disjunction. Thus, embedded implicatures are predicted to be possible.

(23)



(24) The approach is implicitly interactional in the following ways:

a. The authors' specific examples are generally placed in contexts that support the target implicatures by ensuring that they are relevant, informative, and truthful.

b. *ALT* makes all the meanings context dependent — not only where it occurs but what values it returns. Discourse participants must model each other in order to coordinate on these matters. How this happens has not been a focus of grammar-driven accounts, but it could be. (One of our contributions is doing just this!)

(25) From this perspective, implicature calculation amounts to reasoning about which logical form was intended. To decide among these options, the listener will go through pragmatic reasoning that we can characterize.

4 Compositional uncertainty model

(26) From Bergen et al. (2012) and Bergen et al. (2014). Extensions to various kinds of joint inference: Smith et al. (2013) and Kao et al. (2014).

(27) Basic ingredients:

a. T is a set of states (worlds, referents, propositions, etc.).

b. M is a set of messages with designated null message $\mathbf{0}$.

c. $\mathcal{L} : M \mapsto \wp(T)$ is a semantic interpretation function. $\mathcal{L}'(\mathbf{0}) = T$

d. $\mathbf{L} = \{\mathcal{L}' : \mathcal{L}'(\mathbf{0}) = T \text{ and } \forall m \in M - \{\mathbf{0}\}, \mathcal{L}'(m) \neq \emptyset \text{ and } \mathcal{L}'(m) \subseteq \mathcal{L}(m)\}$

e. $P : T \mapsto [0, 1]$ is a prior probability distribution over states.

f. $P_{\mathbf{L}} : \mathbf{L} \mapsto [0, 1]$ is a prior probability distribution over lexica.

g. $C : M \mapsto \mathbb{R}$ is a cost function on messages.

(28) Agents (with additional parameters λ and γ):

a. $l_0(t \mid m, \mathcal{L}) \propto \frac{\mathbb{I}(t \in \mathcal{L}(m))}{|\mathcal{L}(m)|} P(t)$

b. $s_1(m \mid t, \mathcal{L}) \propto \exp\left(\lambda\left(\log\left(l_0(t \mid m, \mathcal{L})\right) - \gamma\, C(m)\right)\right)$

c. $l_1(t \mid m, \mathcal{L}) \propto s_1(m \mid t, \mathcal{L}) P(t)$

d. $L(t \mid m) \propto P(t) \sum_{\mathcal{L} \in \mathbf{L}} P_{\mathbf{L}}(\mathcal{L}) s_1(m \mid t, \mathcal{L})$

(29) We can generalize the above by allowing further iteration beyond L, but it would be nice if we could get away with just this form. We could also remove γ by assuming it is implicitly built into C.

(30) Crucial step (still perhaps in need of fleshing out): the set of messages is derived by the grammar, and then lexical uncertainty generates more refined lexica from those messages in accordance with the constraint in (27d). And our hypothesis is that this suffices to generate the attested range of embedded implicatures under non-monotone quantifiers.

(31) Example involving disjunction:

This uses a bit of a lazy implementation. We should perhaps have 'disjoined' and 'conjoined' states, as in Bergen et al. (2014). It takes a while to get used to that meaning space, but it can give more intuitive results for p and q if the space of forms is expanded.

a. $T = \{w_1, w_2, w_3, w_4\}$

b. Atomic messages: $\{p, q\}$

c. Additional step: close M under disjunction and conjunction: $M = \{p, q, p \vee q, p \wedge q\}$

d. $\lambda = 1$; $\gamma = 1$

e. $C(a \vee b) = C(a) + C(b) + 1.0$. Same for conjunction.

f. $\mathbf{L}$ based on the truth table in (21a).

$$\begin{bmatrix} p \mapsto \{w_1, w_2\} \\ q \mapsto \{w_1, w_3\} \end{bmatrix} \begin{bmatrix} p \mapsto \{w_1, w_2\} \\ q \mapsto \{w_1\} \end{bmatrix} \begin{bmatrix} p \mapsto \{w_1, w_2\} \\ q \mapsto \{w_3\} \end{bmatrix}$$

$$\begin{bmatrix} p \mapsto \{w_1\} \\ q \mapsto \{w_1, w_3\} \end{bmatrix} \begin{bmatrix} p \mapsto \{w_1\} \\ q \mapsto \{w_1\} \end{bmatrix} \begin{bmatrix} p \mapsto \{w_1\} \\ q \mapsto \{w_3\} \end{bmatrix}$$

$$\begin{bmatrix} p \mapsto \{w_2\} \\ q \mapsto \{w_1, w_3\} \end{bmatrix} \begin{bmatrix} p \mapsto \{w_2\} \\ q \mapsto \{w_1\} \end{bmatrix} \begin{bmatrix} p \mapsto \{w_2\} \\ q \mapsto \{w_3\} \end{bmatrix}$$

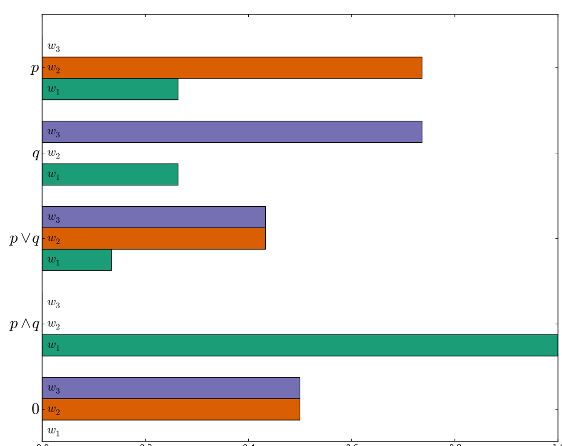
g. Additional step: $\mathbf{L}$ respects the logic of $\wedge$ and $\vee$:

$$\begin{bmatrix} p \mapsto \{w_1, w_2\} \\ q \mapsto \{w_1, w_3\} \\ p \vee q \mapsto \{w_1, w_2, w_3\} \\ p \wedge q \mapsto \{w_1\} \end{bmatrix} \begin{bmatrix} p \mapsto \{w_1, w_2\} \\ q \mapsto \{w_1\} \\ p \vee q \mapsto \{w_1, w_2\} \\ p \wedge q \mapsto \{w_1\} \end{bmatrix}$$

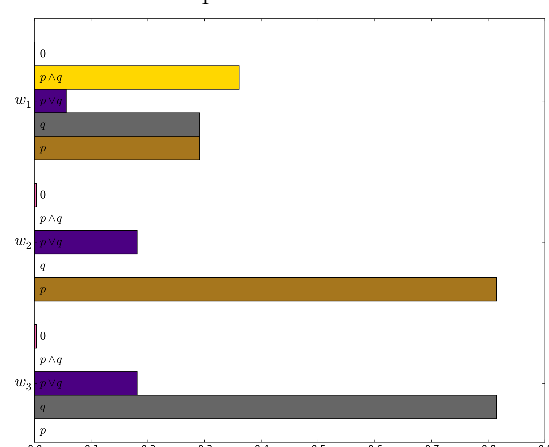
$$\begin{bmatrix} p \mapsto \{w_1\} \\ q \mapsto \{w_1, w_3\} \\ p \vee q \mapsto \{w_1, w_3\} \\ p \wedge q \mapsto \{w_1\} \end{bmatrix} \begin{bmatrix} p \mapsto \{w_1\} \\ q \mapsto \{w_1\} \\ p \vee q \mapsto \{w_1\} \\ p \wedge q \mapsto \{w_1\} \end{bmatrix}$$

The plotted values come from a slightly different model that delivers essentially results.

h. L inferences



Speaker behavior



5 Experimental evaluation of our model

5.1 Experiment 1: scalars under quantifiers

(32) Rationale: improve upon Chemla and Spector (2011) by using better items, more normal response patterns, and more standard assumptions about what the responses mean. Also perhaps make it easier to open things up to additional manipulations (e.g., QUDs).

5.2 Experiment 2: explicit exhaustification

(33) Rationale: CFS use an operator that shares many characteristics with *only*. (This is part of the theoretical appeal, in that the operator seems to be needed anyway.) Adding an explicit *only* gives us a sense for the pattern with explicit signaling — a kind of upperbound on the effects we would expect.

(34) Relevance for our model: adding *only* constrains the space of alternatives in ways that boost the strength of the embedding and basically/fully remove the need for pragmatic reasoning.

5.3 Experiment 3: prosodic focus

(35) Rationale: CFS's operator is also closely related to what one expects on accounts of topic and focus intonation that are based in alternatives. The *ALT* operator embodies one of many things that one might do pragmatically with alternatives (negate them; in other contexts, they could be affirmed, highlighted because of speaker ignorance, etc.). Thus, we might expect prosodic focus to boost the signal.

(36) Relevance for our model: harder to say. We could assume that focus alternatives are somehow part of the messages. We could also see what happens when focal forms are simply made more costly (in terms of the cost function C) than their unfocussed counterparts.

References

Alonso-Ovalle, L. (2008). Innocent exclusion in an alternative semantics. *Natural Language Semantics*, 16(2):115–128.

Beaver, D. I. and Clark, B. Z. (2008). *Sense and Sensitivity: How Focus Determines Meaning*. Wiley-Blackwell, Oxford.

Bergen, L., Goodman, N. D., and Levy, R. (2012). That's what she (could have) said: How alternative utterances affect language use. In Miyake, N., Peebles, D., and Cooper, R. P., editors, *Proceedings of the Thirty-Fourth Annual Conference of the Cognitive Science Society*, pages 120–125, Austin, TX. Cognitive Science Society.

Bergen, L., Levy, R., and Goodman, N. D. (2014). Pragmatic reasoning through semantic inference. Ms., MIT, UCSD, and Stanford.

Büring, D. and Hartmann, K. (2001). The syntax and semantics of focus-sensitive particles in German. *Natural Language and Linguistic Theory*, 19(2):229–281.

Chemla, E. and Spector, B. (2011). Experimental evidence for embedded scalar implicatures. *Journal of Semantics*, 28(3):359–400.

Chierchia, G., Fox, D., and Spector, B. (2012). The grammatical view of scalar implicatures and the relationship between semantics and pragmatics. In Maienborn, C., von Heusinger, K., and Portner, P., editors, *Semantics: An International Handbook of Natural Language Meaning*, volume 3, pages 2297–2332. Mouton de Gruyter, Berlin.

Fox, D. (2007). Free choice disjunction and the theory of scalar implicatures. In Sauerland and Stateva (2007), pages 71–120.

Fox, D. (2009). Too many alternatives: Density, symmetry, and other predicaments. In Friedman, T. and Gibson, E., editors, *Proceedings of Semantics and Linguistic Theory 17*, pages 89–111. Cornell University, Ithaca, NY.

Gajewski, J. (2012). Innocent exclusion is not contradiction free. Ms., UConn.

Geurts, B. (2009). Scalar implicatures and local pragmatics. *Mind and Language*, 24(1):51–79.

Grice, H. P. (1975). Logic and conversation. In Cole, P. and Morgan, J., editors, *Syntax and Semantics*, volume 3: Speech Acts, pages 43–58. Academic Press, New York.

Groenendijk, J. and Stokhof, M. (1984). *Studies in the Semantics of Questions and the Pragmatics of Answers*. PhD thesis, University of Amsterdam.

Hirschberg, J. (1985). *A Theory of Scalar Implicature*. PhD thesis, University of Pennsylvania.

de Jager, T. and van Rooij, R. (2007). Deriving quantity implicatures. In *Proceedings of Theoretical Aspects of Rationality and Knowledge*. ACM Digital Library, New York.

Kao, J. T., Wu, J. Y., Bergen, L., and Goodman, N. D. (2014). Nonliteral understanding of number words. *Proceedings of the National Academy of Sciences*.

Magri, G. (2009). A theory of individual-level predicates based on blind mandatory scalar implicatures. *Natural Language Semantics*, 17(3):245–297.

McCarthy, J. (1980). Circumscription — a form of non-monotonic reasoning. *Artificial Intelligence*, 13(1):27–39.

Rooth, M. (1985). *Association with Focus*. PhD thesis, UMass Amherst.

Rooth, M. (1992). A theory of focus interpretation. *Natural Language Semantics*, 1(1):75–116.

Rooth, M. (1996). Focus. In Lappin, S., editor, *Handbook of Contemporary Semantic Theory*, pages 271–298. Blackwell, London.

Russell, B. (2006). Against grammatical computation of scalar implicatures. *Journal of Semantics*, 23(4):361–382.

Sauerland, U. (2001). On the computation of conversational implicatures. In Hastings, R., Jackson, B., and Zvolenszky, Z., editors, *Proceedings of Semantics and Linguistic Theory 11*, pages 388–403, Ithaca, NY. Cornell Linguistics Circle.

Sauerland, U. and Stateva, P., editors (2007). *Presupposition and Implicature in Compositional Semantics*. Palgrave Macmillan, Houndmills, Basingstoke, Hampshire.

Schulz, K. and van Rooij, R. (2006). Pragmatic meaning and non-monotonic reasoning: The case of exhaustive interpretation. *Linguistics and Philosophy*, 29(2):205–250.

Smith, N. J., Goodman, N. D., and Frank, M. C. (2013). Learning and using language via recursive pragmatic reasoning about other agents. In *Advances in Neural Information Processing Systems 26*, pages 3039–3047.

Spector, B. (2007). Aspects of the pragmatics of plural morphology. In Sauerland and Stateva (2007), pages 243–281.