Pragmatic Inference & Semantic Development

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Society for Language Development
Is Semantics Possible?

**Problem** (circa 1950): Natural language resists logical characterization because it is replete with ambiguity, vagueness, and because sentences change meaning from one context to the next – “ordinary language has no exact logic” (Wittgenstein / Strawson, Russell, etc.)

**Solution**: The inadequacy of logic is an illusion created in part by a failure to consider a role for pragmatic inference.

Partee, 2011; Grice, 1967
e.g., Did you eat my cake?
I ate some of your cake.

Implied: I did not eat all of your cake.

The explananda of semantic theory may be both narrower and simpler than supposed by early linguists and philosophers of language.
My analogy
**Problem:** Acquiring some abstract content, like the positive integers, seems to require the construction of more powerful logical resources than those present in infants (Piaget / Carey). But this seems impossible (Fodor, 1980).

**Solution:** Word learning & conceptual development isn’t a just problem of composing primitives. The explananda of word learning are simpler when the role of pragmatic inference (among others) is considered.
Learning a word is a joint inference over:

1. A space of alternative word forms
2. A space of primitive meanings & combinations

Core concepts: Defined by association to primitives & combinations

Derived concepts: Defined by relations to core concepts & each other

- e.g., contrast, negation, subset relations, logical functions
More than analogy: They’re the same problem
This form of (logically) structured inference subserves both word learning and pragmatic inference.

In adult state: “intentional abductive inference”

i.e., making informed guesses at the mental states of others.
Abductive Inference & Word Learning

In absence of prior linguistic knowledge or constraints on meaning, \textit{gavagai} could mean anything, but humans converge nevertheless.

Word learning requires strong constraints on possible / likely meanings to limit hypothesis making.

“Quine’s problem”
Quine’s Problem

In hypothesis space: rabbit, furry, fast, dinner, jumpy, animal
Not in hypothesis space? undetached rabbit parts, rabbit after 2010
Relevant alternatives: rabbit, animal

Contrast too weak:

\[ X \text{ is a rabbit} \quad \therefore \quad \neg (x \text{ is a dog})? \]
\[ \therefore \quad \neg (x \text{ is a animal})? \]

Mutual Exclusivity too strong:

\[ X \text{ is a rabbit} \quad \therefore \quad \neg (x \text{ is a dog}) \]
\[ \therefore \quad \neg (x \text{ is a animal}) \]

Structured alternatives must constrain word learning
Abductive Inference & Implicature

When we utter a sentence, the listener infers the negation of a small set of alternative inferences.

Q. Do you like the soup?  
A. The asparagus is delicious!  
   (I do not like the soup).

Q. Did you eat my cookies?  
A. I ate some of your cookies.  
   (I did not eat all of your cookies)

“Horn’s problem”
Q. Did you eat my cookies?      A. I ate some of your cookies.

Theory 1 - Negate all alternatives:
I did not eat a pig. I did not eat yesterday. I am not a giraffe. It’s not 5pm.

Theory 2 – Negate all stronger alternatives:
I did not eat some cookies and drink some milk

Theory 3 – Negate stronger alternatives of same type:
I did not eat three of your cookies.

Theory 4 – Negate specific set of scalar alternatives:
a, some, several?, many?, most, all
What these problems have in common

1. Association of word form with a meaning

2. Represent set of alternatives

2. Contrast (negation of other alternatives)

Wagner, Dobkins, & Barner (2013)

Tillman & Barner (2015)
A Final Example: Number

Lexical Meanings

A banana: 🍌

One banana: 🍌

Strengthened Meanings

One, two, three, four, five, six, seven, eight, nine

Inference: one banana = 🍌 & ¬( 🍌 🍌 🍌)

Put a banana in the circle

Put one banana in the circle

Is there a banana in the circle? Y

Is there one banana in the circle? N

Evidence from Wynn

Point to 5 bananas!
Point to blick bananas!

Knowledge of 1 includes knowledge that it contrast with 2, 3, 4, 5 etc.

Wynn, 1992
So: Are Contrast & Implicature the Same Thing?
An Informal Model

**WORD LEARNING**

S: The farmer has a blicket \(_L\) / ALT<or a cat; or a dog; or a cow; etc.>

1. Compute some literal meaning for S.
2. Generate a set of relevant, more informative, alternative meanings for S, by accessing substitutes for L (blicket)
3. Negate those alternatives that the speaker could have uttered but chose not to (i.e., alternatives with existing labels).

**SCALAR IMPLICATURE**

S: The farmer has a cow or \(_L\) a horse / ALT<a cow and a horse>

1. Compute some literal meaning for S.
2. Generate a set of relevant, more informative, alternative meanings for S, by accessing substitutes for L (or)
3. Negate those alternatives that the speaker could have uttered but chose not to (i.e., alternatives with existing labels).
And a Formal Model

**Smart (Bayesian) Human Inference:**
With known & finite lexicon, and known & finite referent set human solution to both inferences can be characterized as a Bayesian inference to the best explanation.

\[ P(r_s|w, C) = \frac{P(w|r_s, C)P(r_s)}{\sum_{r' \in C} P(w|r', C)P(r')} \]

where \( P(\text{referent}) \); \( P(\text{word} \mid \text{referent}) \)
These models are powerful

Nouns: Xu & Tenenbaum: (2007); Frank & Goodman (2014)

Number: Piantadosi et al. (2012)

And so many more!

∀(n): S(n) is a natural number.
Formal models will allow us to solve

Tenenbaum et al: Formal machinery alone will not solve problem of abductive inference.

We also need a theory of:

1. How to restrict alternatives

2. Where structure of alternatives comes from

**AND:** Evidence that these inferences share a psychological format of representation.

Tenenbaum, Griffiths, Kemp, 2006
Starting point: An empirical puzzle
Empirical puzzle

Many argue that the same machinery underlies word learning and implicature.

BUT:

1. Children mutual exclusivity for nouns, number words, etc. by age 2

2. They often fail to compute scalar implicatures beyond the age of 5

Barner & Bachrach (2010); Clark (1989); Frank & Goodman (2014); Gathercole (1988)
Empirical puzzle

Context: All farmers cleaned both a horse and a rabbit

e.g., Every farmer cleaned a horse or a rabbit

Children: Totally fine ✔
Adults: Not ok. ✗

Papafragou & Musolino, 2003; Noveck, 2001; Chierchia et al., 2001; many others
Puzzle: If inferences are the same, why different performance?

Option 1: These are not the same – they differ in format
- Implicature is Gricean & Epistemic, Contrast is not

Option 2: These are the same – but differ in content
- Kids access classes of nouns, adjectives, numbers as relevant alternatives, but not quantifiers, modals, etc.
1. Access to Alternatives
Evidence: Ad hoc vs. Some/All Entailment

- a. Are some of the animals sleeping? Y Y
- b. Are only some of the animals sleeping? N Y
- c. Are the cat and the cow sleeping? Y Y
- d. Are only the cat and the cow sleeping? N N

Kids can make inference, but only for contextually provided alternatives.
All of the blickets have a pencil.

Some of the blickets have a pencil.

Results

<table>
<thead>
<tr>
<th>Condition</th>
<th>Reject</th>
<th>Accept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some-First</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Mixed</td>
<td>12</td>
<td>9</td>
</tr>
</tbody>
</table>

Children n=30 in each, adults n=12
More Evidence

Chierchia et al: Children easily choose stronger alternative when explicitly provided

Miller, Schmitt, Chang & Munn: Kids perform much better at all implicatures when in a forced choice that makes alternatives salient

Stiller, Goodman, Frank: Ad hoc implicatures as early as 3 in a forced choice

Katsos & Bishop: Earlier success with forced choice tasks
2. Format of Inference: Epistemic?
Do **Contrast** and **Scalar Implicature** have different timelines because only SI relies on advanced epistemic reasoning?

**NO:**

1. Problems with implicature persist after children can make Gricean epistemic inferences
2. Children can compute ad hoc implicatures before they can make Gricean epistemic inferences
3. Teens with ASD compute scalar implicatures in absence of epistemic reasoning.

**Contrast & Implicature** are the same, but differ only in alternatives.
Ignorance Implicature

Each animal has an banana or an apple.

¬B: Each animal has an banana.
¬B: Each animal has an apple.

Scalar Implicature is an abductive leap:
B: ¬(Each animal has an apple and an orange).
Look, an apple, a banana! Someone said, “The bear took an apple or a banana” Who said that?
Someone said, “Each animal has an apple or a banana” Who said that?

Hochstein, Bale, Fox, & Barner, 2015; *Journal of Semantics*
Ad Hoc Implicature before Epistemic Inference

Hochstein, Bale, & Barner (in prep.)
Access to Alternatives

Children have computational ability to make complex pragmatic inferences

5-yr-olds reason about epistemic states, but still fail at scalar implicature

AND

4-yr-olds can compute ad hoc implicatures without epistemic reasoning

Kids struggle when inferences require access to alternatives that are not contextually accessible
High functioning individuals with ASD have deficits in theory of mind:

*false belief, irony, sarcasm, prosody, etc.*

There’s evidence that teens with ASD can compute SI

BUT: These results are ambiguous

**Possibility 1:** SI is computed without Gricean epistemic reasoning

**Possibility 2:** Or, SI depends on epistemic inferences that are within capacity of teens with ASD:

Pijnacker et al., 2009; Chevallier et al., 2010
Adolescents with ASD & Implicature

N = 17 typically developed (non-ASD) adults
N = 18 high-functioning individuals with ASD

Hochstein, Bale & Barner, under review
Conclusion: Success at both II and SI in ASD

Consistent with Gricean, epistemic view:

Scalar Implicature *requires* Ignorance Implicature

But, also consistent with non-Gricean View:

Scalar Implicature and Ignorance Implicature are independent

**QUESTION:** Do teens with ASD access speaker states when computing scalar implicature?
Implicature & Speaker Knowledge

Full Knowledge Condition: Peeks inside the last box
Partial-Knowledge Condition: Does not peek

See also Goodman & Stuhlmüller, 2013; Bergen & Grodner, 2012
Part 2: Adolescents with ASD & Implicature

N= 17 typically developed (non-ASD) adults
N = 18 high-functioning individuals with ASD

Hochstein, Bale & Barner, under review
Summary

Five-yr-olds and teens with ASD reason about epistemic states when explicitly asked

BUT:

1. Teens with ASD compute scalar implicatures without consulting epistemic states

2. 4-yr-olds compute Ad Hoc implicatures before Ignorance

Contrast & Implicature are non-epistemic inferences, defined over logically structured lexical alternatives
Developmental Trajectory

Phase 1. Smart Bayesian inference
  contrast and implicatures for salient scales

Phase 2. Learn lexical domains & logical relations of words
  nouns > adjectives > numbers > quantifiers > modals

Phase 3. Gradual maturation of epistemic reasoning ability

Implicature = Enriched Contrast / Mutual Exclusivity
Is Conceptual Change Possible?
Language meaning isn’t restricted to concatenations of lexical building blocks.

Same mechanism that makes semantics possible also makes semantic change possible.

Abstract Concepts: Combinations of core building blocks are enriched by logical inferential relations between words.
Abstract words are defined by these relations

- **Simple Contrast**: red/green/blue
- **Entailment Relations**: Some/all
- **Taxonomic Relations**: dog/animal
- **Containment Relations**: second/minute
- **Logical Functions**: “five” = 4+1
Thank you

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