An evolutionary effect of simplicity bias on the typology of logical operators

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Overview

Evolutionary simulations show that a learning bias for simple semantic denotations creates a diachronic pressure against conjunction of non-sentential meanings, which is arguably unavailable in language

A complex semantics for conjunction?

- *And* appears in a broad range of environments – we consider two:

(1) Mary saw a linguist and John saw a philosopher. *(TP _ TP)*
(2) Mary saw a linguist and a philosopher. *(DP _ DP)*

- Most obvious semantics: *and* operates on truth-values, like the logical $\wedge$ connective:

(3) $[\![\text{and}_t]\!] = \lambda p_t \,.\, \lambda q_t \,.\, p \wedge q$

- **Problem:** $[\![\text{and}_t]\!]$ composes with TPs, but not DPs: DPs do not denote truth-values.
- **Widespread solution:** add complexity into the semantics.

⇒ In one conception, *and* is ambiguous between multiple meanings, incl. $[\![\text{and}_t]\!]$, $[\![\text{and}_{ett}]\!]$.

(4) $[\![\text{and}_{ett}]\!] = \lambda P_{ett} \,.\, \lambda Q_{ett} \,.\, \lambda f_{et} \,.\, P(f) \wedge Q(f)$

⇒ $[\![\text{and}_{ett}]\!]$ composes with quantificational DPs in (2), outputting a new quantifier.

(related analyses include: Montague 1973, Gazdar 1980, Partee & Rooth 1983, Keenan & Faltz 1985, Rooth 1985, Jacobson 1999)

The semantics is simple (Hirsch 2017)

There <u>is</u> a parse of (2) with $[\![\text{and}_t]\!]$: ellipsis obscures underlying syntax.

- Apparent object DP conjunction = *v*P conjunction + ellipsis (*v*Ps denote truth-values).

(5) $[_{TP}$ Mary $[_{vP}$ t_1 saw a linguist] and $[_{vP}$ t_2 ~~saw~~ a philosopher]]

- Sample evidence for hidden *v*Ps: distribution of adverbs (cf. Collins 1988).

⇒ Certain adverbs can adjoin on the clausal spine, but not to DPs, e.g. *yesterday*.

(6) a. Yesterday, Mary saw you. b. ?*Mary saw, yesterday, you.

⇒ Yet, these same adverbs can adjoin in a second apparent DP conjunct.

(7) Mary saw me and, yesterday, you.

There is <u>no</u> parse with $[\![\text{and}_{ett}]\!]$: such a parse seems to over-generate readings.

(ex. (10) adapted from Rooth & Partee 1982, ex. (11) adapted from e.g. Moltmann 1992, Fox 2000)

- *DP and DP* would be interpreted as a quantifier.

(8) $[\![\text{a linguist and a philosopher}]\!] = \lambda f \,.\, \exists x\, [\text{ling}(x) \wedge f(x)] \wedge \exists y\, [\text{phil}(y) \wedge f(y)]$

- But, it lacks readings (at least certain) quantifiers allow.

⇒ Distributive universal quantifiers in object position can scope above the subject.
⇒ But, *DP and DP* cannot (despite similar overall meaning to a universal).

(9) Some conference accepted every linguist.
a. 'Some single conference accepted every linguist.' *(some>every)*
b. 'Every linguist was accepted, potentially by different conferences.' *(every>some)*

(10) Some conference accepted (both) a linguist and a philosopher. *(some>and, *and>some)*

⇒ Note: frozen scope is consistent with *v*P conjunction, as in the baseline:

(11) Some conference accepted a linguist and rejected a philosopher. *(some>and, *and>some)*

General hypothesis: *and* uniformly means $[\![\text{and}_t]\!]$ (following Schein 2017).

Goal for today

- We accept that *and* is unambiguous, and ask: **why** is $[\![\text{and}_{ett}]\!]$ unattested?
- **One approach**: constraints on the hypothesis space block $[\![\text{and}_{ett}]\!]$ (Heim 2015).
- **Alternative (today)**: $[\![\text{and}_{ett}]\!]$ is available in principle, but a combination of independently motivated factors (learning bias, language transmission) accounts for its absence

Step I: simplicity bias in semantic learning

- **Related puzzle**: why does the child converge on the universal quantifier as the meaning for *every* in the face of plausible alternatives? (cf. Goodman 1955, Quine 1960, Kripke 1982)

(12) a. $[\![\text{every}]\!] = \lambda P \,.\, \lambda Q \,.\, P \subseteq Q$
b. $[\![\text{every}]\!]' = \lambda P \,.\, \lambda Q \,.\, P \subseteq Q \wedge |P| > 2$

Evidence for distinguishing between the two is not systematically available for the child. (Rasin & Aravind, in progress)

- **A solution**: bias for simple denotations (cf. Piantadosi et al. 2012)

(13) <u>Working definition (complexity)</u>:
The complexity of a semantic grammar G is the number of symbols in the lexicon of G

- **Consequences**:

(14) $[\![\text{every}]\!] < [\![\text{every}]\!]'$
(15) $[\![\text{and}_t]\!] < [\![\text{and}_{ett}]\!] < \{[\![\text{and}_t]\!], [\![\text{and}_{ett}]\!]\}$

- **Conclusion**: the same bias that accounts for the puzzle with *every* will push the English-learning child away from an available hypothesis with $[\![\text{and}_{ett}]\!]$

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Step II: evolutionary model

- **Iterated Learning Model** (Kirby 2001 et seq.)

$$I_i \overset{learning}{\rightarrow} G_i \overset{production}{\rightarrow} O_i \overset{transmission}{\rightarrow} I_{i+1}$$

- **Input**

(16) <u>Type I</u> (consistent with: and_t, and_{ett}, assuming ellipsis is always available)
Mary saw a linguist and a philosopher.

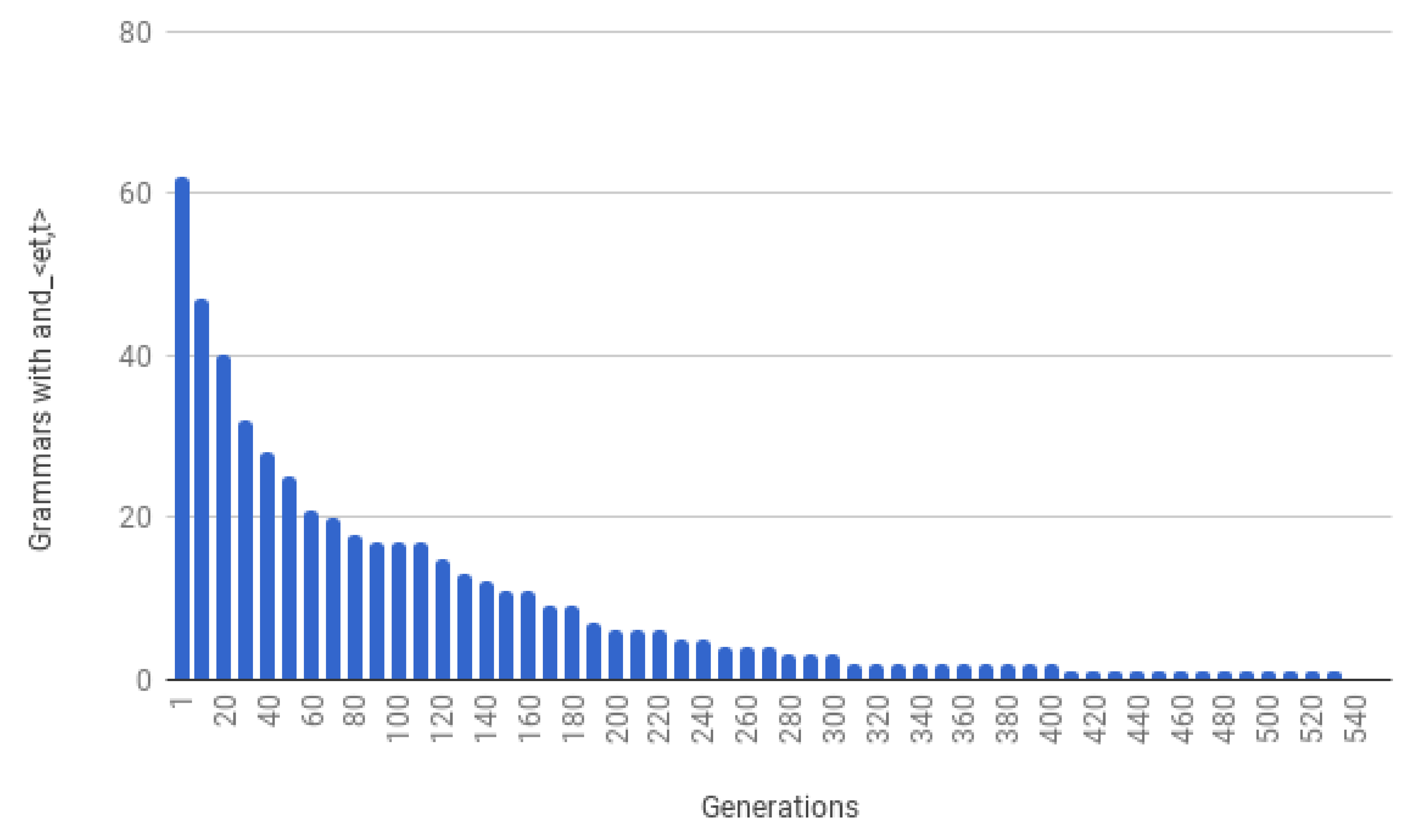
(17) <u>Type II</u> (consistent with: and_t)
Mary saw a linguist and John saw a philosopher.

(18) <u>Type III</u> (consistent with: and_{ett})
Some conference accepted (both) a linguist and a philosopher.
(with context supporting *and > some*)

- **Learning**
  - <u>Hypothesis space</u>: $G_1 = \{\text{and}_t\}$, $G_2 = \{\text{and}_{ett}\}$, $G_3 = \{\text{and}_t, \text{and}_{ett}\}$
  - <u>Complexity</u>: $G_1 < G_2 < G_3$
  - <u>Learning algorithm</u>: choose the simplest grammar consistent with the input
- **Production**
  - Produce a random set of outputs according to some probability distribution
  $G_1 \Rightarrow$ Type I, II $\quad G_2 \Rightarrow$ Type I, III $\quad G_3 \Rightarrow$ Type I, II, III

Simulation

- **Setting**:
  - Population size = 100
  - Initial grammar for each agent chosen randomly (uniform distribution)
  - Number of outputs = 7 (generated randomly, uniform distribution)
- **<u>Result</u>: number of grammars with and_{ett} declines exponentially**



Further issues

- **Robustness**: unrealistic assumptions regarding number of outputs (too low) and probability of producing Type III examples (too high); we get a similar graph for:
  - Type III = 10%; Number of outputs = 48
  - Type III = 5%; Number of outputs = 100
  - Type III = 1%; Number of outputs = 480
- **General question:** what aspects of the semantics are predicted to simplify over time given the learning bias?

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