

# Constituency Deficits in Bonobo Comprehension of Spoken English

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## Some Background

### The result from Fitch and Hauser (2004)

- ▶ Humans can learn to recognise patterns of the form  $(AB)^n$  and  $A^nB^n$ , for  $n=2,3$ .
- ▶ Cottontop tamarins can recognise  $(AB)^n$  but not  $A^nB^n$ .

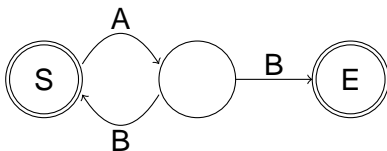
### Fitch and Hauser's inference

- ▶ Humans can recognise patterns generated by regular grammars and context-free grammars.
- ▶ Cottontop tamarins can only recognise patterns generated by regular grammars.

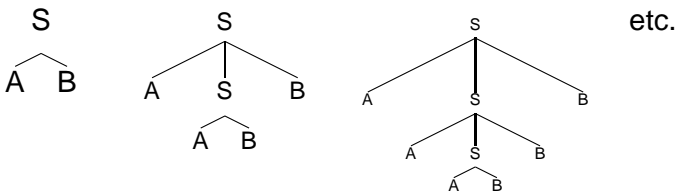


## The Target Grammars

$(AB)^n$



$A^nB^n$



## Lots of Criticism

- ▶ Both stringsets are finite, and so sub-context-free.
- ▶ The target underlying grammars are not good representatives of the finite state/context free classes.
- ▶  $A^nB^n$  can be recognised by a counter grammar.
- ▶ The standard CFG generating  $A^nB^n$  requires self-embedding, which humans are bad at.
- ▶ Starlings can recognise both patterns if you train them very intensely.
- ▶ Etc...



## The Formal Problem

- ▶ The increased expressive power of CFGs over RGs is due to the more flexible notion of **constituency**.
  - ▶  $X \rightarrow \phi$ , where  $X$  is a nonterminal and  $\phi$  is a string of terminals and nonterminals.
  - ▶  $X \rightarrow aY$ , where  $a$  is a terminal and  $X, Y$  are nonterminals.
- ▶ But we can never be sure that a subject is making use of nontrivial constituency while ever
  - ▶ They don't have to **generalise** beyond the input;
  - ▶ They don't have to **interpret** the patterns.



## Semantics as Evidence for Constituency

- ▶ [The man] saw [a woman]
- ▶ Clearly not just a matter of adjacency:
  - ▶ [The ticket collector]. . .
  - ▶ \*[The ticket] collector. . .
- ▶ Material in NP forms a semantic unit in its own right, and externally (as an argument of V)
- ▶ Getting the correct interpretation without constituency is not impossible over a finite corpus, but requires positing massive lexical ambiguity for most function words (*the, and, . . .*).



## Prediction

Without constituency, a subject should struggle to interpret such function words.



## The Plan

- ▶ The ape language experiments are still unique in requiring a nonhuman to pair a syntax and a semantics.
- ▶ If the apes are using a sub-context-free model of English grammar, they will struggle whenever they need to treat a substring of the full utterance as a semantic unit.
- ▶ This includes NPs with determiners, coordinated NPs, etc.



## Kanzi: Background

- ▶ Probably *the* most impressive nonhuman user of human language.
- ▶ Receptive vocabulary of a couple of thousand words;
- ▶ Production vocabulary (via a keyboard of 'lexigrams') of a few hundred.
- ▶ Appears to use words symbolically, use language for non-instrumental reasons, and various other humanlike characteristics.

All following data taken from Savage-Rumbaugh *et al.*'s (1993) corpus of Kanzi's responses to 660 English requests.



## Kanzi Has Some Syntax

### Sensitivity to Word Order

- ▶ Put the tomato in the oil.
- ▶ Put some oil in the tomato.
  
- ▶ 43 such items in 21 pairs.
- ▶ 77% accuracy.



## A Lower Bound on Kanzi's Interpretive Strategy

- ▶ Word order sensitivity rules out a 'semantic soup' strategy.
- ▶ Kanzi makes use of ordering information, and so interprets utterances on the basis of some sort of grammar.
- ▶ Do we have evidence for semantic constituency too?



## Some Non-evidence for Semantic Constituency

### Locatives and other Modifiers

Modifiers in the structures where Kanzi saw them can always be interpreted as semantic soup:

- ▶ Go get the rock that's outdoors →
- ▶ Get the rock (outdoors is involved somehow).

### Sentential embedding

The particular sentential embeddings that Kanzi heard can always be ignored without a significant effect on the semantics:

- ▶ I think we need to give the balloon to Kelly →
- ▶ Give the balloon to Kelly.



## Function Words

Some surprising slips from Kanzi:

- ▶ *Could you pour some/a little Coke in the water?* [Kanzi pours in the whole can]
- ▶ *Go to the refrigerator and get a tomato.* [Kanzi brings back a bag of tomatoes]
- ▶ *Kanzi, go get a carrot for Rose, carrot.* [Kanzi starts taking carrots out of a 50lb bag and pushes several towards Rose]



## Function Words: Discussion

- ▶ Kanzi only hears three determiners, *the*, *a* and *some*.
  - ▶ He responds to *the* appropriately.
  - ▶ He responds to *a* and *some* as if they meant *the*.
- ▶ Conclusion: Kanzi ignores determiners and treats every noun he hears like it means *the N(s)*.
  - ▶ Humans interpret the **phrase** [<sub>NP</sub> Det (Adj) N (PP)];
  - ▶ Kanzi interprets the **word** N alone.
  - ▶ Any other NP-internal material is plausibly treated as a sentential modifier rather than an NP-modifier.
- ▶ Other functional material (auxiliaries, prepositions) is treated similarly.



## Function Words: Evaluation

This evidence is sound, but:

- ▶ The semantics of function words is pretty obscure in the first place.
- ▶ Children expect to hear them in the right place before they figure out what they mean.
- ▶ Not clear that Alia was significantly better than Kanzi in this respect.
- ▶ Not clear that his lexigram keyboard included such function words at this stage.

Conclusion: This evidence may support the hypothesis that Kanzi lacks constituency, but needs to be treated with caution in the light of these potential confounds.



## Thematic Relations: Background

- ▶ Part of understanding the lexical semantics of a verb is understanding how many participants it requires.
  - ▶ Giving requires a *giver*, a *receiver*, and a *thing given*.
  - ▶ Scaring requires a *scarer* and a *scaree*.
- ▶ Part of understanding syntax is understanding how those *θ-roles* relate to other parts of the sentence.
  - ▶ NP<sub>giver</sub> give NP<sub>receiver</sub> NP<sub>thing given</sub>
  - ▶ NP<sub>scarer</sub> scare NP<sub>scaree</sub>
- ▶ The *θ-criterion* for humans: each **NP** receives a *θ*-role and each *θ*-role is assigned to an **NP**.
- ▶ But what if Kanzi only cared about nouns, not noun phrases?
- ▶ A word-level *θ-criterion*: each **noun** receives a *θ*-role and each *θ*-role is assigned to a **noun**.



## Thematic Relations and NP-Coordination

- ▶ NP-coordination leads to a discrepancy between the number of nouns and the number of noun phrases in a sentence:  $[_{NP_1} [_{NP_2} \text{Det } N_1]]$  and  $[_{NP_3} \text{Det } N_2]$
- ▶ This is a prime case where we need constituency to get the interpretation right: externally,  $NP_1$  functions as a unit, despite its internal complexity.



## Results

- ▶ 23 test sentences from the Savage-Rumbaugh *et al.* corpus involving NP-coordination.
- ▶ 6 have clear confounds and have to be discarded.
- ▶ 1 sentence produced an entirely irrelevant response from Kanzi.
- ▶ This leaves 16 good trials.
  - ▶ 8 times out of 16, Kanzi ignored the first NP:  
*Show Sue the toothpaste and the milk.* [Kanzi shows only the milk]
  - ▶ 4 times out of 16, Kanzi ignored the second NP:  
*Show me the ball and the doggie. Show me the ball and the doggie.* [Kanzi shows only the ball]
  - ▶ 4 times out of 16, Kanzi acts on both NPs:  
*Give me the milk and the lighter.* [Kanzi does so]



## Results

- ▶ Kanzi's accuracy on this construction is **25%**.
- ▶ His accuracy over the 660-sentence corpus as a whole is **72%**.
- ▶ A 2-year-old infant's accuracy is **66%** over the whole corpus, and  $\geq$  **67%** on the NP-coordination trials.
- ▶ This is a **species-specific, construction-specific** deficit.



## Summary

- ▶ Kanzi's impressive performance only dips significantly in two areas:
  - ▶ He fails to interpret functional content (determiners, prepositions, etc.) within a phrase.
  - ▶ He performs below chance on NP-coordination.
- ▶ Even a 2-year-old human doesn't show at least the second deficit.
- ▶ These are the only cases in the corpus which require sensitivity to constituency for correct interpretation.
- ▶ **Conclusion:** Kanzi's syntax cannot give him the constituents he needs to interpret these constructions.



## Idle Speculation

- ▶ Cognitive scientists since Lashley (1951) have seen hierarchical structure everywhere in human behaviour.
- ▶ Is Kanzi's deficit indicative of a more domain-general lack of hierarchical structure?
- ▶ The question is pertinent to Hauser, Chomsky and Fitch's (2002) claim that recursive embedding distinguishes the narrow language faculty from general cognition.
- ▶ An answer would require consideration of vision, planned action, navigation, social cognition, etc. Here, just one case study.

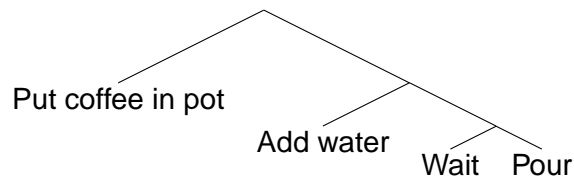


## Human Planning I

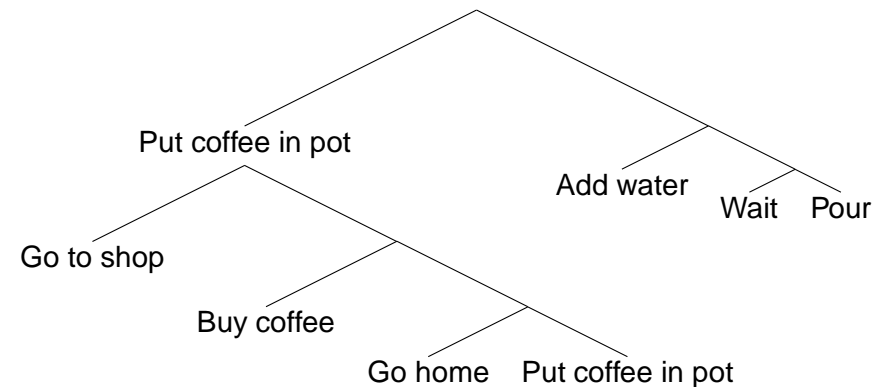
- ▶ Humans can productively combine a finite set of fixed routines into novel problem solving plans.
- ▶ Jackendoff (2007) on making coffee. If we run out of coffee, we don't necessarily give up, but can replace a simple part of making coffee (spooning coffee into pot) with a complex part (going to the shop, buying more, and spooning some into the pot).
- ▶ This ability to insert internally complex structures anywhere within a larger structure looks like the same notion of constituency that we find in human syntax.



## Human Planning II



## Human Planning II



## Chimp Planning

- ▶ It seems from Köhler (1925) that chimps don't do this, though there isn't much good evidence one way or the other.
- ▶ Experiment 1:
  - ▶ Put a chimp in a room with a box and a banana suspended from the ceiling.
  - ▶ The chimp can push the box under the banana then jump and reach it.
- ▶ Experiment 2:
  - ▶ Put a chimp in a room with a banana but no box, having previously made the chimp aware of a usable box nearby.
  - ▶ The chimp doesn't get the box and push it under the banana.



## Chimp Planning



## Chimp Planning



## Chimp Planning II

- ▶ We can see our ability to embed plans within other plans as an ability to see subgoals as proxies for wider goals (see Steedman 2002 for a related analysis).
  - ▶ If I had some coffee, I could make some coffee.
  - ▶ So I need to get some coffee.
- ▶ Chimps apparently don't do this: they can perform actions which allow them to make monotonic progress towards a goal, but they don't make progress towards a subgoal while ignoring the ultimate goal.
- ▶ If goals define units for planning, then their planning deficit here is formally very close to Kanzi's phrase structure deficit.



## End of Idle Speculation

- ▶ Kanzi's constituency deficit may be related to a more domain-general inability to handle hierarchical structure among great apes.
- ▶ How domain-general remains to be seen. . .