Artificial Language Learning with Apes, Primates and Songbirds

Referents:
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Structure

Review

- Apes and Pointing
- Universal Grammar

Chomsky Hierarchy

Type-0		No restrictions
Type-1	Context-Sensitive	rules of the form $S \rightarrow \varepsilon$ or $\alpha A \beta \rightarrow \alpha\gamma\beta$ $A, S \in V_N$ (S start symbol), $\alpha, \beta, \gamma \in (V_T \cup V_N)^*$, $\gamma \neq \varepsilon$ If S → ǫ is a rule, then S never occurs as the right hand side of a rule.
Type-2	Context-Free	Rules of the form $A \rightarrow \gamma$ $A \in V_N$, $\gamma \in (V_T \cup V_N)^*$
Type-3	Finite-State	Rules of the form $A \rightarrow xB$ or $A \rightarrow \vec{x}$ $A, B \in VN$, $\vec{x} \in V_T^*$

Sequental Pattern Learning

Connection between sequential learning and language:

Fixed sequences: idioms, stock phrases, words
Statistical learning: discovery of word transitions
Hierarchical structure: phrase structure of sentences

Common neural basis of language and sequential learning:

- Agrammatic aphasics also have problems with sequence learning

Caveats when comparing non-human and human performance

- Imitating a non-conspecific
- Training non-verbal animals
- „Upgraded“ primates
- Homology vs. analogy
- Methodological differences
- Natural context vs. the laboratory
- Human experience

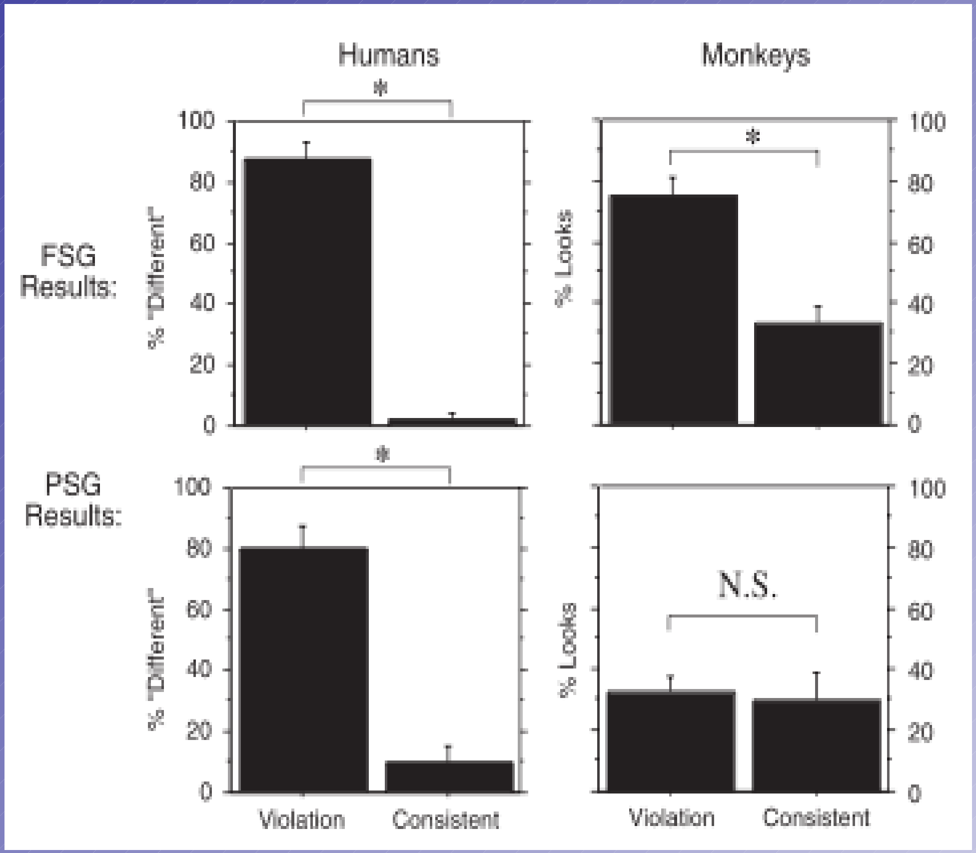
Hauser & Fitch

- Human syntax vs. concatenation of symbols in animal communication
  → Ability to process hierarchical structures?
- Suggested that nonhuman primates are able to procede FSGs
- Assumption: Only humans are able to understand PSG-Grammars

Hauser & Fitch – The Experiment

- Subjects: two groups of ten cotton-top tamarins
- FSG: $(AB)^n$ and PSG: A^nB^n with n=2 or n=3
- A and B: classes of eight CV-syllables
- Training: 20 min of repeated playback of the grammatic strings
- A-stimuli read by woman, B-stimuli by man
- Observation of the primates' orientation:
  - Suggested, they would look towards the speaker, when there was a grammar violation

Hauser & Fitch - Results



Hauser & Fitch - Results

- For the FSG: Significant difference between looking-rates (72% to violation; 34% to consistent)
- For PSG: No significant difference (29% to violation; 31% to consistent)

→ Primates don't have the ability to master this rule.
→ They are not able to understand the hierarchical structure of PSG.

Perruchet and Rey

Evidence against Fitch & Hauser:

- Discovery of the hierarchical structure not essential to recognize the violations
- Different testing method for primates and humans
- No sequences in the material that made counting necessary (as AAABB)

  → human subjects could have discriminated the cases with one voice transition from the others

→ Modified the F&H experiment

Perruchet and Rey - Experiment

- Subjects: 32 undergrad students
- Materials: Strings of an center-embeding grammar, with possible violations in two dimensions (center-embedding and pitch variation)
- 3 min learning phase
- Judgement task

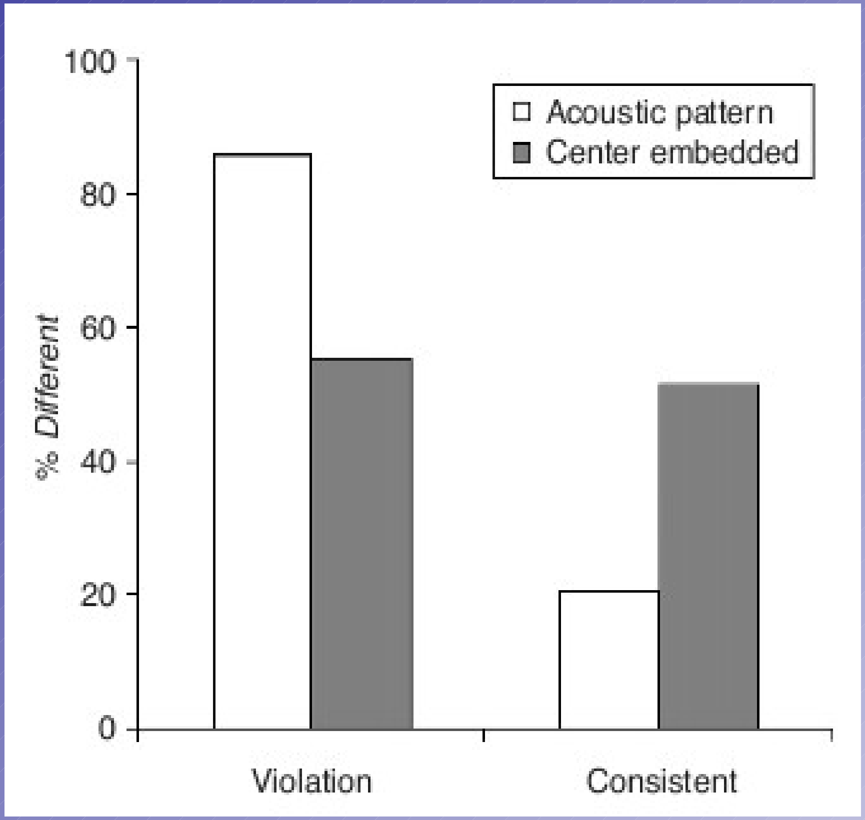
Perruchet and Rey - Experiment

Structure of the Strings Used During the Test Phase

Grammatical Structure (Center-Embedding)	*n*	Acoustic Pattern (Pitch Variation): Violation	Acoustic Pattern (Pitch Variation): Consistent
Violation	2	**A1** A2 **B1** B2	**A1** **A2** B1 B2
	3	**A1** A2 **A3** B2 **B1** B3	**A1** **A2** **A3** B2 B1 B3
Consistent	2	**A1** A2 **B2** B1	**A1** **A2** B2 B1
	3	**A1** A2 **A3** B3 **B2** B1	**A1** **A2** **A3** B3 B2 B1

Note—Bold and underlined characters = high pitch; normal characters = low pitch.

Perruchet and Rey - Results



Perruchet and Rey - Results

- No significant difference between violation and consistance for center embedding
- Significant difference for the acoustic pattern
- Subjects' sensitivity to changes in acoustic pattern was better when the strings were longer

→ Results of F&H don't give evidence for a difference between hierarchical structure processing of primates and humans

Conway & Christiansen

As sequential pattern learning plays an important role concerning the human ability of producing and understanding language and grammar, Conway and Christiansen want to examine how far non-humans also possess this ability.

Three experiments:

- Learning action sequences by observation
- Serial ordering of stimuli: The role of planing
- Examination of combinatorial seriation strategies

Conway & Christiansen – Experiment 1

- Capuchin monkeys, chimpanzees, human children (2-4 years)
- Artificial fruit consisting of different sub-components
- Subjects observed experimenter bypassing one or more of the sub-components, then were allowed to manipulate the fruit in order to procure treat contained within.

Conway & Christiansen – Results 1

- When the artificial fruit consisted of only two sub-components, both non-humans and humans copied the action they observed.
- Human children copied the details of the actions more carefully than the primates did.

Conway & Christiansen – Experiment 2

- Japanese monkeys , chimpanzees, human adults
- 2-4 colored circles of different size on a touch screen
- Subjects required to press each stimulus in a pre-determined order
- Primates recieved pre-training before testing
- Reaction times were collected

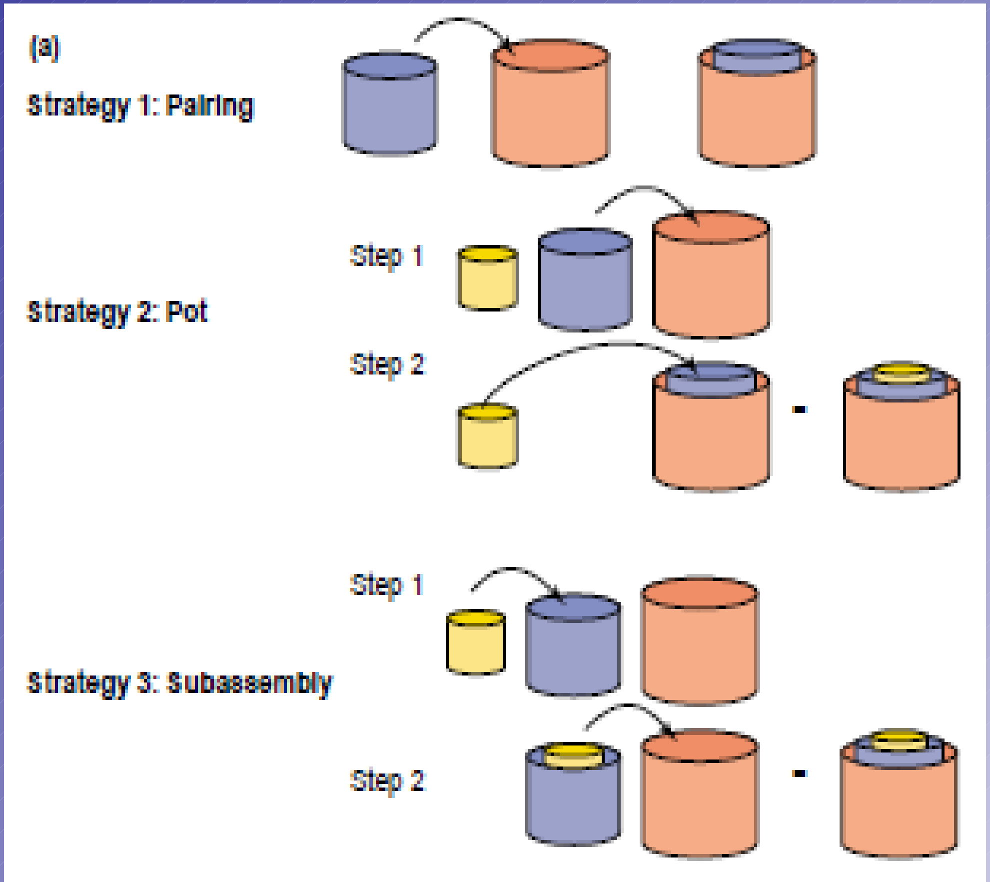
Conway & Christiansen – Results 2

- When the artificial fruit consisted of only two sub-components, both non-humans and humans copied the action they observed.
- Human children copied the details of the actions more carefully than the primates did.

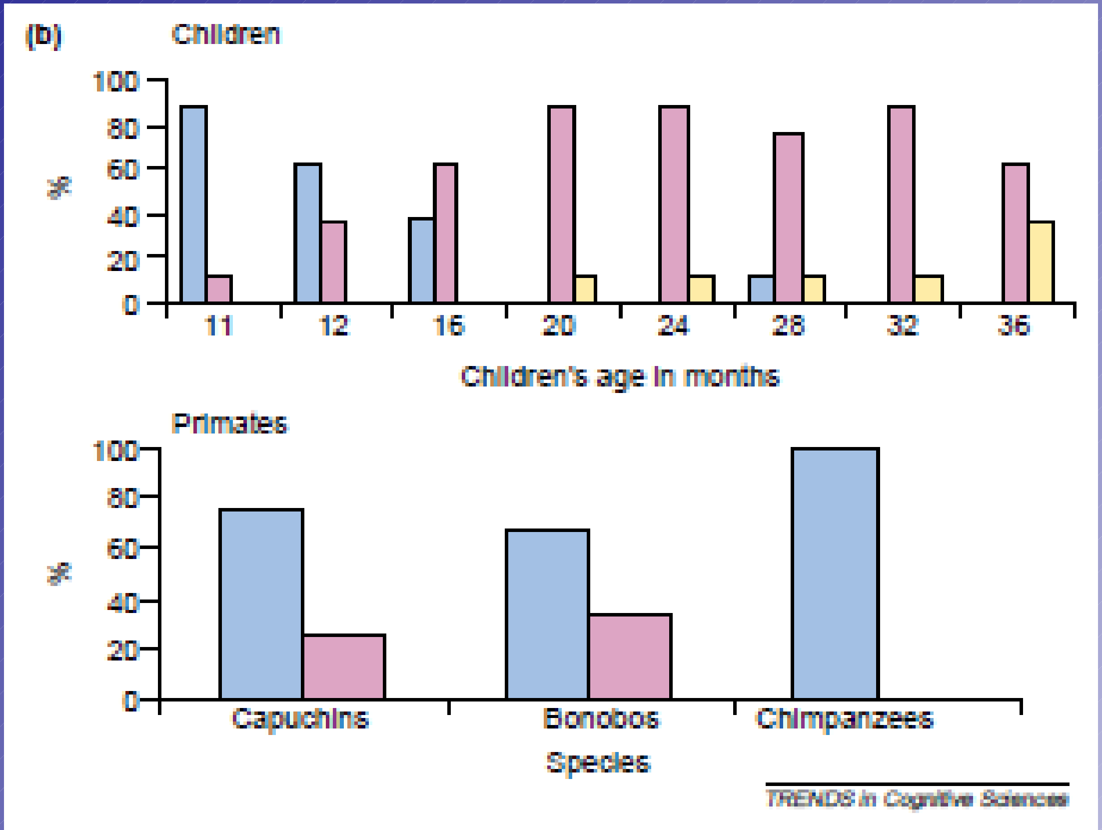
Conway & Christiansen – Experiment 3

- Capuchin monkeys, chimpanzees, bonobos, human children
- Nesting cups of different size
- Experimenter demonstrated nesting the cups using a hierarchical strategy
- Subjects verbally encouraged to combine the cups

Conway & Christiansen – Experiment 3



Conway & Christiansen – Results 3



blue – pairing strategy

magenta – pot strategy

yellow - subassembly

Conway & Christiansen – Results

- Primates seem to be capable of encoding, storing and recalling arbitrary fixed sequences (motor actions, visual stumuli)
- Primates encode and represent a list of sequential items by learning each items ordinal positionChimpanzees show evidence of planning their movement sequences to some extent, monkeys do not.

Gentner et al.: Recursive syntactic pattern learning by songbirds

- 11 European starlings
- „language“ of 8 „rattle“ and 8 „warble“ motifs from the repertoire of a single male starling
- Context-free grammar of the form A^2B^2
- Finite-state grammar of the form (AB)“
- Starlings were trained to classify subsets of sequences
- Second test: Birds were transferred abruptly from the 16 baseline training stimuli to 16 new sequences from the same two grammars.

Gentner et al. - Experiment

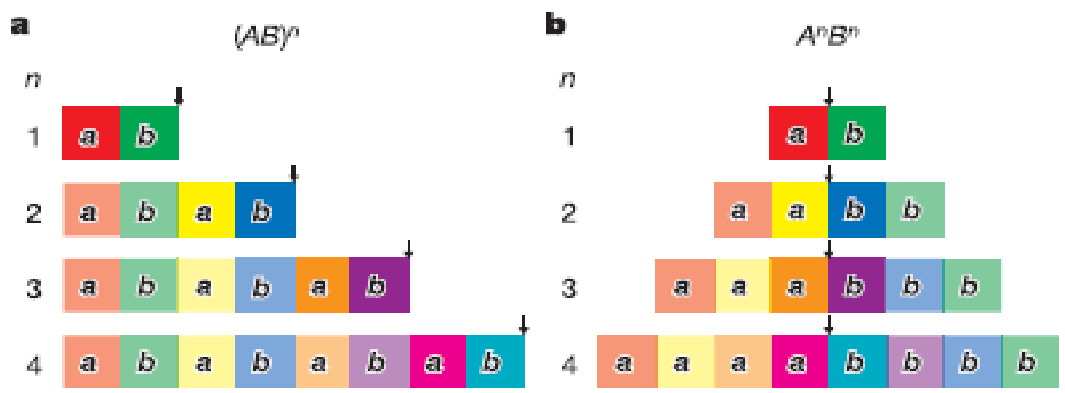


Figure 1 | Grammatical forms. **a**, Finite-state form $(AB)^n$. **b**, Context-free form A^nB^n. Both grammars describe patterned sequences of elements (lower-case letters) of the sets '*A*' and '*B*'. Longer strings of the form $(AB)^n$, where n gives the number of *AB* iterations, are produced by appending elements to the end of an $n-1$ sequence. Longer strings with the form A^nB^n are produced by embedding elements into the centre of an $n-1$ sequence. Learning of and generalization to an A^nB^n pattern implies the capacity to process syntactic structures generated through recursive centre-embedding. Black arrows denote insertion points for higher-order sequences. Brightly coloured squares mark the '*AB*' phrase inserted at each order. Different hues denote different elements.

Gentner et al. - Results

9 out of 11 starlings learned to classify FSG & PSG sequences accurately

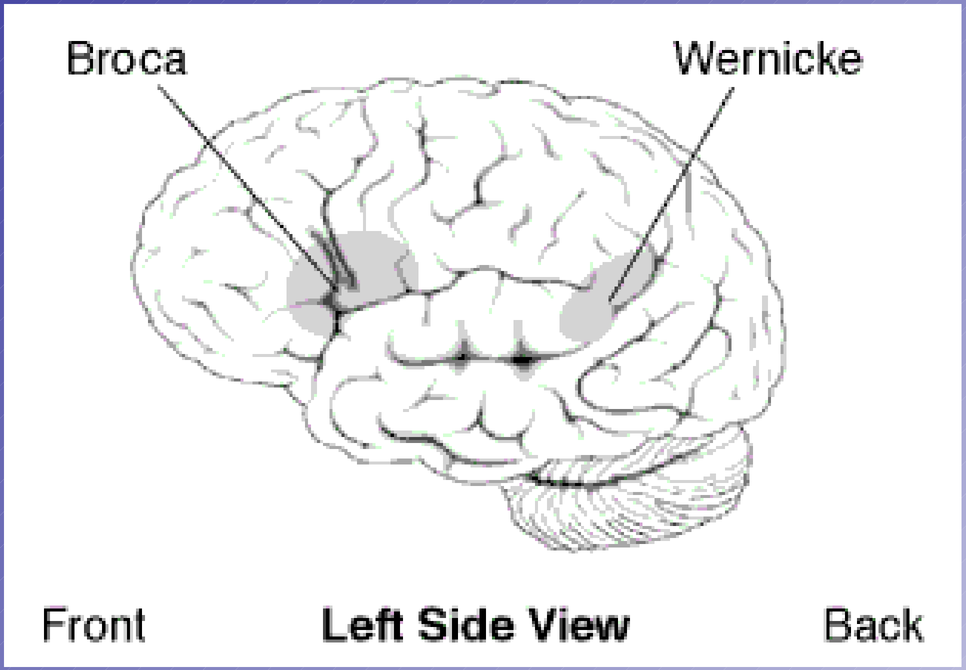
Second test:

- Birds classified sequences correctly
- Acquired general knowledge about features diagnostic of the two grammarsand applied this knowledge to classify the stimuli correctly.

Neuronal notes (A. D. Friederici)

- Brain regions differ in phylogenetic age
- In humans processing of FSG and PSG in separable brain structures that are adjacent but of different phylogenetic age.
- FSG: phylogenetically older structure
- PSG: younger structure

Neuronal notes



Humans and Non-Humans:
Differences in function of Broca's Area?

Neuronal notes

- Broca‘s area plays important role in grammatical aspects
- Not sure which aspects of syntactic processing are supported by this area.
- Word-order, agreement, verb-subcategorization or local phrase-structure violations do not activate Broca‘s area.
- Involved when syntactic movement and transformational structures come into play
- Activated for learning of language-like rules
- No activation when rules could not exist in any natural language

Tries to teach language to apes

To some extent apes were able to learn ASL (American Sign Language)

- Nim Chimpsky (chimpanzee)
- Washoe (chimpanzee)
- Koko (gorilla)
- Chantek (orangutan)

Azy, orangutan: able to communicate with written symbols

Conclusion

- Not all of the experiments provide essential evidence (→ P&R, caveats)
- Apes show the ability of sequential learning (but not for hierarchical sequences) which is obligatory but not sufficient

→ Apes can't speak