

INPUT COMPLEXITY & RULE INDUCTION

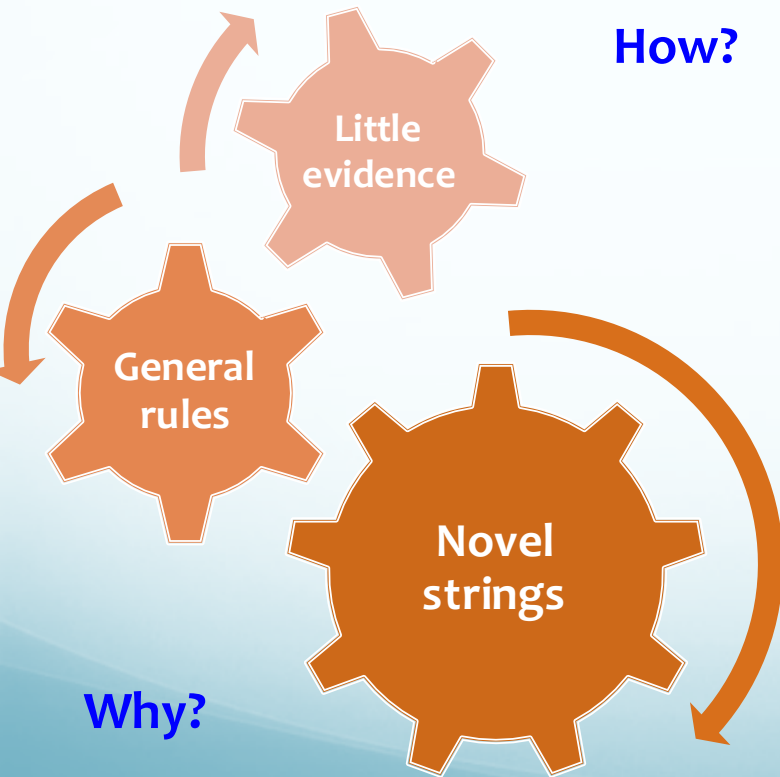
An Entropy Model

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Rule Induction

A Puzzling Mechanism

Puzzle



Types of Rule Induction

Perceptually-bound generalizations

→ relations between perceptual features of items

- e.g. a relation based on physical identity: *ba ba* (*ba* follows *ba*) OR “end in *d̄i*”

Category-based generalizations

→ operations over abstract variables (*X* follows *X*, where *X* is a variable)

- e.g. an identity relation over variables *X_X*, “end in *Y*”

- Based on Gómez and Gerken (2000)

Previous research. Artificial Grammar Learning

Underlying mechanisms

(1) **statistical learning** → transitional probabilities

- phonotactic regularities (Chambers et al, 2003),
- word boundaries (Saffran et al, 1996)

→ blind to novel items



vs.

(2) **abstract rule learning**

→ algebraic rules that apply to categories

(Marcus et al, 1999)

- first item is the same as third item
(*li_na_li; ga_ti_ga, etc.*)

→ How do we tune into such rules? Any input factors?



Factors

(1) **input variability** -> **rule reliability** → if input allows for several generalizations, most statistically consistent (reliable) one is formed (Gerken, 2006)

→ What makes a rule reliable? How much variability?



(2) **richness of contexts**, (3) **overlap of contexts**, (4) **systematic gaps**, (5) **exposure time** → factors modulate category formation in a different manner (Reeder et al, 2009)

→ Are these independent factors? Why different effects?



Independent mechanisms underlying these types of generalization?

1.

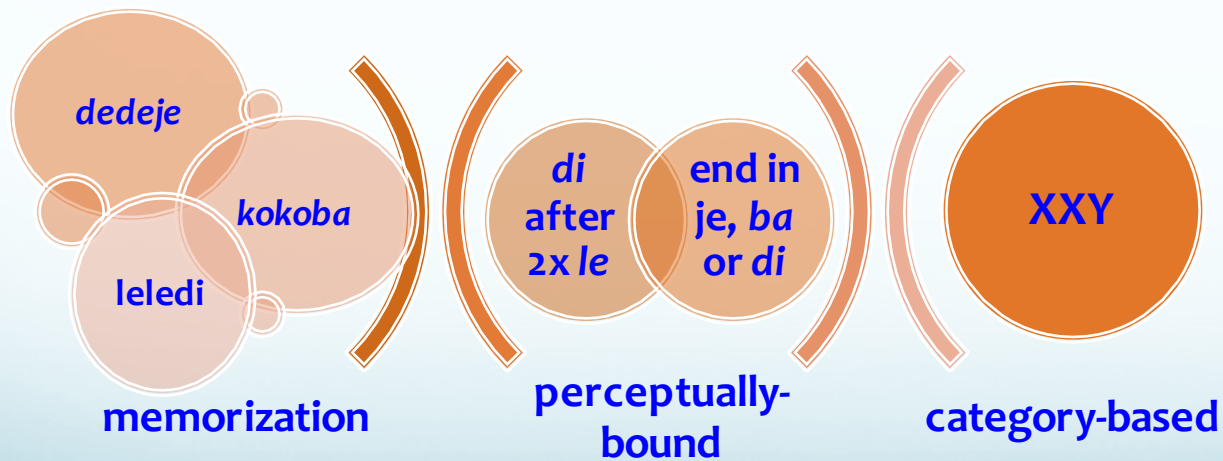
- **Statistical learning** -> **Perceptually-bound generalizations**
 - *ba* follows *ba*, end in *di*

2.

- **Abstract rule learning** -> **Category-based generalizations**
 - *varX* follows *varX*, end in *varY*

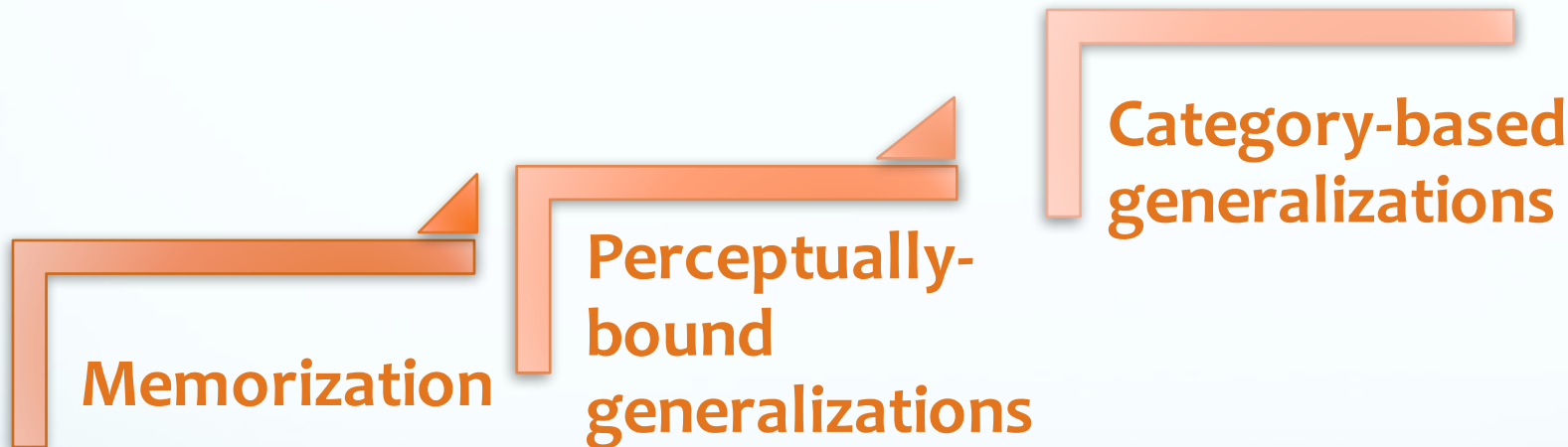
OR

Phased mechanism?



Research Questions

- 1. What are the **independent factors** that trigger the **inductive leap** from memorizing specific items to forming perceptually-bound and category-based generalizations?

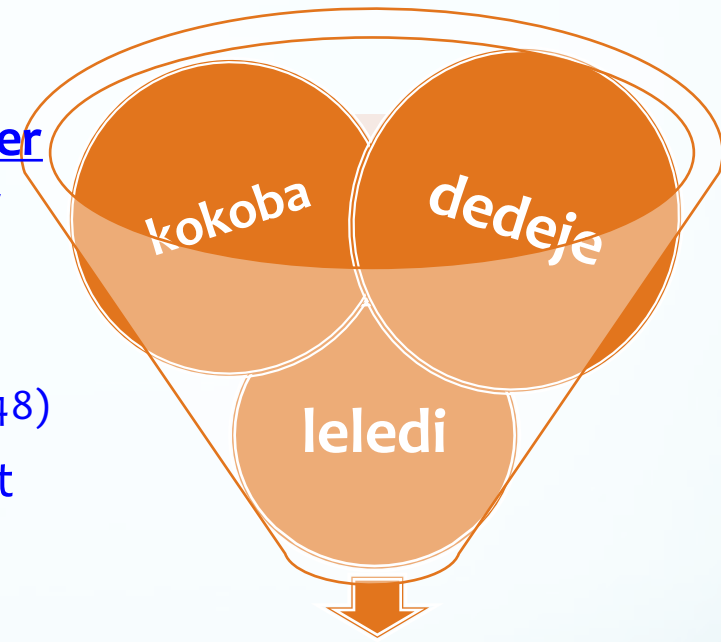
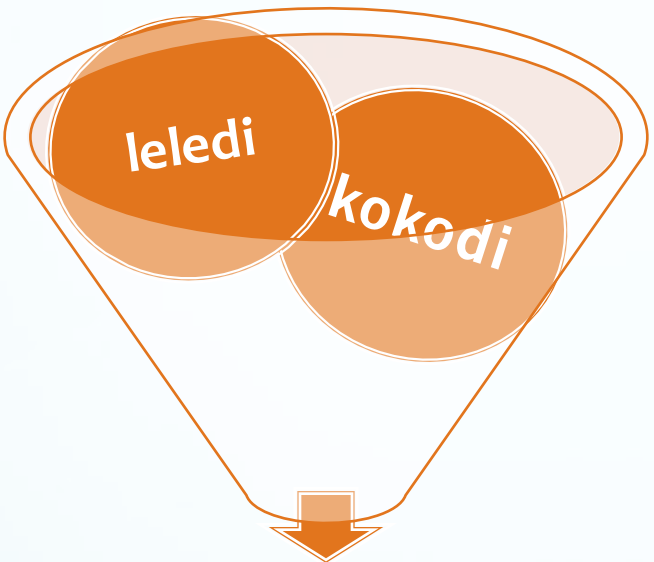


- 2. Are there independent mechanisms underlying these two types of generalization
OR
Are they different outcomes of ***the same learning mechanism?***

New Entropy Model

Perceptually-bound generalizations

Category-based generalizations



Entropy

→ a function of number of items and their probability (frequency)

(Shannon, 1948)

→ a measure of input complexity

le_le_di ✓ end in di ✓

X_X_Y ✗

X_X_Y ✓

Input complexity entropy

≤

Channel capacity entropy/time

Input complexity entropy

>

Channel capacity entropy/time

Predictions

Rule Induction → a cognitive mechanism that results from the interaction of **input complexity (entropy)** and the processing limitations of the human brain (a limited **channel capacity**).

Less complexity (entropy) → perceptually-bound generalizations

High complexity (entropy) → category-based generalizations

Perceptually-bound generalization and category-based generalization are outcomes of the same learning mechanism → create structure (rules) in response to the degree of entropy in the input to prevent channel overloading

Effect of Input Complexity on Rule Induction Experiments

- Experiment 1 - 35 adults, ~22y, ~4min, bet-subj
- 3-syllable XXY: *goo_goo_sjie*
- manipulated number & frequency
 - LowEN - 3.5 bits (4 × 6Xs / 4 × 6Ys)
 - MedEN - 4 bits (2 × 12Xs / 2 × 12Ys)
 - HiEN - 4.58 bits (1 × 24Xs / 1 × 24Ys)
- Experiment 2 - 36 adults, ~22y, ~4min, bet-subj
- 3-syllable XXY: *daa_daa_lie*
- manipulated number & frequency
 - LowEN - 2.8 bits (4 × 7Xs / 4 × 7Ys)
 - MedEN - 4.25 bits (2 × 14Xs / 2 × 14Ys)
 - HiEN - 4.8 bits (1 × 28Xs / 1 × 28Ys)

Test (“Could this string be possible in the language that you heard?” YES / NO) – 20 strings

→ XXY_new_syll: *too_too_suu v*

→ XXY_trained_syll: *goo_goo_sjie v*

→ X₁X₂Y_trained_syll: *teu_duu_saa**

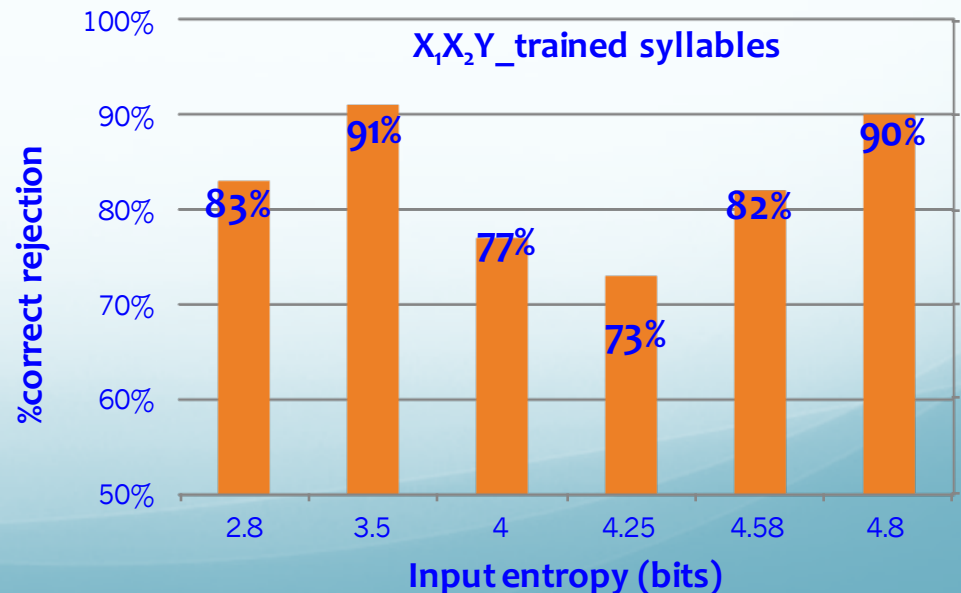
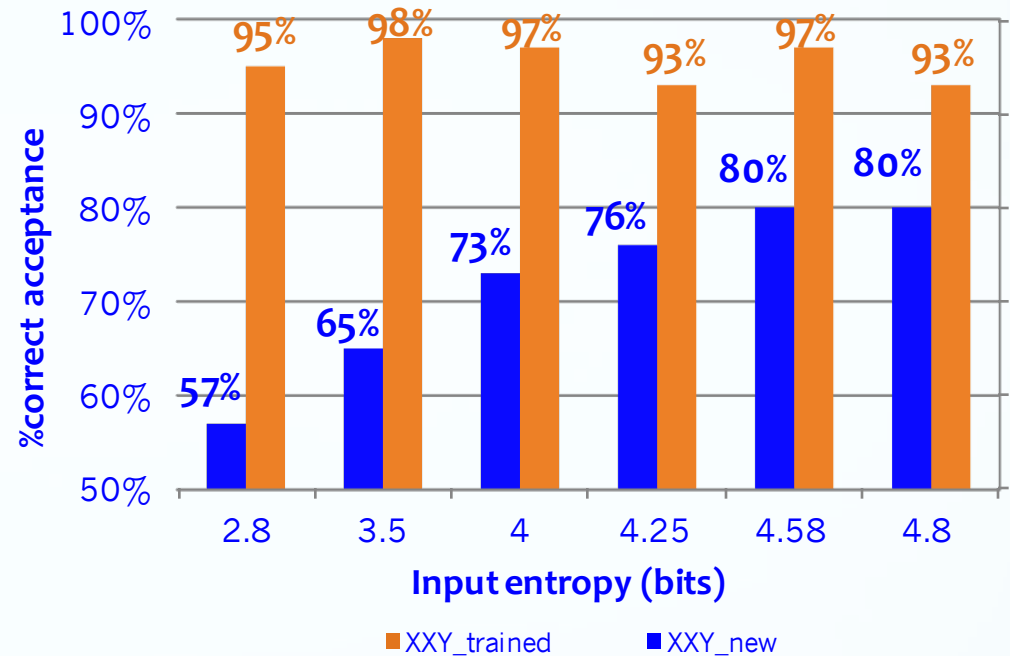
→ X₁X₂Y_new_syll: *reu_loo_gee**

Results

→ the higher the entropy, the higher the tendency to accept **new XXY** strings

→ at all tested levels of entropy, there is a very similar high acceptance of XXY strings with trained syllables

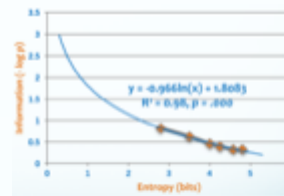
→ X₁X₂Y_trained syllables
- U-shape pattern of correct rejection



Information load regarding the structure (rules)

What is information?

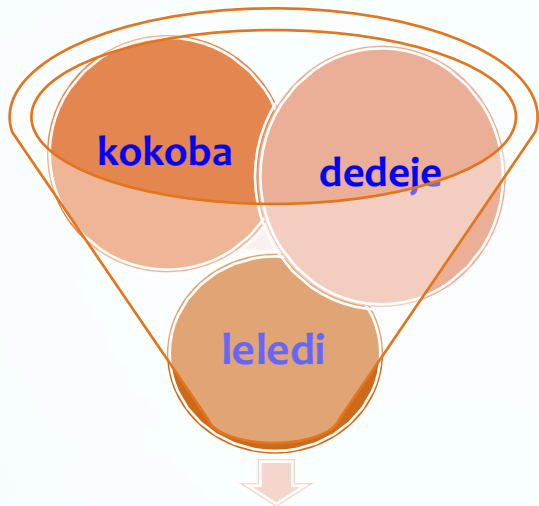
→ a quantitative measure of how uncertain we are about the structure when exposed to a certain input entropy



The uncertainty about structure decreases logarithmically, as the input entropy increases.

Information load for the six values of acceptance of new XXY strings

Conclusions



XXY ✓

→ the tendency to abstract away from the memorized input increases as the input complexity (entropy) increases

→ perceptually-bound generalization and category-based generalization are outcomes of the same learning mechanism → create rules in response to the degree of entropy in the input to prevent channel overloading

Further research

→ test the effect of input complexity with infants and compare with adults (fNIRS)

→ test the effect of channel capacity on rule induction

→ what are the cognitive processes that modulate channel capacity (short-term memory and pattern recognition tests)

