INPUT COMPLEXITY AND RULE INDUCTION

An Entropy Model

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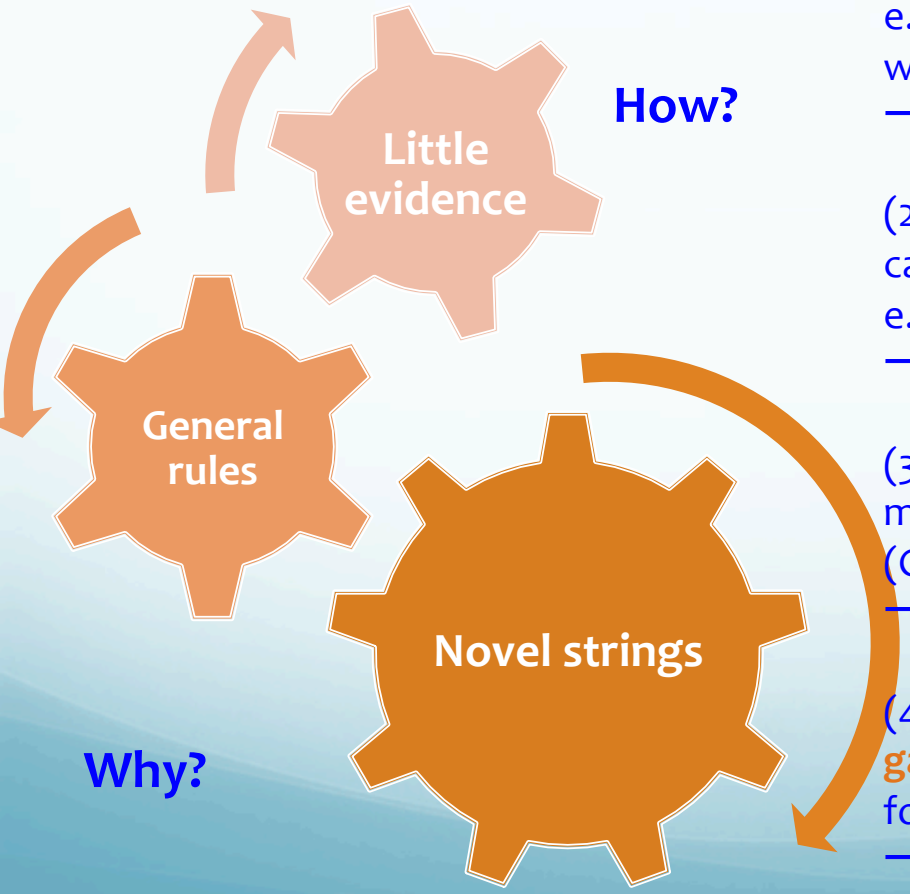
Rule Induction

A Puzzling Mechanism

Puzzle



How?

Why?

Previous research. Artificial Grammar

(1) **statistical learning** → transitional probabilities
e.g. phonotactic regularities (Chambers et al, 2003), word boundaries (Saffran et al, 1996)
→ blind to novel items

(2) **algebra-like system** → algebraic rules that apply to categories (Marcus et al, 1999)
e.g. first item is the same as third item (*li_na_li*)
→ How do we tune into such rules? Any input factors?

(3) **rule reliability** → if input allows for different rules, most statistically consistent (reliable) rule inferred (Gerken, 2006)
→ What makes a rule reliable?

(4) **Richness of contexts, overlap of contexts, systematic gaps, exposure time** → factors modulate category formation (Reeder et al, 2009)
→ Are these independent factors? Why different effects?

Types of Abstractions

Perceptually-bound rules → relations between perceptual features of items

e.g. a relation based on physical identity: ***ba_ba*** (*ba* follows *ba*)

Category-based abstractions

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

e.g. **Noun_Verb_Noun** - an identity relation over the abstract linguistic category of noun

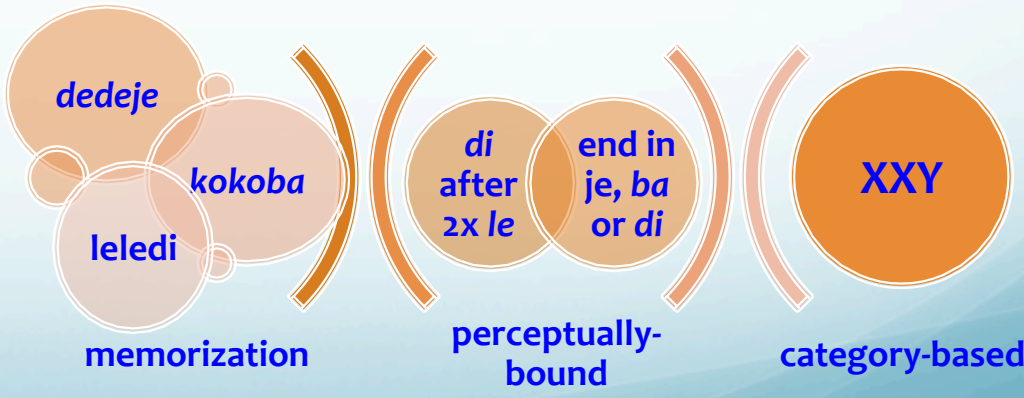
Based on **Gómez and Gerken (2000)**

Independent mechanisms?

1. • **Perceptually-bound rules**
   • *ba* follows ko, ends in *di*
2. • **Category-based abstractions**
   • *varY* follows *varX*, *varY* follows 2 *varX*

OR

Phased mechanism?



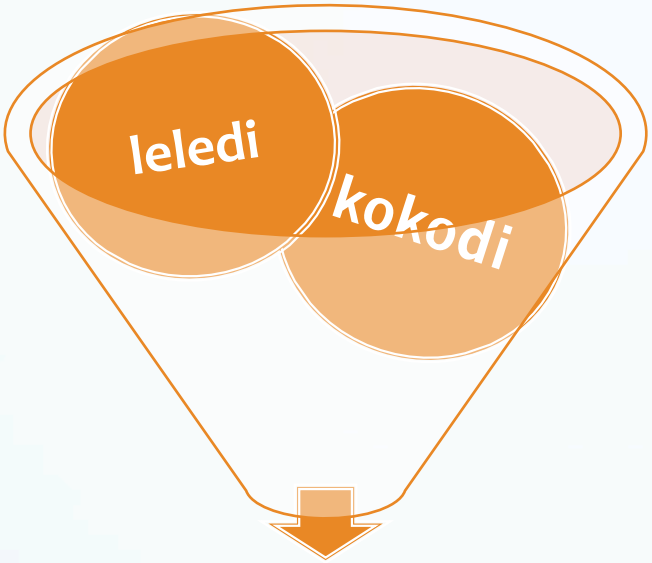
Research Questions

- 1. What triggers and what limits the ***inductive leap*** from memorizing specific items and extracting perceptually-bound rules to making category-based abstractions?

2. Are they independent mechanisms
OR
different outcomes of ***the same learning system***?

New Entropy Model

Perceptually-bound abstractions



le_le_di ✓ ends in *di* ✓

X_X_Y ✗

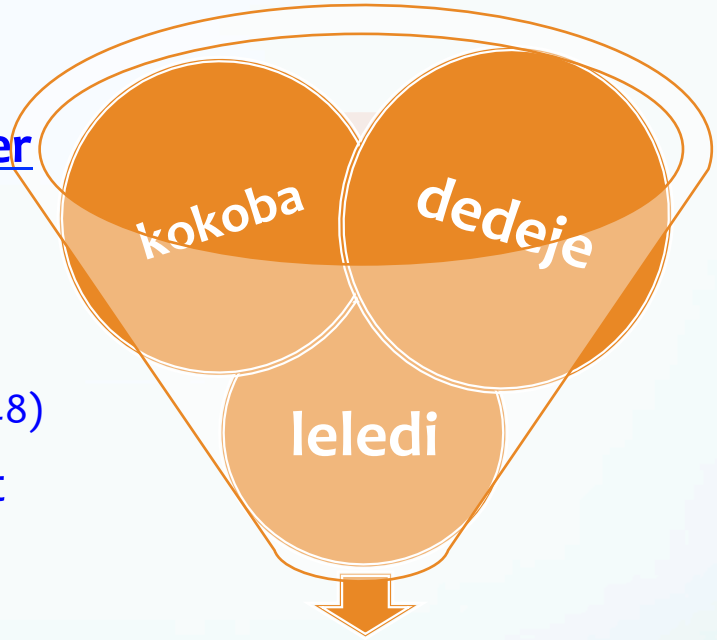
Entropy

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

(Shannon, 1948)

→ a measure of input complexity

Category-based abstractions



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 rules

High complexity (entropy) → category-based abstractions

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

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* √**

→ **XXY_trained_syll: *goo_goo_sjie* √**

→ **X1X2Y_trained_syll: *teu_duu_saa****

→ **X1X2Y_new_syll: *reu_loo_gee* ***

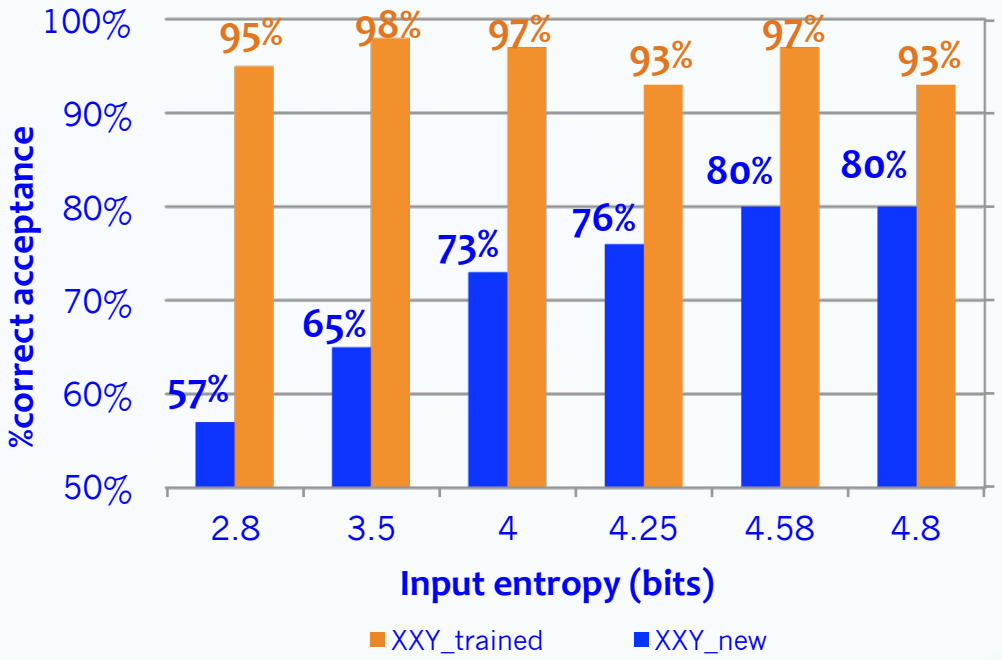
Results

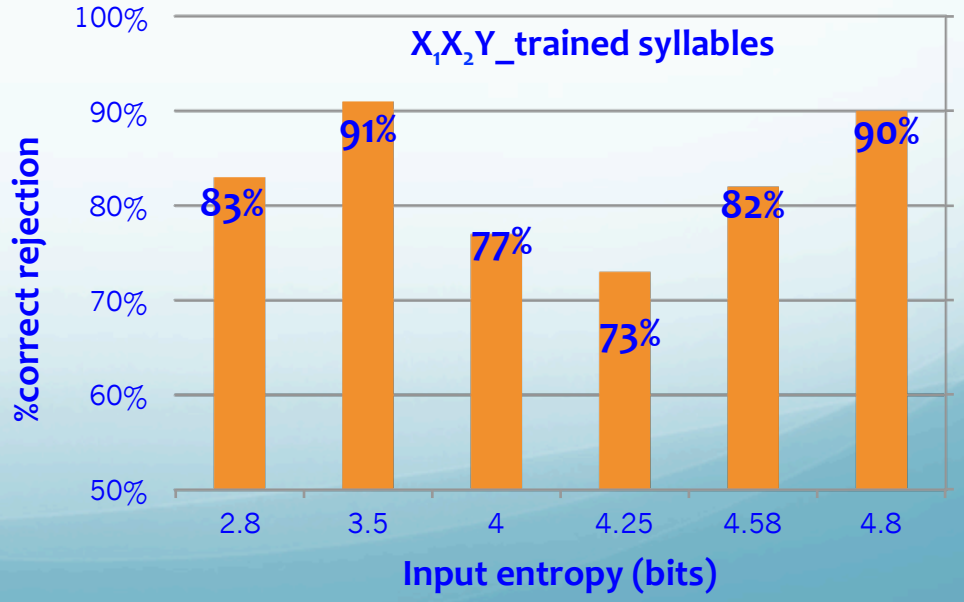
→ the higher the entropy, the higher the tendency to accept new *XXY* strings

→ 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

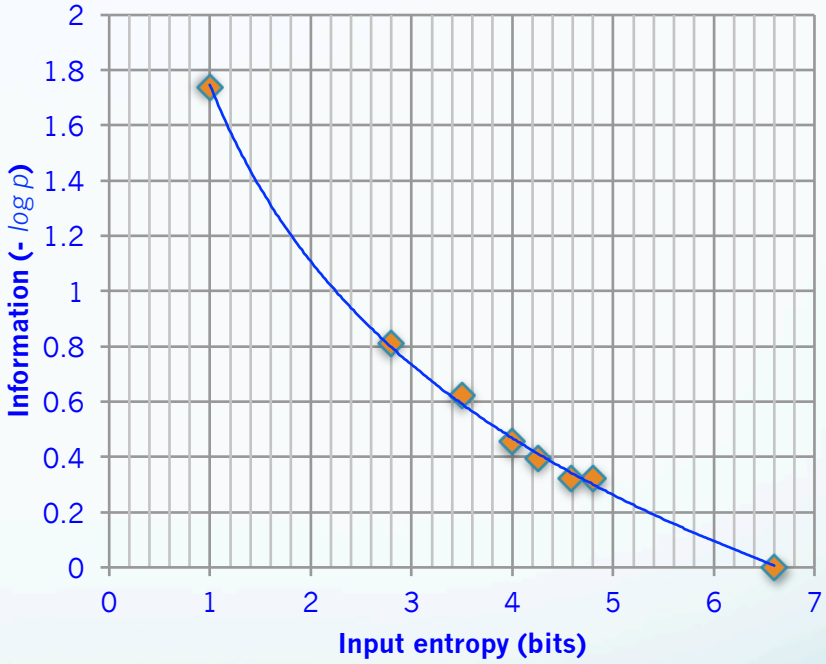




Information load regarding the structure in the input

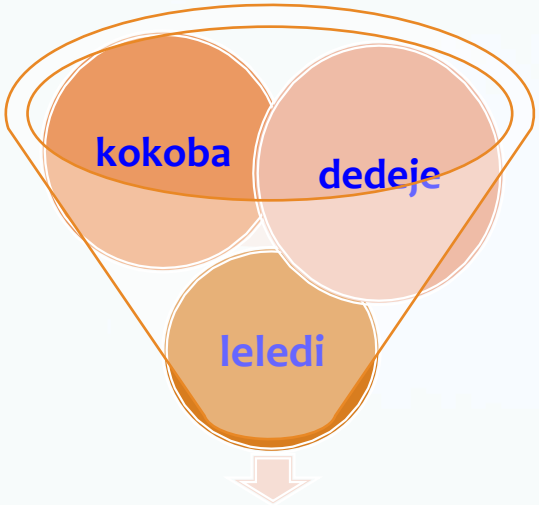
What is information?

→ a quatitative measure of how uncertain the brain is about the structure when exposed to a certain input entropy



The uncertainty about structure decreases as the input entropy increases.

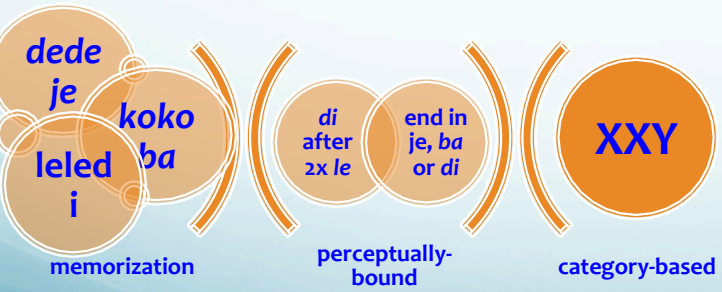
Conclusions



XXY ✓

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

→ perceptually-bound learning and category-based abstractions are outcomes of the same learning mechanism → create structure (rules) in response to the degree of entropy in the input



Further research

→ test the effect of input complexity with infants (run similar experiments with 10-month-olds)

→ what are the cognitive processes/capacities that modulate channel capacity

→ test the effect of channel capacity on rule induction (manipulate memory capacity and a domain-general capacity to extract patterns)