INPUT COMPLEXITY
&
RULE INDUCTION

An Entropy Model

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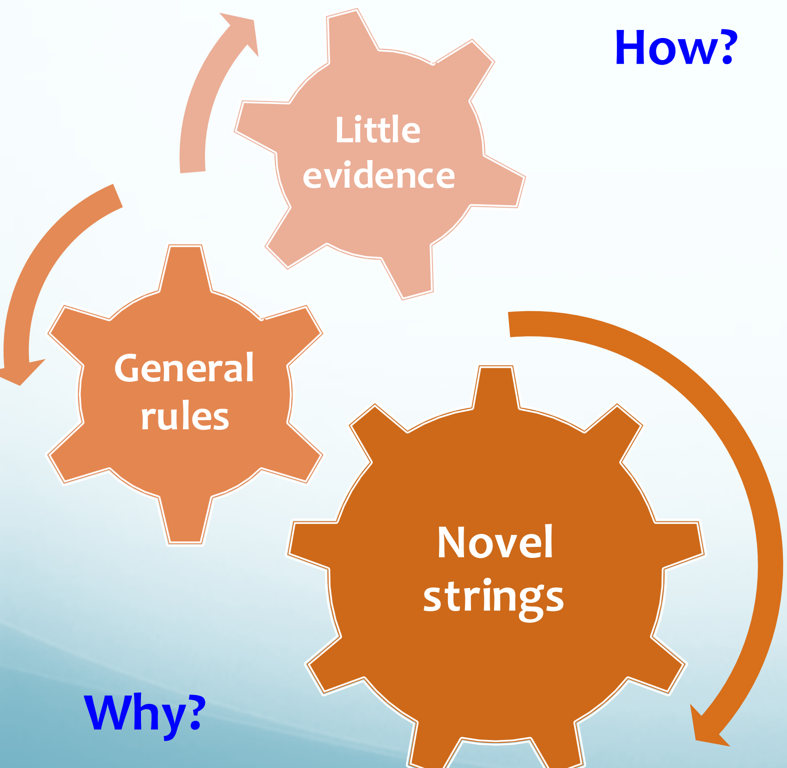
Rule Induction

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 **di***"

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?** ?

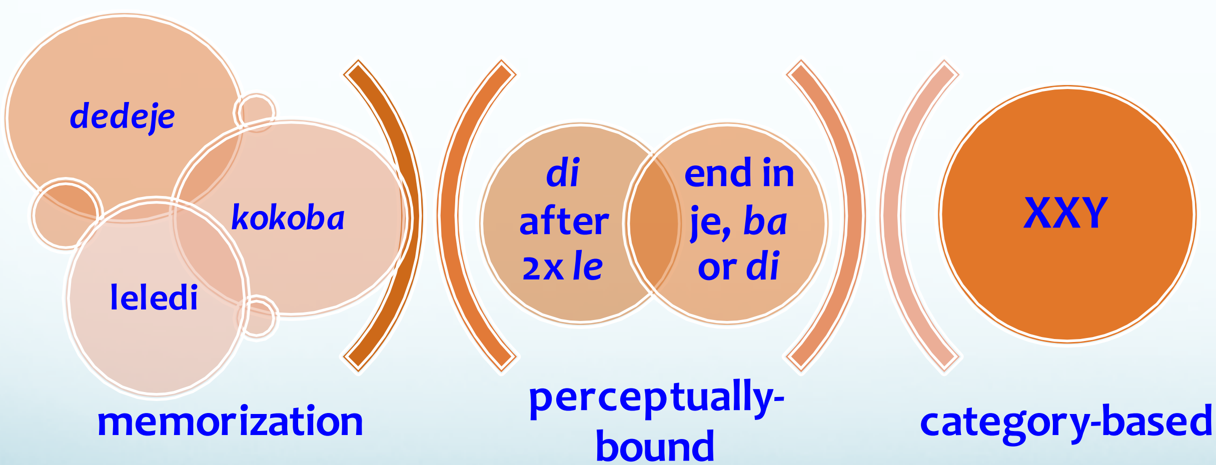
(2) **richness of contexts,** (3) **overlap of contexts,** (4) **systematic gaps,** (5) **exposure time** → factors modulate category formation in a different manner (Reeder et al, 2009)
→ **Are these independent factors? Why different effects?** ?

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*

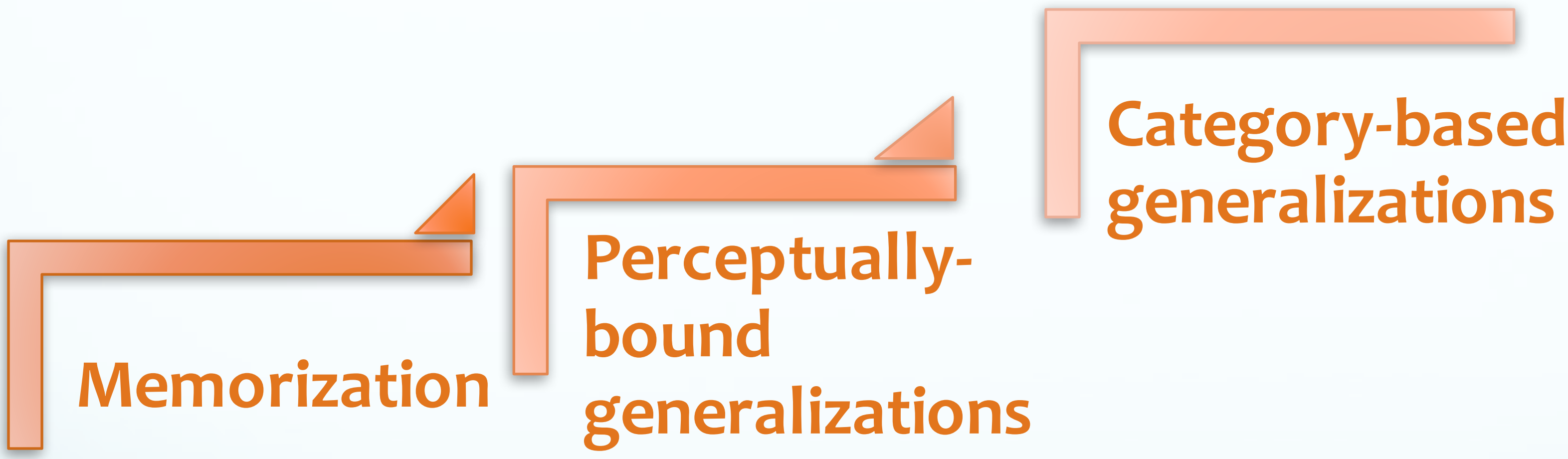
OR

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?



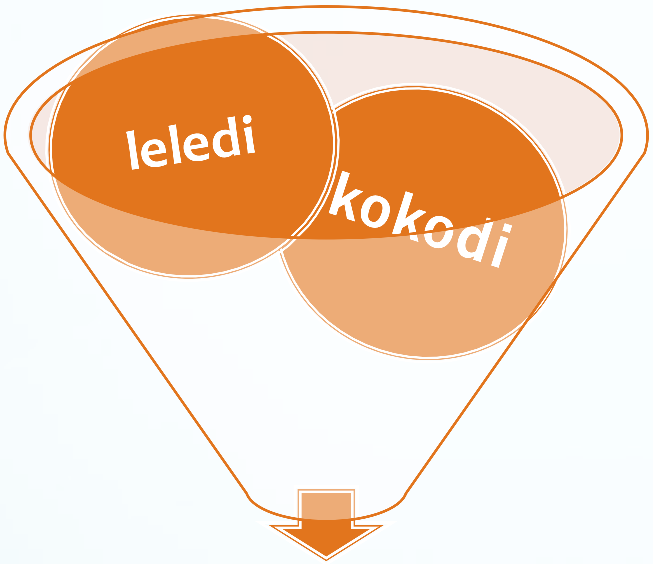
2. Are there independent mechanisms underlying these two types of generalization

OR

Are they different outcomes of ***the same learning mechanism***?

New Entropy Model

Perceptually-bound generalizations



le_le_di ✓ end in *di* ✓

X_X_Y ✗

Input complexity
entropy

≤

Channel capacity
entropy/time

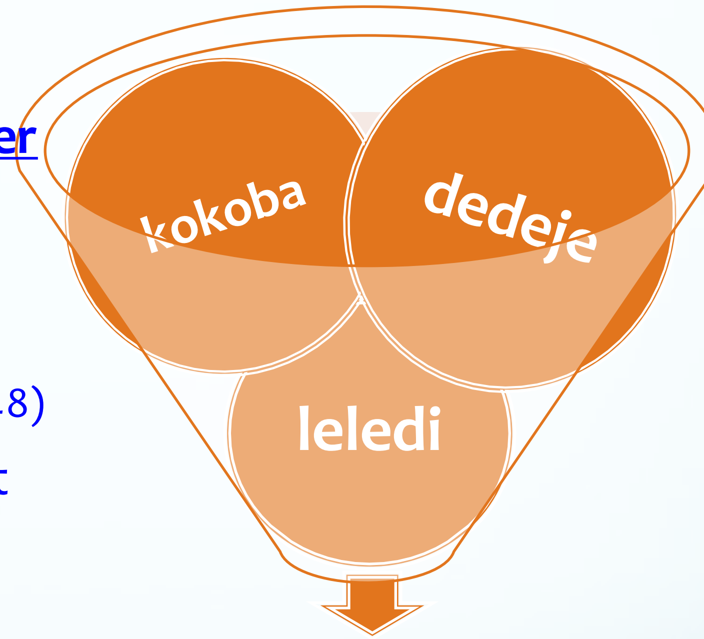
Entropy

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

(Shannon, 1948)

→ a measure of input complexity

Category-based generalizations



X_X_Y ✓

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*** **√**

→ **XXY_trained_syll**: ***goo_goo_sjie*** **√**

→ **X1X2Y_trained_syll**: ***teu_duu_saa****

→ **X1X2Y_new_syll**: ***reu_loo_gee*** *****

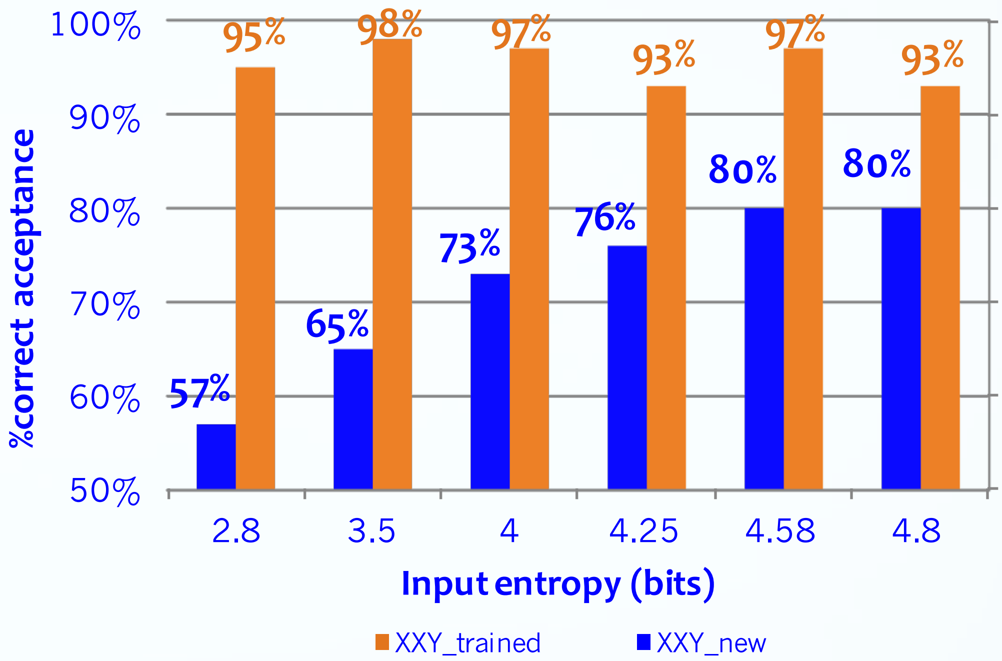
Results

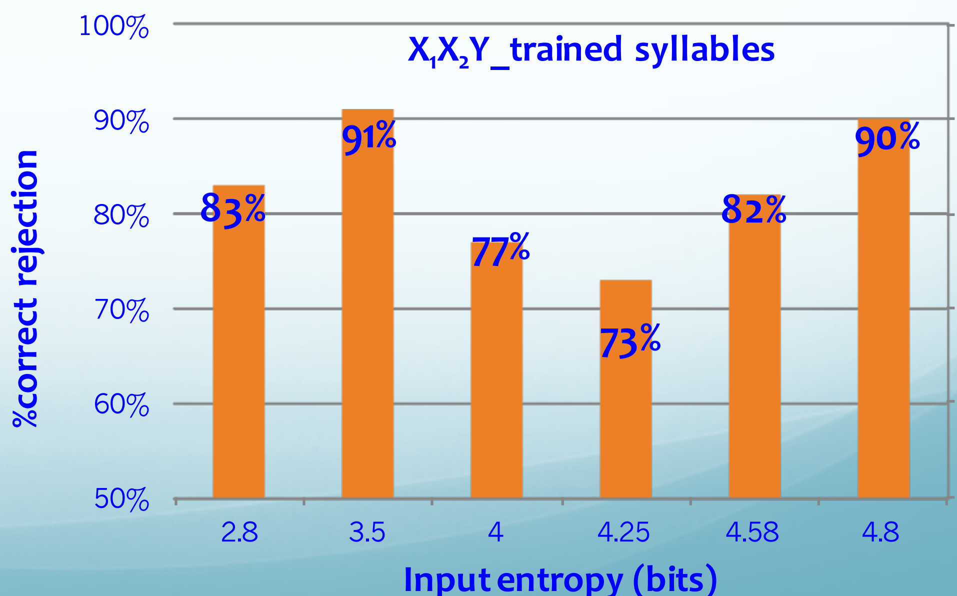
→ the higher the entropy, the higher the tendency to accept **new XXY** strings

→ 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



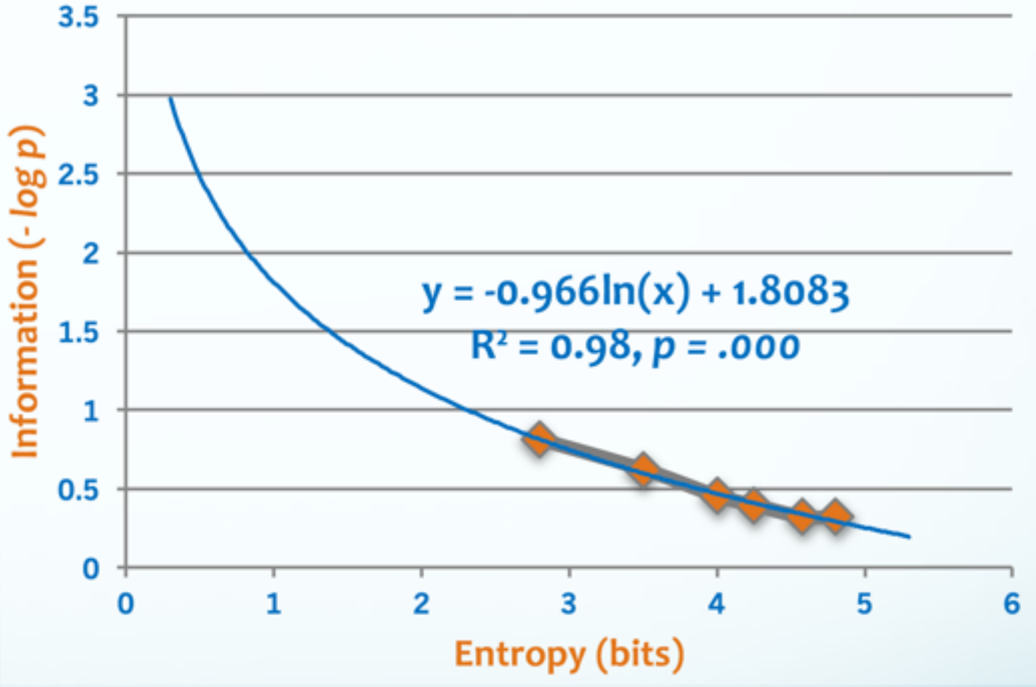


Information load regarding the structure (rules)

What is information?

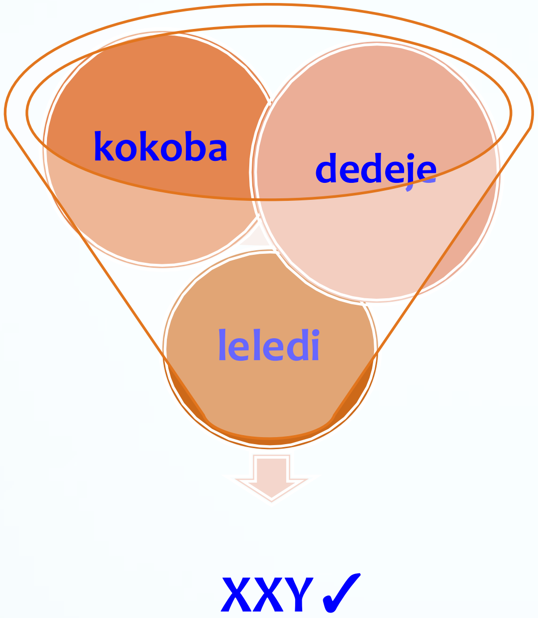
→ a quantitative measure of how uncertain we are about the structure when exposed to a certain input entropy

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



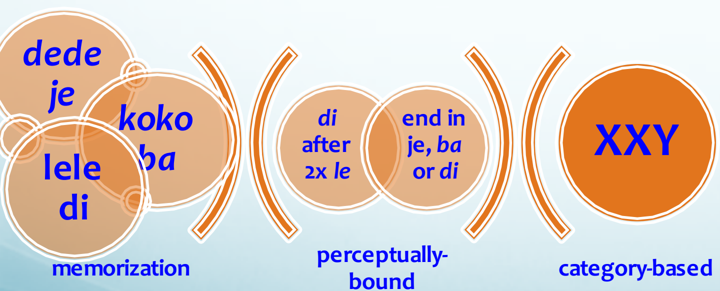
Information load for the six values of acceptance of new XXY strings

Conclusions



→ 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)