A Bayesian Model of Joint Category and Feature Learning

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"Cognition is categorization" (Harnard, 2003)

The ability to generalize from experience
underlying a variety of common mental tasks, such as learning, perception or language use

Learning categories of concepts
Is a scarf a piece of clothing?

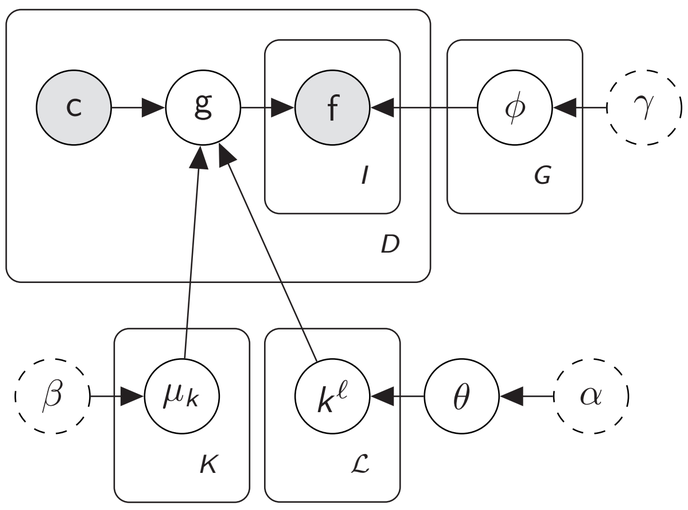
Learning structured types of features
Do all pieces of clothing have color? or material?

Learning incrementally
Immediately utilizing novel insights and information

Large(r)-scale training and testing
Approximating the learning environment with text

We present the first cognitive Bayesian model which learns **categories** and their **structured feature representations** in a **joint process**.

The BCF model



Input
concept mentions in linguistic context

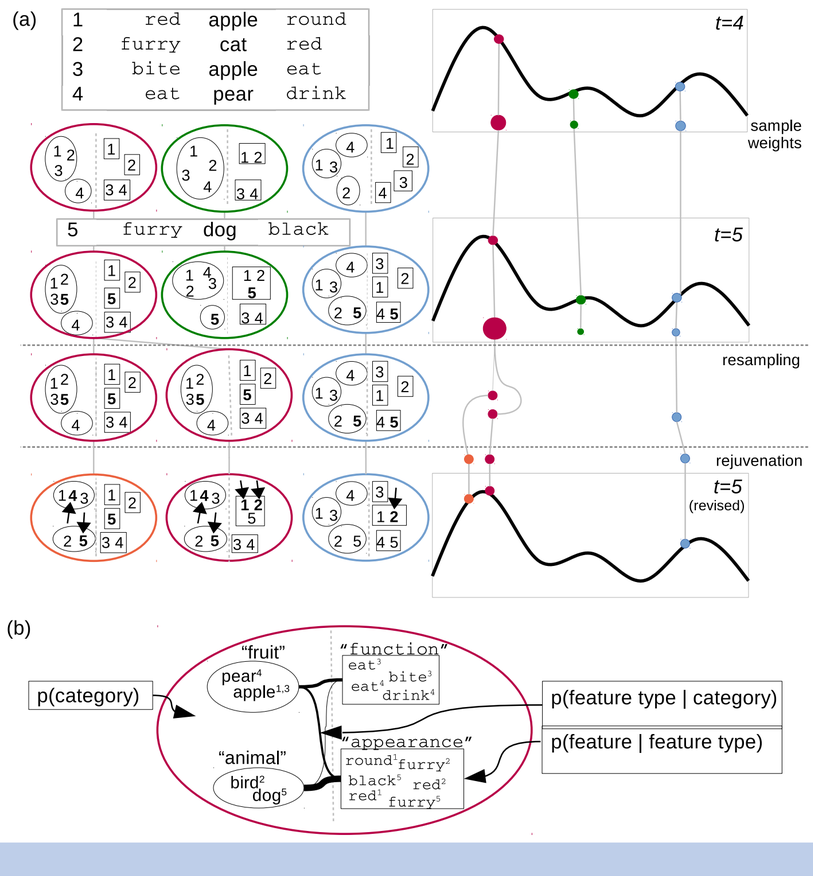
Output
1. categories of concepts
2. feature types
3. category-feature type associations

Assumptions
- each concept *c* belongs to a single category *k*
- each input refers to a single feature type *g*
- feature types capture one aspect of meaning
- categories differ in feature type associations

Incremental inference: particle filtering (Doucet, 2008)

Sequential Monte Carlo
- incrementally approximate a target distribution through a sequence of intermediate distributions
- represent each distribution through a set of weighted samples (**particles**)
- recursively update each particle with information from novel observations
- approximate memory limitations: # of particles, or allowed capacity for re-consideration of past decisions
- known issues: sample degeneracy and sample impoverishment

A particle filter for the BCF model



Experiments

Data – The CHILDES corpus
- speech from child-parent interaction
- we take child-directed speech only
- 21 English-speaking children
- age between 0y11m and 4y11m
- extract mentions of concepts in context

age	utterance		
1;05	bed brush brush	bed	brush teeth tooth
2;00	sleep tired book	bed	bed sit fall
2;00	eat apple red	apple	mmm nice first
2;07	apple cut quarter	apple	seed pip core
	...	...	...

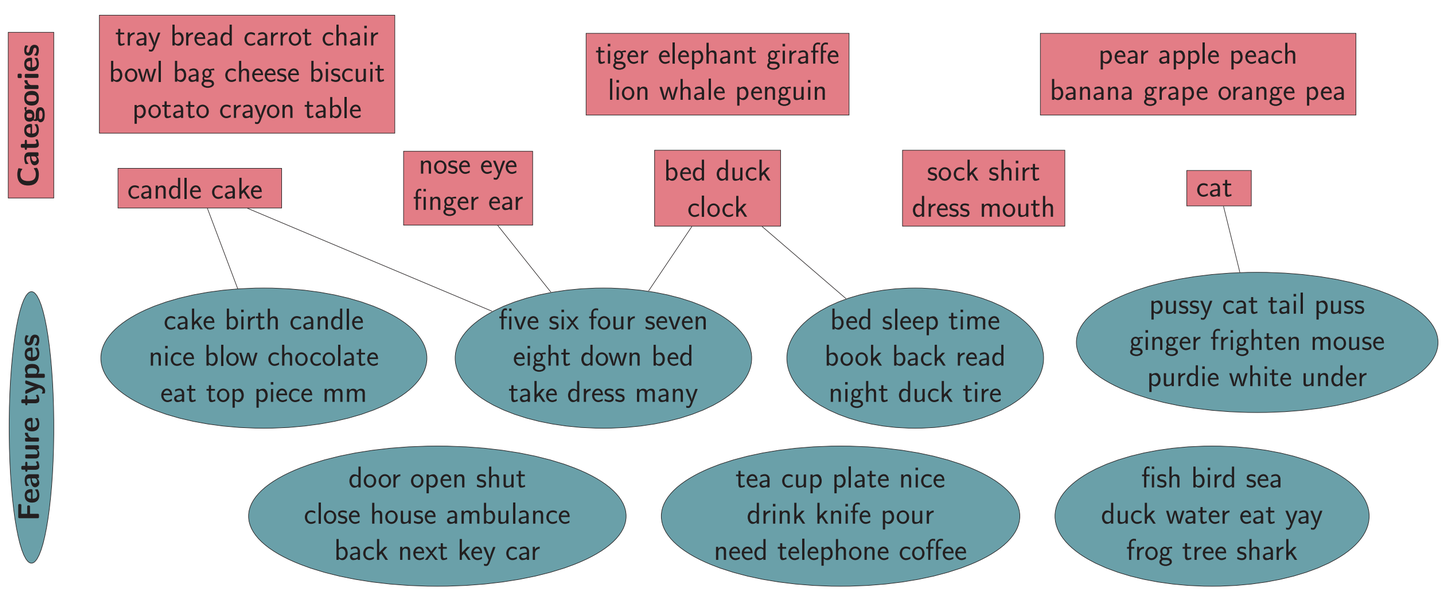
Procedure
- bucket data into 3-month intervals
- present them in chronological order to the model

Evaluate
1. learning behaviour → do representations improve over time?
2. memory constraints → how does limited memory (# of particles) effect performance?
3. quality of learnt categories and features

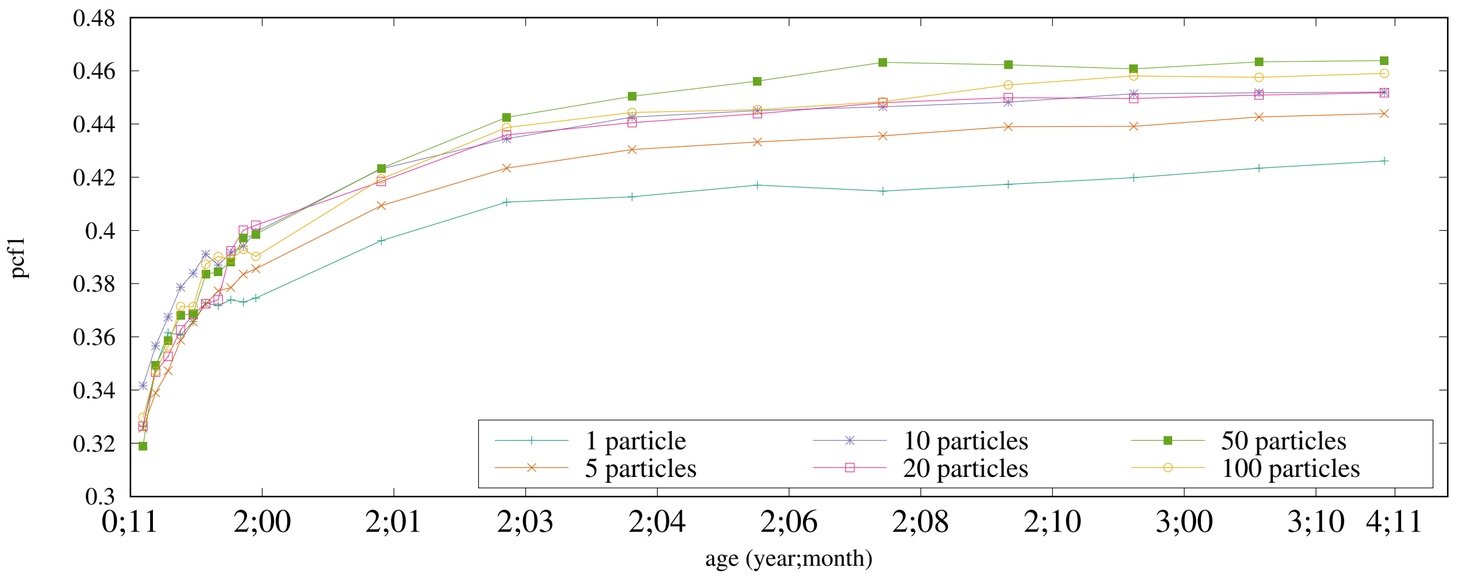
Discussion

✓ first cognitive model of joint category and feature learning
✓ cognitively motivated learning algorithm
✓ model training and testing on a (more) realistic scale
✗ realistic model input – visual or pragmatic signals

Qualitative examples of learnt categories, feature types, and their associations



Improvement of learnt categories over time and under memory constraints



[1] Harnad, Stevan (2005) *Cognition is categorization.* Book Chapter.
[2] Doucet, A. and Johansen, A. M. (2008). *Tutorial on Particle Filtering and Smoothing: Fifteen years Later.* Technical report.
[3] Frermann, L. and Lapata, M. (2015). *A Bayesian Model for Joint Learning of Categories and their Features.* In Proceedings of ACL.
[4] Frermann, Lea (2016) *Bayesian Models of Category Acquisition and Meaning Development.* PhD Thesis.