Concepts and Categories
Informatics 1 CG: Lecture 11

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Reading:

> *Trevor Harley (2001). The Psychology of Language,*
> *Chapter 10*

- What information sources are useful?
- Model of how distributional information aids the acquisition syntactic categories.
- Using agglomerative clustering on CHILDES corpus
- General approach uses computationally explicit model of specific aspects of language acquisition.

Word Meaning

Q₁: How do we organize our knowledge of the world?

Q₂: What are concepts?

Q₃: How are objects placed into categories?

Q₄: How do we represent the meaning of words?

MEMORY

Procedural
(Skills)

Declarative
(Knowledge)
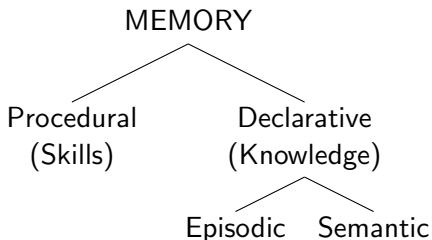
Episodic   Semantic

- **Episodic memory**: memory for events and particular episodes.
- **Semantic memory:** general knowledge (is abstracted from episodes that may happen many times).

Concepts and Categories

A **concept** is a mental representation of a class of objects or events. It determines how things are related or categorized.

- All words have an underlying concept.
- Not all concepts are labeled by a word.
- We do not have a special word for BROWN DOG.
- How is the meaning of DOG represented and how do we pick instances of dogs in the environment?
- How do we categorize the world?

[We use SMALL CAPS to denote concepts or categories]

- The way in which we categorize the world is not arbitrary.
- The categories we form are determined in part by the way in which we perceive the structure of the world.
- By dividing the world into classes of things, we decrease the amount of information we need to learn, perceive, remember, and recognize: cognitive economy.
- Concepts permit us to make accurate predictions.
- Categorization serves a communication purpose.

Superordinate level

Furniture

Basic level

Chair

Subordinate level

Windsor

Is there a Preferred Level of Conceptualization?
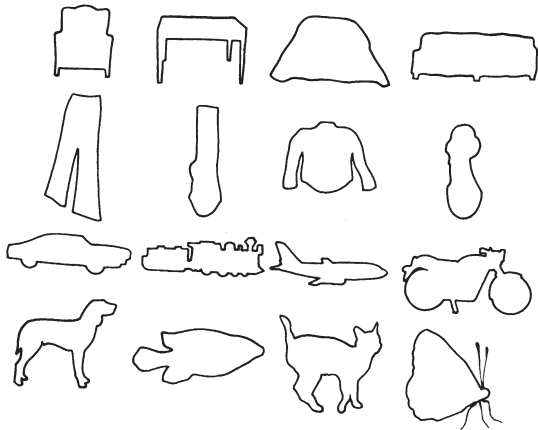

Superordinate level

Furniture

Basic level

Chair

Subordinate level

Windsor

1. Most abstract level at which objects have similar shapes.
2. First words are learned at the basic level (*doggy*, *car*, *ball*)
3. We name objects at the basic level faster
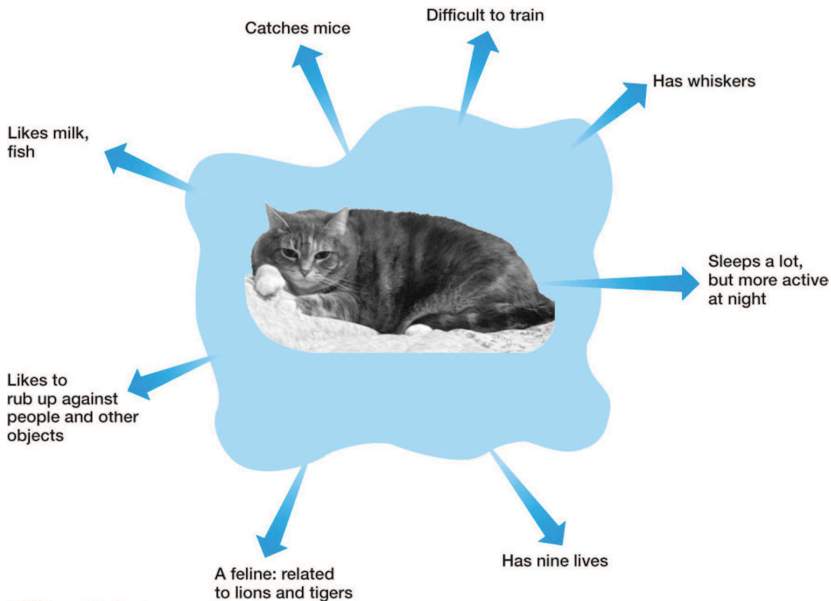4. Participants list attributes of the basic level easily.

What is Categorization?

Categorization is the process by which things are placed into groups called **categories**.

- results in a compact and efficient representation of the world;
- presumably involves a process of abstraction or generalization;
- makes it possible to recognize a new object quickly and determine (for example) its use;
- we learn new categories (children learn new categories frequently; adults learn new categories from time to time).

Catches mice

Difficult to train

Has whiskers

Likes milk, fish

Sleeps a lot, but more active at night

Likes to rub up against people and other objects

A feline: related to lions and tigers

Has nine lives

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Representation and Classification

Definitional Theory

Originated with Aristotle. Categories are represented as list of features which are both necessary and sufficient. Category membership is determined by checking if an item possesses all requisite features.

TEA CUP
1. *concrete object*
2. *concave*
3. *can hold liquids*
4. *has a handle*
5. *can be used to drink hot liquids*

Representation and Classification

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<div align="center">

TEA CUP

1. *concrete object*
2. *concave*
3. *can hold liquids*
4. *has a handle*
5. *can be used to drink hot liquids*

</div>

Properties 4 and 5 are debatable (Chinese tea cups). If you drop 4 and 5, then there are many objects (bowls) that satisfy 1–3.

Family Resemblance

- Ludwig Wittgenstein: the structure of a concept is like a family resemblance photo.
- Take multiple exposure photo of all family members.
- Only the common features are retained.
- Photo looks like everyone in family, but isn't any one person.

Typicality Effects

Typical

- is robin a bird?
- is dog a mammal?
- is diamond a precious stone?

Atypical

- is ostrich a bird?
- is a whale a mammal?
- is turquoise a precious stone?

Slower verification times for atypical items.

Typicality Effects

Typical

- is robin a bird?
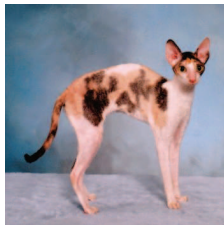- is dog a mammal?
- is diamond a precious stone?

Atypical

- is
- is
- is   stone?

Slower verification times for at

Is this a *chair*?

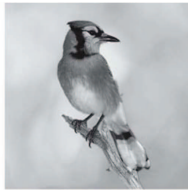

Is this a *cat*?

Is this a *dog*?

Prototype Theory

Categories are organized around a category prototype. A prototype is an average family member. Potential members of the category are identified by how closely they resemble the prototype (best example of a concept).
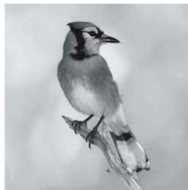

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Prototype Theory

Categories are organized around a category prototype. A prototype is an average family member. Potential members of the category are identified by how closely they resemble the prototype (best example of a concept).

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- Categories under prototype view are "fuzzy"
- Organized around typical properties or correlated attributes
- Category membership is similarity-based

Is this a CUP or a BOWL?

Is this a CUP or a BOWL?

- It can be both!
- It is perhaps more prototypical of a BOWL.
- Fuzzy boundary means membership can be graded (0.9 BOWL vs. 0.3 CUP).

Exemplar Theory

A category is represented by list previously encountered exemplars. New exemplars are compared to known exemplars — most similar item will influence classification the most.
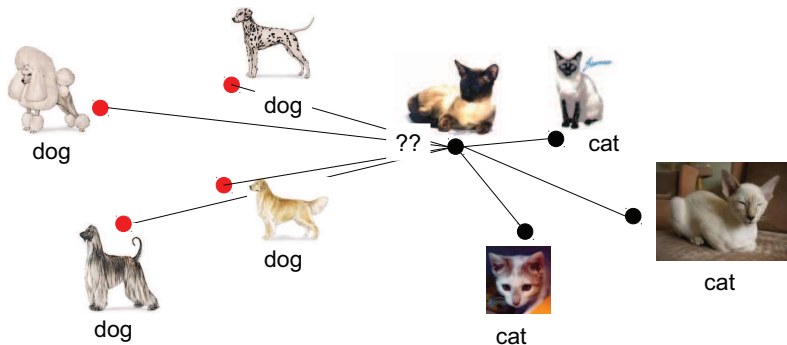
Exemplar Theory

A category is represented by list previously encountered exemplars. New exemplars are compared to known exemplars — most similar item will influence classification the most.

1. Retrieve memories of specific cats we have encountered.
2. Retrieve memories of relevant non-cats e.g., memory of a dog; memory of a stuffed animal; memory of a raccoon.
3. Compute total similarity of current instance to memories of positive and negative exemplars (exemplars of cats/non-cats).
4. Decide that exemplar is a cat if it is more similar to the memories of cats than to memories of relevant non-cats.

Prototype vs Exemplar Theory

In both theories category membership is based on resemblance.

Prototype theory:

- category structure is based on prototypes;
- categorization based on similarity to prototype of category.

Exemplar theory:

- categorization based on total similarity of object to exemplars of the category versus total similarity of object to non-exemplars of the category;
- assumes only that we can retrieve memories of specific instances of a category;
- no abstraction of prototypes.

Maybe both theories are true but for different situations.

Problems for Resemblance-based Approaches

How do we know which properties to compare?
(Murphy and Medin, 1985).

- Both plums and lawnmowers weigh less than a ton
- They are both found on earth
- They are both bigger than a grain of sand.

Theory-based View

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.
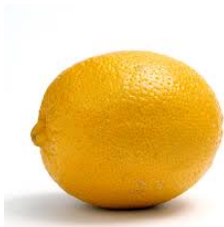
Is this a lemon?

Theory-based View

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

What if we paint it?

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

Or make it sweet?

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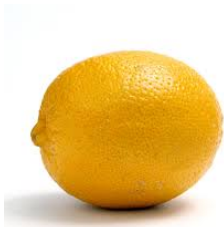

Or squash it?

Theory-based View

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

Is this a lemon?

People say its still a lemon – the substance is still "the same".

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

Is this a teapot?

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

What if a bird lives inside it, in a tree?

Theory Theories

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What if a bird lives inside it, in a tree?

Function also plays an important role in category membership.

Theory-based View

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

Is a counterfeit dollar bill a dollar bill?

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

What if we buy stuff with it?

Theory-based View

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

What if it looked exactly like a real dollar?

Theory-based View

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

What if it looked exactly like a real dollar?

No amount of resemblance can make counterfeit dollar into real one!

Theory-based View

Theory Theories

Organization of categories is based on theories about the world; understanding a category involves having a theory about that category and why its members cohere. Classification is based on explanatory relationships.

- Classification is based on explanatory relationships
- "Deep" features more important than surface ones (if something functions as a home for birds, must be a birdhouse)
- Theories give us coherent concepts ("wings" and "can fly" go together for a reason)
- Medin (1989): we learn categories faster when we understand why the features go together.

Summary

Categorization is one of the classical problems in the field of cognitive science, one with a history dating back to Aristotle.

- Ability to generalize from experience underlies a variety of common mental tasks
- Perception, learning, and the use of language.
- Definitional, prototype, exemplar, and theories theory.
- Basic-level categories, prototype, family resemblance.

Next lecture: theories of word meaning.