Categories

- what are they, and why do we need them?

- how do we represent them? + computational complexity

- i. rules, ii. prototypes, iii. exemplars, iv. qualia, v. schemas, vi. ad hoc

Small exercises throughout! Drawing and writing: paper/pencil or screens ok.

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Some ideas/examples from Frank Keller, and also from http://penta.ufrgs.br/edu/telelab/2/lec7.htm

What is a category?

in what sense?

- **A grouping of things that are, in some sense, equivalent or similar**

"cat"   "apple"   "artist"   "sport"   "toy"

- We often use the term "concept" to refer to such a grouping, to emphasize that it can be treated as a coherent single entity
  - But people often use "concept" and "category" interchangeably or in various ways. Don't get hung up on this terminology. Concept, category, same thing!

- Things inside a category: members, instances

Why do we put things into groups?

- Learning – we can use less memory to store what we know about cats
- Generalization – we can infer extra information about new cats
- Prediction – we can guess what the enraged tiger will do next
- Interaction – we can pet the new cat just like we petted an old cat
- Communication – we can say "cat" to another person

- Different goals probably imply different kinds of groupings......

Are the groups "real"?

- "In a much-cited passage in the *Phaedrus* (265e), Plato says giving a good definition involves "dividing things… where the natural joints are, and not trying to break any part, after the manner of a bad carver". "

https://plato.stanford.edu/entries/natural-properties/

- Often shorthanded as "carving nature at its joints"

- I heard a very funny speaker once talking about this (can't remember who!), who pointed out: "Anyone who has ever actually butchered an animal can tell you: it's not that obvious where the joints are!"

Are the groups "real"?

- Sometimes they are real!
  - For example, the grouping of animals into species has a biologically justifiable rationale:
  - "It can be defined as the largest group of organisms in which any two individuals of the appropriate sexes or mating types can produce fertile offspring, typically by sexual reproduction." (wikipedia)
- BUT:
  - "Other ways of defining species include their karyotype, DNA sequence, morphology, behaviour, or ecological niche."

- In cognitive science, any time there is a "yes/no" question, often better to ask, "Under what conditions is it XYZ?"

How we mentally represent categories

Exercise

- Please draw a triangle.

- What is a triangle? Write it down.

I. Rule-based categories

- Sometimes called "classical view" of categories, because early theories focused on this

- **Category is defined by a set of necessary and sufficient rules.**

- Triangle
- Integer
- Bachelor

Computational complexity

- In computer science, we often analyze algorithms according to how much <u>time</u> and <u>space</u> (memory) they take to do things

- We can analyze different types of category representations in this way

- Sometimes shorthanded as "complexity"

- Our analyses here are not meant to be exact. Just rough thought experiments! To lend some intuition into what these theories imply
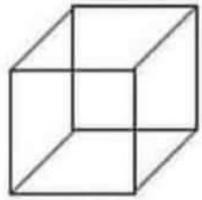
Rule-based categories: Complexity

- How much space does it take to store a category?

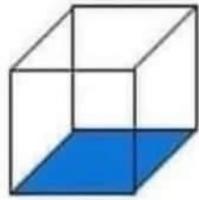 depends on # of rules

- How much time does it take to decide if something belongs to this category?
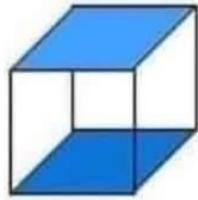
  depends on # of rules

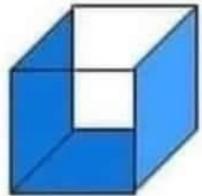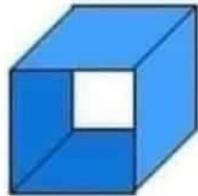# One of my favorite examples of rule-based categories...
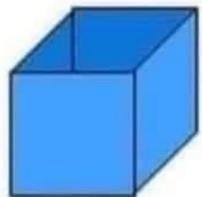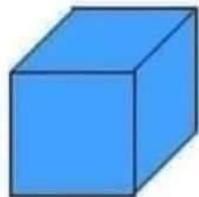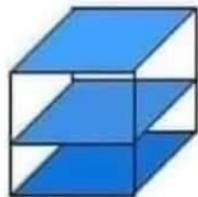
(but is a burrito a type of sushi????)

Exercise

- Write down rules that define this category:

a game

- Now, look at the rules that your neighbor wrote down. Can you think of a counterexample?
  - Something that meets the rules that is NOT a game
  - Or… Something that does not meet the rules but IS a game

Problems with rule-based categories

- Many categories are hard to define using rules!

Exercise

- Draw a bird

Problems with rule-based categories

- Many categories are hard to define using rules!

- Does not allow for <u>typicality</u> effects:

  - Show someone a photo of an animal, ask them "Is this a bird?"
  - Faster to respond yes to "robin" than to "ostrich"
  - Rule-based definition would not predict this

- Does not allow for <u>ambiguity</u>: Is a priest a bachelor?

II. Prototype-based categories

- **Category is defined by a sort of template that averages over all category members.**
    - in programmer speak, template = "uninstantiated default"
    - meaning, not an actual concrete example, but something a bit more abstract

- If we average over all birds, what do we get?

- Prototypes can predict many typicality effects.

Prototype-based categories: Complexity

- How much space does it take to store a category?

  small: size of a single prototype

- How much time does it take to decide if something belongs to this category?

  fast: time to calculate similarity to prototype

- How do we learn/modify a category given a new example?

  modify the prototype, i.e., add the example into the average

Exercise: Just notice what you think of…

- Category is:

    best friends

III. Exemplar-based categories

- **Category is defined by a set of previously encountered instances**
- Unlike prototypes, which are somewhat generic and abstract, exemplars are specific and concrete

- Maybe store all previous instances, or maybe a subset

- Category membership is decided by similarity to exemplars

- Lots of personal categories are well-described by exemplars: "my favorite foods"

Exemplar-based categories: Complexity

- How much space does it take to store a category?

  large: set of all (or multiple) exemplars

- How much time does it take to decide if something belongs to this category?

  slow: have to compare to multiple exemplars

- How do we learn/modify a category given a new example?

  fast! just store the new exemplar in memory, don't have to modify anything

Exercise

- Write down a definition of this category:

blue

IV. Qualia-based categories

- **Category is defined by subjective sensory experiences**

- Might have chemical/biological bases that we can describe formally…

- But think of how a 4-year-old represents the category

- Colors, tastes, emotions, etc.

Exercise

- Write down a definition of this category:

  justice

V. Schema-based categories

- **Category is defined by a framework of other concepts and relations between them**

- Kind of like rules? But more complex and ambiguous

- Kind of like prototypes as a template? But way less specific

- Many "abstract" concepts: infinity   health   fun

- Lots of social concepts!

- Love triangle   Dating   Revenge   Evil

Exercise

- Write down a definition of this category:

  things that keep you dry

VI. Ad hoc categories

- **Category is defined in the moment to serve a current goal**
- **Can be represented in various ways….**

- No long term storage, because it's not a permanent concept
- Lots of time to process in the moment, because you are creating the category, evaluating or generating instances, etc.

- Often relevant to creativity: "Possible products that meet this need"