Concepts, Categorical Perception, Categories, and Similarity

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What are categories? What are concepts?

- Basic definition
  - Categories are: Outside
    - Independent of the mind, they exist in the outside world
      - Example: Solids, liquids, and gases
  - Concepts are: Inside
    - We have internal concepts that hopefully pick out the categories of the outside world
      - Concept of liquid has adjusted as we learn more and more about it
      - Learning, cognitive development

- Today’s talk focuses on concepts and the theories of how concepts are structured

Concepts-general issues

- "a theory of concepts is the center piece of all psychological theories" (Fodor, 2001)
  - LTM Remembering....concepts
  - WM Storing....concepts
  - Visual Search based on....concepts
  - Identification of objects determined by....concepts
    - Concepts begin at the perceptual/conceptual interface (fairly early in processing (e.g., object concept, see Brain Scholl & Feigenson's Developmental week in this class)
    - Major distinction: Content versus Format of a concept. The concept TREE and OAK are different concepts even if their format is similar (and processed by the same neurons). The concept TREE (held in LTM) might be an image of a tree (imagistic) or (a language like description of trees (propositional) even though these might have the same content.
    - Recent example: Rule versus Item info in WM

Concepts- an example

- Natural Kind Concepts
  - Concept of dogs
    - What are some features that make up the concept DOG?
Why do we have concepts?

- Efficiency
  - "Betsy is afraid of dogs"
    - System one - individuals only
      - Betsy is afraid of Pluto, Betsy is afraid of Santa’s Little Helper, Betsy is afraid of Astro, Betsy is afraid of Sweetie, Betsy is afraid of Snoopy etc.
    - System two - concept DOG

Evidence for categories and concepts

- Deficit Work
  - Capitani et al. (2003)
    - Found evidence for three ‘natural categories’ after examining 79 case studies of brain injured patients
      - Animate objects
      - Inanimate biological objects
      - Artifacts
    - Some patients were disproportionately impaired when dealing with some categories than others.

Research and Implications cont’d

- Freedman et al. (2003)
  - Single-cell recordings from monkeys
    - Results suggest that the monkeys were forming categories across conceptual, not perceptual bounds.
      - Sharp differences between a cat exemplar and a dog exemplar that looked very perceptually similar
      - Slight or no difference between a two cat exemplars that looks quite perceptually different (far apart on the continuum)
Theories of concepts

- Four main ‘schools’ of thought when it comes to concepts:
  - Classical
  - Prototype
  - Theory-theory
  - Conceptual Atomism

Classical View

- Concepts are made up of ‘necessary and sufficient conditions’
  - One concept (A) is made up of other simpler concepts and if all these simpler concepts (B, C, D, and E) are activated, then concept A must be true. Alternatively, if concept A is activated, then concepts B, C, D, and E are also activated.
    - Structure: Example of Containment Model

Classical view- example

- “Bachelor”
  - “not married”
  - “male”
  - “adult”

- If someone is a bachelor, all of these underlying concepts must be true.

Classical view- Strengths

- Makes categorization transparent and efficient
  - Categorization- Using your existing concepts to discern to which category an exemplar belongs
  - If Bob is an unmarried adult male (concepts B, C, and D), then he must be a bachelor (concept A).
**Classical view - Strengths**

The classical view makes inference easy and transparent.

- Bob is a bachelor
  - What do we know about Bob?
    - We know that he is:
      - An adult
      - A male
      - Unmarried

**Classical view - Strengths**

- The classical view makes inference easy and transparent.
  - More commonly, we get bits of information, and use that information to gather more information
  - Other examples:
    - "Jim is an adult male"
    - Reasonable question to ask: Is he a bachelor?

**Possible example of Classical Theory at work**

Beiderman’s Theory of Object Recognition

- Our friends, the geons

**Classical View - Weakness**

- Do you agree with the necessary and sufficient concepts that constitute being a bachelor?
Necessary and Sufficient Conditions

- Problem of counter-examples
  - What about the Pope is he a bachelor?

Problem of conceptual primitives

- Empiricist approach to concepts is similar to the idea of Biederman’s geons in object recognition
  - All about necessary and sufficient conditions
  - Define something in terms of simpler concepts
- Problem: breaking things down doesn't always mean you get to anything simpler than the original concept
  - Are the concepts unmarried, male, and adult any simpler than the concept bachelor? Is the concept unmarried any closer to a perceptual primitive than the concept bachelor?

Typicality effects

- If being a member of the concept 'bachelor' means that you need only fulfill the necessary and sufficient conditions, then all members of that concept should be considered equal members
- However, we tend to judge some things as better examples of a concept than others.
  - Example
    - Concept of bird: many would rank a robin as more 'birdy' than an ostrich
  - Error rates and response speed reflect this
    - We would be faster to say that a robin is a bird when compared to saying that an ostrich is a bird.
    - We would make fewer mistakes when asked if a robin is a bird compared to when we are asked if an ostrich is a bird.
Prototype Theory - Introduction

- Concepts are complex representations that use a statistical analysis of the features its members tend to have.
  - Probabilistic features
    - No single feature is necessary or sufficient
  - Some features weighted more than others

Prototype Theory - Example

- Example:
  - BIRD
    - Includes features like:
      - "has feathers" ****
      - "has a beak" *****
      - "flies" ***
      - "migrates during the winter" *
  - Duck
    - Includes all of these features
  - Ostrich
    - Does not include all of these features
    - Explains why we are faster and less error prone when asked if a duck is a bird.

Prototype Theory - Strengths

- Categorization
  - We compare the current exemplar to the concept we have in memory
  - We see
    - "has feathers" ****
    - "has a beak" *****
    - "flies" ***
    - "migrates during the winter" *
  - Because it satisfies enough of the features listed above, it is likely to be a bird

Prototype Theory - Strengths

- Great explanation of typicality effects
  - A duck is more 'birdy' because it has more prototypical features of bird than does 'ostrich' or 'emu'
Possible example of the Prototype Theory at work

- Support for prototype theory
  - Maye, Werker, & Gerken (2002)
  - We have concept of /ta/ which is distinctly different from the concept of /da/
    - All speech sounds which are in a certain range are characterized by one unified concept (/ta/ or /da/)

Categorical speech perception
- /ta/ vs. /da/

Infants familiarized with bimodal distribution later showed discrimination while infants familiarized with unimodal distribution did not.
Prototype Theory- Weaknesses

- Concepts without prototypes
  - The Grandmothers of students in Psychological and Brain Sciences
    - We can form a concept of this group, but do you think we have a "Grandmother of PBS students" prototype?
  - Jenn’s aunt
    - You can form a concept of my aunt without knowing anything about her; also, my aunt changes in appearance throughout life but I think of her as the same aunt, a prototype wouldn’t be able to account for those changes
  - “Not a dog”
    - Expansive concept, we don’t have a prototype of “not a dog”

Theory-theory- Introduction

- Concepts are:
  - ‘A concept’s identity is determined by its role within a theory’
  - ‘Structured mental representations’ whose structure consists in their relation to other concepts specified by their embedded theories’
    - Similar to scientific theories

Prototype Theory- Weaknesses

- Compositionality
  - “Big red balloon” made up of ‘bigness’ ‘redness’ and ‘balloon-ness’
  - Prototypes not always made up of their prototypical parts
    - Example: ‘Pet Fish’
      - Prototype of Pet Fish is something like a goldfish
      - Prototype of a Pet is usually something like a dog or cat
      - Prototype of Fish is usually something like a trout or salmon

Theory of Theory-theory

- Scientific theories
  - Example: The concept LIVING THING
    - In science, living things are understood via the role they play in other scientific theories
      - We have a theory of Reproduction, of Metabolism, of Animacy and in each of these theories the concept of LIVING THING plays a functional role
      - Thus, the concept of LIVING THING is determined by its role in our theories.
Theory-theory- Introduction cont’d

- No longer a definition or a checklist of features
- Psychological essentialism
  - Concept membership not about displayable features, instead it’s about the underlying ‘essence’ of the exemplar
  - Responsive to more considered judgments

Theory-theory example

- Pepe LePew

  Pepe, a skunk, likes Penelope, a black cat who has been mistakenly painted head to toe with a white stripe, which makes her appear to be a skunk.

Theory-theory example

- Pepe LePew cont’d

  Penelope looks like a skunk and there is nothing about her appearance that makes her look like a cat
  What do we think Penelope is—a cat or a skunk?
  Pepe thinks she’s a skunk

Theory-theory example

- Psychological essentialism?
  - Us ✔
  - Pepe ✗
**Theory-theory example**

- **Pepe LePew cont’d**
  - Classical model:
    - Does Penelope have four legs, is mostly black with a long white stripe, etc? Yes? She is a skunk.
  - Prototype model:
    - Do her features appear to be more similar to the prototype of cat or skunk? Skunk!

**Theory-theory - Strengths**

- More realistic - actually corresponds to how we think about the world
  - Why Penelope is a cat and not a skunk
  - Why a dog that has lost three legs, its tail, its ability to bark, and all of its hair is still a dog
- Both children and adults tend to display psychological essentialism and the other theories of concepts can’t account for these tendencies

**Theory-theory - Strengths**

- More realistic - actually corresponds to how we think about the world
  - Shows flexibility of concepts:
    - Jenn’s aunt
      - Solves prototype problem - regardless of how she looks, my aunt is still my aunt because of the role she plays in my concept of ‘family’

**Theory-theory - Strengths**

- Shows flexibility of categories:
  - Example - “Scattergories”
    - Things in a suitcase: B------
      - Bible
      - Bag (purse)
      - Bookmark
      - Baby toys
      - Blanket
      - Blanket
      - Belly ring
Theory-theory - Strengths

- Shows flexibility of categories:
  - Example- “Scattergories”
    - Things in a suitcase: B------
      - There are no necessary and sufficient conditions for things in a suitcase that start with B
      - We don't have a prototype of things in a suitcase that start with the letter B
      - But we have a theory about travel, sizes of objects, and containment; theory-theory allows us to come up with these "off the cuff" categories

Theory-theory - Weaknesses

- Lack of represented information
  - Ok, so Penelope is a cat not a skunk- why?
  - What makes the core essence of a cat different than that of a skunk, of a dog, of an antelope?

- Scientific theory
  - Processes underlying theory change in science are not well understood
  - We also don't understand concepts very well
  - It is hard to legitimize basing our ideas about concepts on something that we don't really understand

Example of possible Theory-theory at work

- Grandmothers of Psychological and Brain Sciences Graduate Students
  - Classical? ✗
  - Prototype? ✗
  - Theory-theory? ✗

Conceptual Atomism

- Introduced by Jerry Fodor
- In response to the failed hunt for definitions

- All lexical concepts are innate
  - “You can’t get something from nothing”
  - “Big Red Balloon” ➔ BIG innate RED innate, BALLOON innate
  - “Pet Fish” is its own innate concept
  - Innate conceptual ‘atoms’
Conceptual Atomism - Strengths

- Avoids the problems of definitions
- Captures the power of compositionality: avoids the problem of prototypes
  - Grandmothers of PBS students
    - Allows us explain our concept by forming a relation between three atoms (grandmother, PBS, student)

Conceptual Atomism - Weaknesses

- Problem of radical nativism
  - Huge stock of innate concepts
    - Broccoli?
    - Galaxy?
    - Electron?
  - Are these really innate concepts?

Overview

- Conclusions-
  - Concepts are building blocks of cognition—every aspect of cognition that we study either deals with representations or the computations performed on those representations
    - Concepts are all about these representations and their underlying structure

Overview

- Conclusions-
  - These four theories empower us to say something specific rather than something vague about any aspect of cognition that we chose to study
Overview

- Conclusions-
  - We can ask about the representations involved, the computations performed on those representations and the format of those representations (classical? Prototype? Theory-theory? Atomistic?)
    - Classical = Biederman’s geons
    - Prototype =
      - Maye’s Phoneme perception
      - Tarr’s exemplar model
    - Theory-theory = Infants’ "theory of objects"
    - Conceptual atomism =
      - Simplest: Receptive fields in vision
      - High level: The lexicon and syntax in language

In closing

This week’s readings are an invitation to use these four ways of thinking as a tool to approach any problem in cognition

Thanks to:

- Dr. Justin Halberda
- Cognitive Proseminar
- Category researchers everywhere

Structure of Concepts

- Two main schools of thought
  - Containment
    - This is the idea that one concept is made up of (contains) other concepts and that when this concept is activated, all of the other concepts under it MUST be activated
      - Ex. the concept ‘bird’, when activated, the concepts of “feathers,” “builds nests,” “lays eggs” must all be activated.
    - Sentence Model
      - “Stole the pencil” must activate the concept of pencil because pencil is a structural element in this phrase.
Two main schools of thought
  – Inferential
    • This is the idea that one concept is composed of other concepts, but these concepts do NOT have to be activated for the original concept to occur.
    – Ex. the concept ‘bird’, when activated, the concepts of ‘feathers,’ ‘builds nests,’ may activate, but NOT ‘lays eggs’ even though ‘lays eggs’ is a concept that helps to make up the concept of ‘bird’

Example: Concept A
  – Concept A is made up of concepts B, C, D, and E
    • Containment
      – When A activates, so must B, C, D, and E.
      – Classical view
    • Inferential
      – When A activates, B, C, D or E may or may not activate
      – Prototype, Theory-theory