9.85 Cognition in Infancy and Early Childhood

Concepts: From definitions to features to theories

Today

- Carey/Gelman
- Classical theory of concepts
- Prototype/Exemplar theories of concepts
- Theory theory of concepts

When object knowledge isn't enough …

- Spatiotemporal features, Spelke principles, support relations, number …

- But how do you know a banana is a banana?

Two (intersecting) problems of inductive inference

- How do you go from a small sample of instances to a general category? (How do you learn the “sense” of a concept?)
- Given that you have a general category, how do you recognize an instance of it? (How do you identify the “reference” of a concept?)

How can you learn a concept?

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http://www.merriam-webster.com/dictionary/truth

How can you learn a concept?

- By definition … learn this definition, decide if these examples fit the definition.
- “Classical view” of concepts (since Aristotle)
- Applied to everything: causality, truth, justice, dogs.
- Want to capture everything that is an instance of causality, justice, truth and dogs and nothing that is not an instance of these.

Classical theory of concepts

- Captures necessary and sufficient features.
- Useful in logical deduction.

  – All bachelors are unmarried men.
  – John is a bachelor
  – Therefore John is an unmarried man.

Implications of the classical theory

- Everything is or is not a member of a definable category.
  - (We may not know whether Fred is a wildebeest or not, but there's a fact of the matter: Fred really is either a wildebeest or he is not a wildebeest.)
- All members of the category are equally good members of the category.

Classical theory of concepts

- Piaget's view as well …
- "The 'intension' of a class is the set of properties common to the members of that class, together with the set of differences, which distinguish them from another class"
- (Necessary and sufficient features)
- Children's failures at deductive logic suggested to Piaget that they had an immature understanding of most concepts until school-age.

Classical theory of concepts

- Concepts are structured mental representations that encode a set of necessary and sufficient conditions for their application. Most concepts are composed of structurally simpler representations that are ultimately derivable from sensory/perceptual input.

Demise of the classical view

- Theoretical problems:
  - Wittgenstein: necessary and sufficient definitions of word meanings?
  - ignorance and error
- Empirical problems
  - Fails to explain effects of typicality
  - And intransitivity

do for fun by yourself and is a

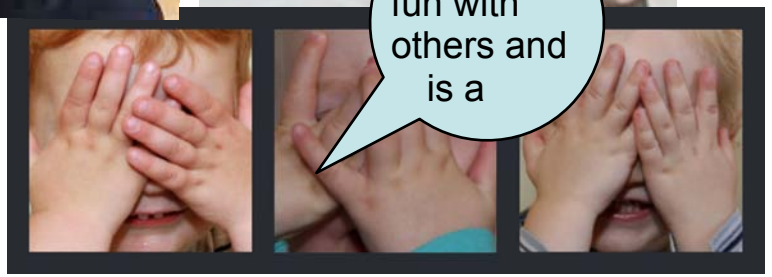
do for fun with others, has rules

do for fun by yourself but not a

do for fun with others, has rules and is not

do for fun by yourself but is a

do for fun by yourself but is



do for fun with others and is a

True of even scientific concepts

- Dr. Robert Pond: Fun with Metals
- “There’s a big group of people who don’t know what a metal is. Do you know what we call them? Metallurgists! Here’s why metallurgists don’t know what metal is. We know that a metal is an element that has metallic properties …
- So we start to enumerate all these properties: electrical conductivity, thermal conductivity, ductility, malleability, strength, high density. How many of these properties does an element have to have to classify as a metal? We can’t get the metallurgists to agree. Some say three properties, some say five properties, some say six properties…” (Robert Pond)
- Even Piaget recognized this in his capacity as a biologist, although never fully encompassed it in his psychological work (Vanity of the Nomenclature). Huge debate on what a ‘species’ is ...

Demise of the classical view

- Theoretical problems:
  - Wittgenstein: necessary and sufficient definitions of word meanings?
  - **ignorance and error**
- Empirical problems
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Theoretical problems: Ignorance and error

- What happens to the classical view if what counts as necessary and sufficient definition changes?
- The ancient Greeks and I both have a concept of water ...
- but only my concept includes H2O.
- Do we have the same concept or not?
- (Problem applies across historical time, cultural differences, development ...)

Are children's concepts like adult concepts?

- Over-extensions
  - Shirt buttons
- Under-extensions
  - Only flying butterflies
- Wrong extensions
  - Boston terrier for pig

Ways concepts can change

- By collapsing (moving and sitting butterflies)
- By dividing (buttons and buttons)
- By eliminating (phlogiston; ether)
- By creating (Boston Terriers, quantum mechanics)

Incommensurability?

- Fodor: if children's concepts weren't like adult concepts we couldn't talk to each other.
- Concepts change historically as well as ontogenetically -- concept of heat …
- How can we read 17th century chemistry books? Or Dante?
- All this suggests we understand something about concepts other than agreed-upon necessary and sufficient conditions ...

Demise of the classical view

- Theoretical problems:
  - Wittgenstein: necessary and sufficient definitions of word meanings?
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- Empirical problems
  - **Fails to explain effects of typicality**
  - And intransitivity

Empirical problems: Classical view fails to explain typicality effects

- What's the definition of a bachelor?
- What's a bachelor pad look like?
- What do bachelors do for dinner?
- What do they do for fun?

Empirical problems: Classical view fails to explain typicality effects

- Are these bachelors? http://www.imdb.com/title/tt0086927/

  How about these (Pope Benedict & Mark Morris)?

Empirical problems: Classical view fails to explain typicality effects

- This is an issue for preschoolers and grandmothers just like it's an issue for you and bachelors.
- Preschoolers emphasize characteristic features
  - grandmothers have white hair and bake cookies
- Over defining features
  - Grandmothers are women with grandchildren.

Characteristic v. defining features

- What's an island?
  - You dance
- Who lives on an island?
  - People … yup, people without clothes on…
- Is there an island in Ithaca?
  - No
- Why not?
  - Cause it's not summertime there yet.

Characteristic v. defining features

- What's a princess?
  - In a castle
- If I live in a castle am I a princess?
  - And kings live in castles!
- Can a princess be ugly?
  - No
- Can a princess be old?
  - No

Characteristic v. defining features

- Maybe it's just due to familiarity. When children have to generate a response, they generate the most accessible examples
- But preschoolers true even given forced choice tasks ...

Characteristic v. defining features

- Jack is a mean, sneaky person. One day he took a dollar bill from his mom's purse. his mom said, "Jack did you take the dollar bill from my purse?" And Jack said "Yes, I took the dollar bill from your purse." Did Jack tell a lie?
- Jane is very friendly to everyone. She is very pretty too. One day, Jane went into the grocery store and she took a package of cookies off the shelf and left the store without paying for them. Is Jane a robber?

Characteristic v. defining features

- Pete is a teenager. Pete has an older sister who is much older and just had a new baby. Is Pete the baby's uncle?
- Fred is a neighbor of Sally's. He has a brown beard and is very fun to play with. Fred isn't related to Sally. but he comes over and takes Sally's daughter Molly out to the zoo and brings present and celebrates her birthdays. Is Fred Molly's uncle?

Typicality effects

- Found in every conceivable area.
- There are more and less prototypical birds
  - robins v. penguins
- Kitchenware
  - pots v. sponges
- Even odd numbers
  - 7 v. 47

Typicality effects

- Generate a range of phenomena …
  - Reaction time
    - participants agree that robin is a bird faster than they agree that a penguin is a bird
  - Production
    - Naming
      - Name a fish
      - How many of you named an eel?
    - Word ordering (apples and limes; golden retrievers and great danes)
  - Cognitive reference points
    - dark reds are reddish; true red isn't marrooonish;
    - 101 is close to 100; 100 isn't close to 101.

Typicality effects

- Robins have high potassium in their blood.
- All birds have high potassium in their blood.
- V.
- Penguins have high potassium in their blood.
- All birds have high potassium in their blood.

- **Premise-typicality matters for induction.**

Demise of the classical view

- Theoretical problems:
  - Wittgenstein: necessary and sufficient definitions of word meanings?
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- Empirical problems
  - Fails to explain effects of typicality
  - **And intransitivity**

Empirical problems: Classical view fails to explain intransitivity

- **Transitivity**
  - According to the classical view, inclusion relationships (IS-A relationships) are transitive.
  - If A is a B and B is a C, then A is a C.
  - If dogs are mammals and mammals are animals then dogs are animals.

Empirical problems: Classical view fails to explain intransitivity

- But Big Ben is a clock.
- Clocks are furniture.
- Is Big Ben furniture?

- Chairs are furniture
- A car seat is a chair.
- Is a car seat furniture?

Prototype theory tried to address failures of typicality and transitivity

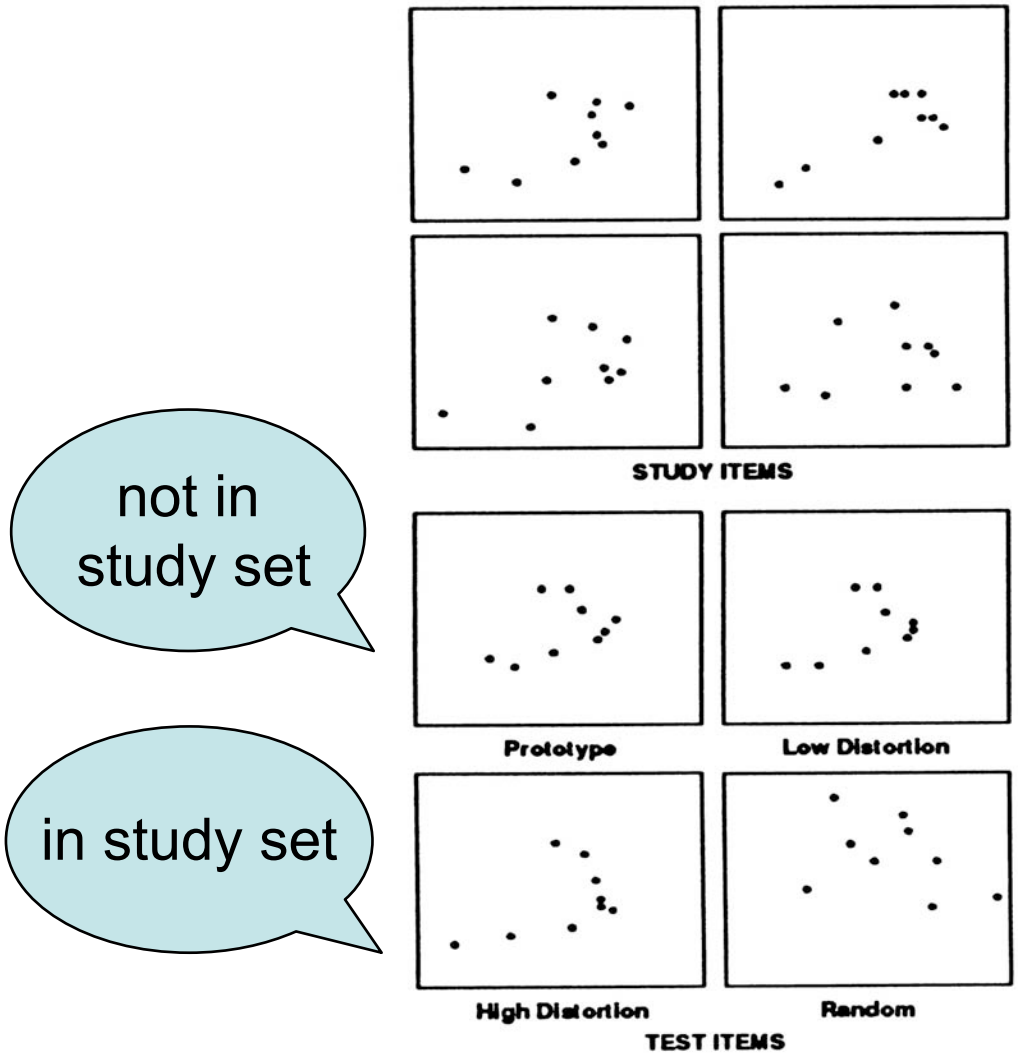
- Some instances are better instances of a category than others because prototypes can have different numbers of features and can have features of different weights.
  - Ability to time is heavily weighted for clocks; being indoors, not so strongly weighted. Being indoors is however, heavily weighted for furniture.
- Transitivity can fail because the features common to Big Ben and clocks might be different than the features common to clocks and furniture. No necessary and sufficient features.

Prototype theories of concepts

- A category's prototype is the exemplar with average values on all the dimensions along which the category's exemplars vary.
- Initial variance is important. Young infants habituated to cats dishabituate dogs; infants habituated to dogs don't dishabituate to cats.
- Like Wittgenstein's idea of family resemblance. We extract a summary representation of the different exemplars.

Prototype theories of concepts

- Prototype effects are not explained by simple frequency (we see more chickens than catbirds but a catbird is still more typical.)
- We can extract prototypes even if we've never seen them at all.



Squire, Larry R. and Zola, Stuart M. (1996) Proc. Natl. Acad. Sci. USA 93, 13515-13522

Prototype theories of concepts

- 3-month-old infants can do this as well …
- When habituated to distortions of a triangle or square as dots, they preferred the novel prototype … suggesting that they'd extracted the prototype from the distortions.

Challenges to the prototype view

- If you store the value and variance of individual features, quickly have a combinatorial explosion
  - think of storing each value of each dot and its variance in the Squire example
- Prompted “exemplar” theories -- you just remember a few exemplars and compare new instances to them.
- (Note -- if you store exemplars, it’s puzzling that a novel prototype should be more “familiar” than an actually-observed stimulus.)

Challenges to prototype theories

- The similarity of any two entities (or their similarity to a prototype or exemplar) depends on what properties you're looking at …
- And context determines how you weigh the importance of similar attributes.

Challenges to prototype/ exemplar theories

- In what respects are these similar?

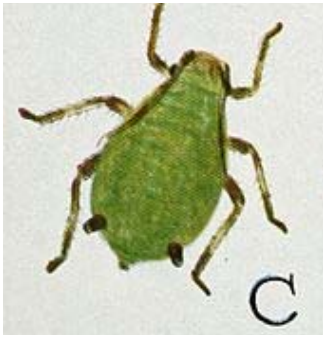


Image: Public Domain. USDA.

Smaller than a breadbox

Subject to the laws of gravity

Aren't letters of the alphabet

Have faces

Challenges to the prototype view

- Suppose you see only a single entity. How would you recognize this again?

Challenges to the prototype view

- Suppose you see only a single entity. How would you recognize this again?
  - Many category inferences from legs, eyes, horn.
  - Very few from being in a living room.
- How did you know which features would be prototypical (or be exemplars) from a single example?

So objections to prototype and exemplar theories:

- The similarity of any two entities depends on what features you're looking at …

- And the same feature can be central to one concept and peripheral to another.

Challenges to prototype/ exemplar theories

Both have features of being yellow and curved ...

Brown bananas and boomerangs are still bananas and boomerangs

But a straight banana is still a banana (although not a prototypical one). A straight boomerang is not.

Challenges to prototype view

- In prototype theories, membership is determined by similarity to a feature list or similarity to a prototype/exemplar.
- But it turns out that some feature combinations are easier to learn than others.

Test

- Category A
  - Green
  - Air bags
  - Vinyl seats
  - Stick shift
- Category B
  - White
  - Seatbelts
  - Cloth seats
  - Automatic transmission

- Category A
  - Made in Africa
  - Lightly insulated
  - Has mudflaps
  - Open top
- Category B
  - Made in Norway
  - Heavily insulated
  - Antilock breaks
  - Has treads

Concepts as embedded in theories?

- Attention to features is context-sensitive
- Suggests that what counts as ‘prototypical’ or an ‘exemplar’ cannot be reduced merely to feature lists ...

- Suggests our theories inform our inductive inferences about concepts.

Theory of concepts should answer:

- What constrains similarity?
- What determines which features are peripheral to a concept and which features are essential to the concept?
- What binds features together and makes some sets of features easier to learn than others?

Theory theory view of concept learning

- Causal knowledge is critical to concept learning in at least three ways:
  - Causal knowledge helps us decide which features are relevant to category membership
  - Causal knowledge helps us decide which features are central and which peripheral.
  - Causal knowledge affects our intuitions about when category members will retain their identity and when they will be transformed.

Theory theory view of concept learning

- Folk causal knowledge (naive theories) is critical to concept learning in at least three ways:
  - **Causal knowledge helps us decide which features are relevant to category membership**
  - Causal knowledge helps us decide which features are central and which peripheral.
  - Causal knowledge affects our intuitions about when category members will retain their identity and when they will be transformed.

Naive theories and identifying relevant features for category-based induction

- Wugs v. Gillies
  - **"Features condition":** Gillies are really cute. Gillies have big ears, wings and a monkeylike tail. See? Gillies have big ears, wings and a monkeylike tail.
  - **"Feature description condition"**: Gillies are really cute. Gillies have big ears to listen to music, wings to fly and monkeylike tail to pick up sticks.
  - **"Causal condition"**: Gillies hide from predators so they have big ears to listen to predators, wings to fly up into a tree and a monkeylike tail for good grip.
- Both immediately and after a 24-hour delay, children categorized new animals more accurately when given causal information than in other conditions.

Naive theories and identifying relevant features for category-based induction

- Causal knowledge determines how children weight features for categorization.
- Shown an ambiguous thing.
- When described as animals, children sorted by habitat (e.g., is found in the mountains) and physical adaptations (has thick wool.
- When described as artifacts, children sorted by function (can crush rocks)

Naive theories and identifying relevant features for category-based induction

- “This robin has semasoid bones”. What else has semasoid bones?”
  - Sparrow
  - Bug
- inductive inferences extended on the basis of taxonomic links (the sparrow)
- But “This robin caught an intestinal virus. What else has an intestinal virus?”
- inductive inference extended on the basis of predator/prey relationships (the bug)

Naive theories and identifying relevant features for category-based induction

- Both children and adults can override taxonomic choices to make inductive inferences on the basis of other ecological relationships -- like food webs.
- Background knowledge has an effect: “Experts” -- rural children, ecologists -- do this better than novices, urban children, university undergraduates.

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Causal knowledge and feature centrality

- These are lake Victoria shrimp.
- They have high levels of ACH neurotransmitter.
- ACH neurotransmitter (C) causes a “flight” response (F1) which triggers an accelerated sleep cycle (F2) which promotes weight gain (F3).
- C-->F1-->F2-->F3

Causal knowledge and feature centrality

- Here's a creature with high levels of ACH neurotransmitter.
- Here's a creature with a "flight" response.
- Here's a creature with an accelerated sleep cycle.
- Here's a creature with high weight gain.
- How confident are you it's a Lake Victoria shrimp?
- C>F1>F2>F3

Causal knowledge and feature centrality

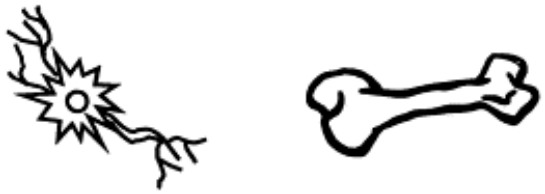
- CAUSAL CONDITION: 'Taliboos have something called promicin in their nerves. Promicin in their nerves makes taliboos have thick bones and large eyes' So what does the promicin in their nerves do?'
- FEATURE LIST: Taliboos have something called promicin in their nerves. They have promicin in their nerves, they have thick bones, and they have large eyes. So Taliboos have promicin in their nerves. What else do they have?

Ahn et al., 2000

Causal knowledge and feature centrality

- Which one is the taliboo?
- Children (7-9 year-olds) in the causal condition chose A (74% of children chose the one with promicin)
- Children given only a feature list chose at chance (44% chose the one with promicin)

A



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Ahn et al., 2000

Causal knowledge and feature centrality

- “Causal status effect”
- In particular, both adults and children think that properties that cause other properties are more critical for category membership than other properties.

Theory theory view of concept learning

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  - **Causal knowledge affects our intuitions about when category members will retain their identity and when they will be transformed.**

Causal knowledge, identity and transformation

- You might think that dogs bark, have four legs, and have fur or that tigers are fierce, striped, jungle animals.
- You might think that a mute, 3-legged, furless dog was an atypical dog.
- Or that a tame, albino, suburban tiger was an atypical tiger.
- But you wouldn’t think it was a “quasi-dog” or “quasi-tiger”.

Causal knowledge, identity and transformation

- In many domains, both adults and children seem to assume that category membership is determined by stable, nonobvious (e.g., unobservable), internal (e.g., not caused by people or outside events) causes.
- “Essentialism”

Causal knowledge, identity and transformation

- In essentialized domains inductive inferences are extended on the basis of assumed essences, rather than on the basis of observable features.

Philosophical puzzles

- “The ship … was preserved by the Athenians down even to the time of Demetrius Phalereus, for they took away the old planks as they decayed, putting in new … timber in their place, insomuch that this ship became a standing example among the philosophers, for the logical question of things that grow; **one side holding that the ship remained the same, and the other contending that it was not the same**.” (Plutarch, Vita Thesei)

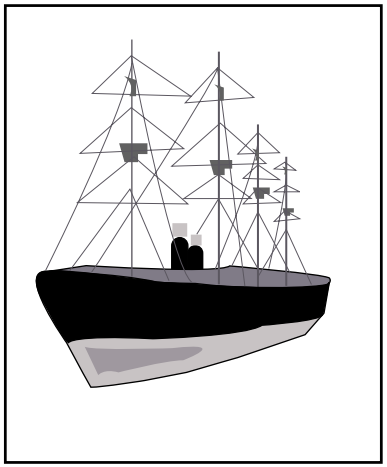

Image by MIT OpenCourseWare.

Causal knowledge, identity and transformation

- In **essentialized** domains (*natural kinds as opposed to artifacts or arbitrary groupings*) **inductive inferences** (*about the extension of non-obvious properties -- insides, functions, causal powers, object labels*) are extended on the basis of assumed **essences** (*stable, unobserved, internal causes*), rather than on the basis of observable features.
-

Inferences based on kind membership -- not feature similarity

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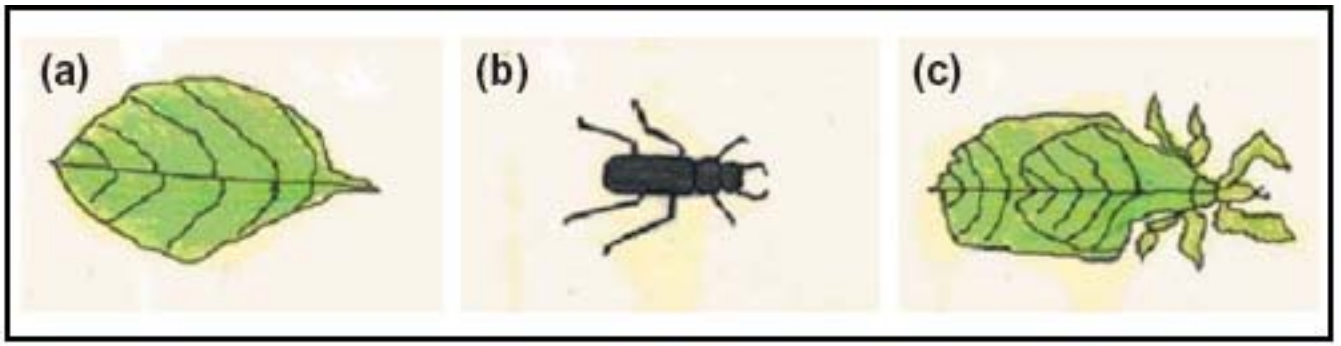

Figure 1. Sample item set used in studies with preschool children [6,7]. The item sets were constructed so that overall similarity (in shape and color) was pitted against shared category membership. This set comprised **(a)** a leaf, **(b)** a beetle, and **(c)** a leaf-insect. When 3- and 4-year-old children heard labels for these items ('leaf', 'bug', and 'bug', respectively), they were more likely to extend new information on the basis of shared label than on the basis of overall similarity.

www.sciencedirect.com

Causal knowledge, identity and transformation

- Children treat natural kind concepts and many social kind concepts as arising from unobservable, stable, internal causes.
- In essentialized domains inductive inferences are extended on the basis of these causal essences, rather than on the basis of observable features.

Causal knowledge, identity and transformation

- Here's a raccoon -- suppose that we paint it black and white and put a smelly sac inside it. Is it a raccoon or a skunk?

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Causal knowledge, identity and transformation

- Children insist that it's a raccoon, no matter what it looks like.
- Its raccoon "essence" hasn't changed.

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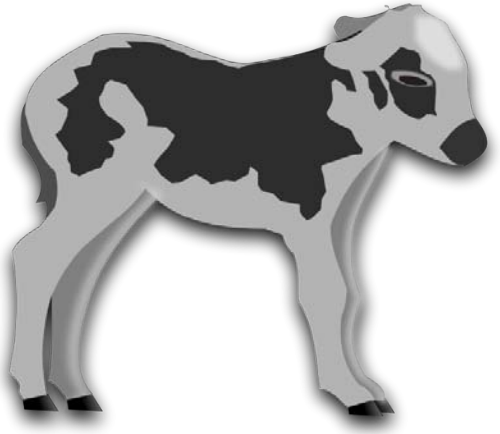
Causal knowledge, identity and transformation

- Holds for natural transformations as well. Children believe things can substantially change their environment and yet retain their identity.
- If I raise this baby calf with pigs will it grow up to have a straight tail like a cow or a curly tail like a pig?
- Will it moo or say oink?



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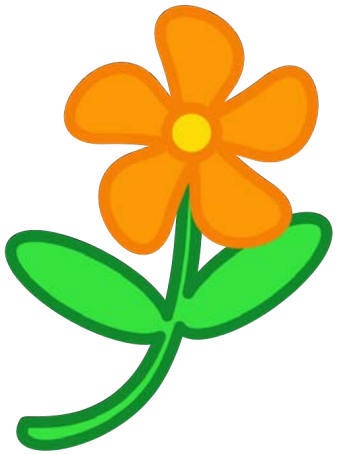
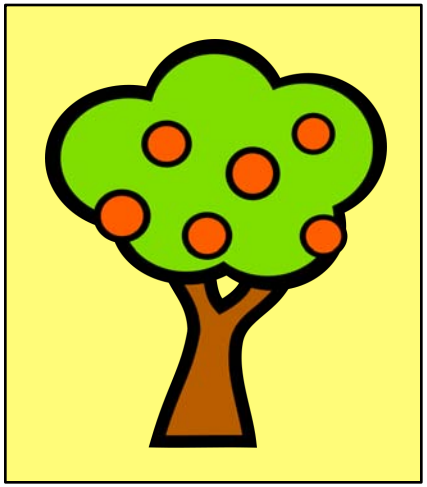
Causal knowledge, identity and transformation

- If I put an apple seed in a flowerpot will it grow up to look like this or like this?





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Causal knowledge, identity and transformation

- If this baby girl is raised on an island with only boys and men …

Image: OpenClipArt. Public Domain.

- Will she have girl blood or boy blood?
- Will she wear a dress or a football shirt? Grow up to be a nurse of a firefighter? Play with a tea set or a toy truck?
- On Girl Island they play fan-tan; On Boy Island they play chuck-luck. If she's raised on Boy Island what will she play?

Causal knowledge, identity and transformation

- Children extend (and over-extend) essentialist assumptions for natural kinds
- They think there are unobserved, inherent causes of these properties that stay constant across transformations like growth and inheritance.
- Challenges prototype view: concepts are not about observable features.

Theory theory view of concept learning

- Causal knowledge is critical to concept learning in at least three ways:
  - Causal knowledge helps us decide which features are relevant to category membership
  - Causal knowledge helps us decide which features are central and which peripheral.
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Theory theory view of concept learning

- Critically, these effects of causal knowledge are apparent even in very young children.
- Despite a widely held belief that young children are most influenced by perceptual properties …
- There is little evidence for a “shift” from judgments based on perceptual similarity to essentialist judgments …
- Rather even the youngest children seem to consider causal relations in their conceptual judgments.
- There are no “theory-neutral” concepts.

Theory theory of concepts

- We still want to “understand where the representations that articulate the hypothesis space come from” Carey, Origin of Concepts, 2009)

Sensory representations and conceptual representations

- Sensory representations have relatively impoverished inferential roles ...
  - little follows from being red or having six sides
  - much follows from being a stop sign
- Sensory representations may be modular (encapsulated)
- Conceptual representations are “informationally promiscuous ... there are no limits on what information may turn out, in the end, to bear on any particular hypothesis, and we seek coherence among all our explicitly held beliefs.”

Quinian bootstrapping

- There is core conceptual knowledge (of objects, agents, number ...)
- But there are genuine discontinuities in conceptual development (e.g., nothing in core knowledge can express 14, 1/3 or pi).
- How do we get these?

Inferential role semantics

- “When I took my first physics course, I was confronted with quite a bit of new terminology all at once: “Energy, momentum, acceleration, mass” and the like. As should be no surprise to anyone ...I never learned any definitions of these new terms in terms I already knew. Rather what I learned was ... relations among the new terms themselves (e.g., the relation between force and mass, neither of which can be defined in old terms) ...” (Block, 1986)

Quinian bootstrapping

- Conceptual change happens as symbols, initially used as placeholders and interpreted only in relation to each other, accrue new content through “modeling processes” (e.g., analogy, induction, abduction, etc.)

Theory theory view of concepts

- “One of the things that theories do is to embody or provide causal linkages from deeper properties to more superficial or surface properties.” (Medin, Concepts and Conceptual Structure)

Theory theory view of concepts

- “Human beings are theory builders; from the beginning we construct explanatory structures that help us find the deeper reality underlying surface chaos” (Carey, Conceptual Development in Childhood, 1985)

9.85 Infant and Early Childhood Cognition
Fall 2012