Conceptual Development
Interview with a kindergartner

- **Experimenter**: It’s 12 o’clock in the afternoon and the sun in shining really bright. You already ate something today, but you’re still very hungry, so you decide to eat pancakes with syrup, orange juice, cereal, and milk. Could that be lunch?
- **Kindergartner**: No. . . because lunch you have to have sandwiches and stuff like that.
Interview with a kindergartner

- **Exp:** Can you have cereal for lunch?
- **Kid:** No.
- **Exp:** Can you have pancakes for lunch?
- **Kid:** No... No.
- **Exp:** Well, how do you know if something is lunch or not?
- **Kid:** If the time says 12:00.
- **Exp:** This was 12:00.
- **Kid:** Well, I don’t think so.
Interview with a kindergartner

- **Exp:** (Repeats story.) Is that lunch?
- **Kid:** I know...that one is NOT lunch..you have to eat sandwiches at lunch.
- **Exp:** Can you have anything else?
- **Kid:** You can have drinks, but not breakfast.
Conceptual Development
What are concepts?

- Concepts are mental groupings of more-or-less interchangeable elements
  - Objects (*dog, island*)
  - Events (*lunch, birthday*)
  - Qualities (*sweet, fast*)
  - Abstractions (*true, good*)
Why Concepts Are Important

- Concepts are basic elements of thinking
  - **language**: most words symbolize concepts
    - E.g., “dog” and “chien” symbolize a mental grouping of dogs and all knowledge about dogs
  - **memory**: concepts link our past and future experiences with the present
    - E.g., If I recognize Lassie to be a dog, I can reasonably infer that Lassie has some of the same properties of the dogs I’ve met before and will meet in the future
  - **learning**: concepts allow us to generalize new experiences
    - E.g., If I know that Lassie and Fido are dogs, and I learn that Lassie and Fido have FRTG-23 in their cells, I can infer that other dogs might too.
How might concepts develop?

- **Two ways concepts might change with age**
  - its relation to other concepts (semantic network)
  - knowledge about the units of the concept (schemas)
Concept Island

- Knowledge about islands
  - Islands are bodies of land
  - Islands are totally surrounded by water
  - Islands have beaches
  - Sometimes the beaches are sandy, with sea shells
  - People travel to islands where there is warm weather and palm trees
  - Australia is the biggest island in the world
  - The combination of N. and S. America is not an island
Semantic Network for Island

- Objects
  - Nonliving
    - Dogs
    - Ferns
  - Natural
    - Tables
    - Houses
    - Gold
    - Rocks
  - Land masses
    - Islands
      - Hawai‘i
    - Peninsulas
    - Continents
      - Australia
Island schema

- **Island schema**
  - *Is a*: land mass
  - *Shape*: any closed figure
  - *Material*: stone, dirt, sand
  - *Function*: habitat, vacation spot
  - *Size*: ≈ 1 - 8,000,00 sq km
How do concepts change?

- **Keil (1983) asked children two kinds of questions**
  - **+D/-C:** On this piece of land, there are apartment buildings, snow, and no green things growing. This pieces of land is surrounded by water on all sides. Could that be an island?
  - **+C/-D:** There is this place that sticks out land like a finger. Coconut trees and palm trees grow there, and the girls sometimes wear flowers in their hair because it’s so warm all the time. There is water on all sides except one. Could that be an island?
How do concepts change?

- For the concept *island*, 5-year-olds most often categorized by characteristic features, whereas 9-year-olds most often categorized by defining features.
- This pattern was observed for many other concepts that have defining features.
How do concepts change?

- **Concept Uncle**
  - Exp (+D/-C): Suppose your mommy has all sorts of brothers, some very old and some very, very young. One of your mommy’s brothers is so young, he’s only 2 years old. Could that be an uncle?
  - **Kid**: No... because he’s little and 2 years old.
  - **Exp**: How old does an uncle have to be?
  - **Kid**: About 24 or 25.
  - **Exp**: If he’s 2 years old, can he be an uncle?
  - **Kid**: No... he can be a cousin.
**Concept Uncle**

- **Exp** (-D/+C): This man your daddy’s age loves you and your parents and loves to visit and bring presents, but he’s not related to your parents at all. He’s not your mommy or daddy’s brother or sister or anything like that. Could that be an uncle?

- **Kid**: Yes.

- **Exp**: What is an uncle?

- **Kid**: An uncle is that he brings you presents at Christmas.

- **Exp**: What else?

- **Kid**: An uncle is that he let you come over to his house?

- **Exp**: Could I be your uncle?

- **Kid**: No ... because I don’t know you.

- **Exp**: If I got to know you and brought you presents, could I be your uncle?

- **Kid**: Yes.
What’s going on?

- **Why do children’s concepts change over time?**
  - Piaget’s theory:
    - Children begin to think taxonomically
  - Information-processing approach
    - Children’s knowledge is heavily influenced by ‘cue validity’
  - Core Knowledge approach
    - Children acquire new causal beliefs or a new application of old causal beliefs
Piaget’s Theory

- **Piaget’s theory:**
  - Concepts are equivalent to defining features
    - *Uncle* = *Mother’s brother* or *Aunt’s husband*
  - Preoperational children fail on tasks like Keil’s because they do not yet represent *taxonomic* relations among concepts, but base their judgments on *thematic* relations
Piaget’s theory: Support

- **Piaget’s theory:**
  - Based view on children’s object sorting, “Put together what goes together”
  - *preschoolers:* put dogs and cars together because dogs like to ride in cars, and cats and chairs together because cats like to curl up in chairs
  - *older children:* put dogs and cats together because they’re animals, and put cars and chairs together because they’re artifacts.
Piaget’s theory: Criticism

- Criticism of Piaget’s theory:
  - Children might represent taxonomic relations, but find thematic ones more interesting.
  - Bauer and Mandler (1989) showed 1-year-olds:

  “See this one?”
  “Can you find another one just like it?”
  1-year-olds chose the bear on 85% of trials.
Piaget’s theory: Criticism

- **Piaget’s theory:**
  - Even on Keil’s task, kindergartners sometimes use defining features, especially for moral terms
    - robber
    - lie
Piaget’s theory: Criticism

- **Concept lie**
  - -D/+C: This girl hated a boy in her class because he was so mean and did really nasty things to her. She wanted to get him into trouble, so she told the teacher all the nasty things the boy had really done. Could that be a lie?
  - +D/-C: This little boy always got good grades in school and prizes for being so smart. The other children were jealous of him because of it, and he didn’t want to make them feel bad and wanted them to be friends. So, one time, when he really got a good mark on a test, he told them that he got a bad mark so they’d be his friends. Could that be a lie?
Piaget’s theory: Criticism

- For moral concepts, 5-year-olds and 9-year-olds most often categorize by defining features.
Information-Processing Approach

- **Concepts are more than just defining features**
- Even for adults, many concepts are difficult to define very precisely (e.g., *game*)
- Precise definitions for some terms are not very useful
  - Dog: A quadruped of the genus *Canis*, of which wild species or forms are found in various parts of the world, and numerous races or breeds, varying greatly in size, shape, and colour, occur in a domesticated or semi-domesticated state in almost all countries. These are referred by zoologists to a species *C. familiaris*; but whether they have a common origin is a disputed question.
Information-Processing Approach

- Rosch & Mervis (1975): Instead of defining features, concepts may be represented in terms of probabilistic features.

Brother of father or mother, OR Husband of Aunt

About as old as one’s parents

Nice

Handsome
Information-Processing Approach: Support

- Evidence in favor of this view is built around three ideas:
  - Cue validity
  - Basic level categories
  - Prototypes
Information-Processing Approach: Support

- **Cue Validities:**
  - Children might decide whether objects are examples of one concept or another by comparing *cue validities*.
  - The cue validity of a feature is the degree to which the frequency of a feature accompanies a category member and the infrequency with which it accompanies non-category members.
  - For example, because most (though not all) birds can fly, and because most (though not all) non-birds cannot fly, flight is a highly valid cue for
Information-Processing Approach: Support

- **Cue Validities:**
  - Cue validity helps to explain
    - why adults are so much faster to identify robins as birds than ostriches, and
    - why children are more likely to say that an ostrich is not a bird than to say that a robin is not a bird.
Information-Processing Approach: Support

- **Cue Validities:**
  - Infants in the first few months are already sensitive to cue validity.
  - This seems to allow them to form basic concepts such as *cat* on the basis of perceptual information.
Quinn & Eimas (1996)
- Showed 3- to 4-month-olds pairs of cat pictures
- From trial to trial, infants looked equally long at new cats, but a very long time at a new dog
- This finding suggests that they treated clearly different cats as alike, whereas they saw a different dog as not alike
• The IP Approach also helps to explain the development of object concept hierarchies.

<table>
<thead>
<tr>
<th>Level</th>
<th>Type of Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most General</td>
<td>Inanimate Objects</td>
</tr>
<tr>
<td></td>
<td>People</td>
</tr>
<tr>
<td></td>
<td>Living Things</td>
</tr>
<tr>
<td>General</td>
<td>Furniture, Vehicles . .</td>
</tr>
<tr>
<td></td>
<td>Europeans, Asians . .</td>
</tr>
<tr>
<td></td>
<td>Animals, Plants . .</td>
</tr>
<tr>
<td>Medium</td>
<td>Chairs, Tables . .</td>
</tr>
<tr>
<td></td>
<td>Spaniards, Finns . .</td>
</tr>
<tr>
<td></td>
<td>Cats, Dogs . .</td>
</tr>
<tr>
<td>Specific</td>
<td>La-Z-Boys, Armchairs . .</td>
</tr>
<tr>
<td></td>
<td>Picasso, Cervantes . .</td>
</tr>
<tr>
<td></td>
<td>Lions, Lynxes . .</td>
</tr>
</tbody>
</table>
Within a given hierarchy, there will always be a basic level category, where cue validities are maximized.

For example, in furniture/chair/kitchen chair

Chair is a basic-level category because its features have the highest cue validities

Legs, a back, and a seat are associated with most chairs (but not beanbag chairs), whereas few other objects have these
Anglin (1977) showed that children typically form basic-level categories before superordinate and subordinate-level categories.

<table>
<thead>
<tr>
<th>Superordinate</th>
<th>Basic</th>
<th>Subordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Transportation</td>
<td>1. Cars</td>
<td>2. Volkswagens</td>
</tr>
<tr>
<td>2. Plant</td>
<td>1. Flower</td>
<td>3. Rose</td>
</tr>
</tbody>
</table>
Information-Processing Approach: Support

- Prototypes are the most representative instances of concepts because they have the highest cue validities
- Lassie is a prototypical dog because she had qualities (e.g., size, shape, bark) representative of dogs in general
- Adults and children are quickest and most accurate in judging the category-membership of prototypes
Research also indicates that infants as young as 3 months abstract prototypes from sets of objects (Bomba & Siqueland, 1983; de Haan et al., 2001).
Face Prototypes

Four Familiarization Faces

Example of Test Pair 1

Example of Test Pair 2
Fig. 2. One-month-olds’ (n = 12; left bars) and 3-month-olds’ (n = 12; right bars) mean proportion of looking to each face in the Average versus Familiar Individual Face test trial (top) and in the Novel versus Familiar Individual Face test trial (bottom) in Experiment 1. The horizontal line at 0.5 shows the level of looking to each face expected by chance.

M. de Haan et al. / Cognitive Development 16 (2001) 659–678
Information-Processing Approach: Criticism

- **Which features matter and which don’t?**
  - For example, when a child encounters a novel object how does she know what features to pay attention to?

- **Features are not unrelated**
  - It’s not simply that birds build nests in trees and fly and have wings and have bird DNA
  - Rather, birds build nests in trees because they can fly, and they can fly because they have wings, and they have wings because they have bird DNA.
  - Features are causally related and causal features are most important (and sometimes most difficult) features for children to grasp
Core Knowledge Approach

- **Core knowledge approach**
  - children’s concepts reflect their understanding of cause-effect relations
Father’s or Mother’s Brother OR Aunt’s Husband

uncle

is

is About Same Age as Parents

Loves Mommy or Daddy

Loves Me
Core Knowledge Approach: Support

- **Krascum & Andrews (1998)**
  - Two groups of children were given identical descriptions of “Wugs” and “Gillies”
  - Exp group was also told *why* wugs and gillies had the properties they did
  - Exp > Control, categorizing and remembering the categories
Core Knowledge Approach

- CK Approach emphasizes children’s use of causal relations in reasoning
  - According to Piaget and Rosch, concepts are formed when different items share many more visual features than they do not share
  - But many adult concepts involve ignoring visual similarity
  - The CK Approach argues that children can ignore visual similarity in their reasoning much earlier than Piaget or Rosch supposed
Development of Early Biological Concepts

- Findings indicating that children go beyond similarity:
  - Conservation of identity over metamorphosis (Rosengren et al., 1991)

What will it look like when it grows up?
Development of Early Biological Concepts

- Findings indicating that children go beyond similarity:
  - 2. Essentialism (Gelman & Wellman, 1991)

Which of these looks most like the pig? Which of these has the same kinds of insides as the pig?
Findings indicating that children go beyond similarity:

3. Category-based inference (Gelman & Markman, 1986)
Development of Early Biological Concepts

Findings indicating that children go beyond similarity:

4. Inheritance-based categorization (Opfer & Bulloch, 2007)
Questions?
Concepts & Learning

- Concepts organize our experiences of the world
  - what or who we experienced
  - how many things were involved in the experience
  - where the experience occurred
  - when the experience occurred
  - why the experience occurred
Previously...

- How children’s **object concepts** change
  
  1. Shift from categorizing objects (e.g., *island*) by **characteristic** features to categorizing by **defining** features
  
  2. Development of **superordinate** and **subordinate** categories (e.g., that a flower is also a **plant** and a **rose**)
  
  3. Development of **long-term memory for new categories** by learning how features are causally related to one another
• Concepts organize our experiences of the world

**people**

- experience of people

**numerical**

- how many things were involved

**spatial**

- where the experience occurred

**temporal**

- when the experience occurred

**causal**

- why the experience occurred
According to the core knowledge approach, all humans are born with domain-specific learning mechanisms that allow children to acquire skills that other animals do not possess.

- Mechanism for learning words and grammatical rules (in Broca’s and Wernicke’s areas) → Language Development

- Question: Are there also innate neural mechanisms for organizing our experiences of **people**, **number**, **space**, **time**, and **causality**?
People Concepts

- Do we think about people in the same way that we think about inanimate objects?
What if your brother was a zombie?

- About zombies
  - Walk slowly
  - Eat brains
  - Mindless
Growing up with a Zombie

- If mindless, then
  - Never pleasantly surprised or disappointed
  - Not very smart but doesn’t believe in things that don’t exist (like Santa Claus)
  - Never in love or jealous
  - No personality
  - No use getting angry at a zombie (couldn’t do otherwise)
Growing up with a zombie would definitely take a lot of getting used to.
Growing up with a person— not so much.
People have minds
Social Cognition

Naturally we seem to have

- A *Mental Conception of People*
  - Understanding that people interact with one another,
  - they must perceive their goals,
  - they have distinct emotions connected with their goals.
  - they act according to their beliefs about their goals, right or wrong.
  - they have personalities or dispositions
Some argue that a mental conception of people is an innate aspect of human psychology (like language):
- is a uniquely human ability
- is present in infants before they can understand language
- is genetically-based
Naive Psychology

- Naive psychology is a common sense understanding of human behavior in terms of mental causes
  - Why did Jack and Jill go up the hill?
  - Common sense: Because they wanted a pail of water and knew a pail of water was at the top of the hill.
Development of Theory of Mind

- By 2 to 3 years old, children typically understand desires.
- But they do not appear to represent others’ beliefs until age 4.
  - Evidence from the false belief task.
False Belief Task:
Unexpected Contents
Unexpected Transfer

1. Maxi places ball in cupboard.
Unexpected transfer

2. Maxi leaves and a second doll enters.
Unexpected transfer

3. Second doll takes ball out of cupboard and puts it under bed.
Unexpected Transfer


Where will Maxi look for the ball?
False Belief Task: Unexpected Transfer
Origins of Naive Psychology

- Evidence for an innate “theory of mind module”
  - Autism
  - Species-Specificity
  - Newborn Attention to Relevant Input (e.g., faces)
Theory of Mind Module?

- **False Picture Task**
  - Picture of apple is taken
  - Apple is replaced by banana
  - *Which object is in the picture?*

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<table>
<thead>
<tr>
<th>Type of test</th>
<th>Percentage passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>False belief</td>
<td>60</td>
</tr>
<tr>
<td>False picture</td>
<td>80</td>
</tr>
</tbody>
</table>

- Autistic children and adolescents
- Normal 4-year-olds
Theory of Mind Module?

- **Hypothesis:** False belief and false picture reasoning depends on distinct neural mechanisms
  - a false belief mechanism that is impaired in autists and young children, but not older children
  - a false picture mechanism that is spared in autists, young children, and older children
Sabbagh & Taylor (2000) gave normal young children a false picture and a false belief task and examined the areas of the brain that were activated.
Theory of Mind Module?

A number of researchers have suggested that the mental operations required for thinking about mental representations may be carried out in an automatic and modularized fashion (Baron-Cohen, 1994; Broth). Both of these observations suggest that reasoning about beliefs requires an additional inferential or integrative step that is not required when thinking about photos. It is possible that the left frontal differences reflect this cognitive disparity (Grafman, Holyoak, & Boller, 1995).

In the present study, ERP differentiations cast doubt on the idea that reasoning about beliefs is automatic. Nevertheless, it remains possible that there is a specialized region of cortex responsible for thinking about beliefs, and not just a representation itself (i.e., photograph of a past situation). That is, a belief involves a propositional attitude (Perner, 1991). That is, a belief involves a propositional attitude (Perner, 1991). That is, a belief involves a propositional attitude (Perner, 1991). That is, a belief involves a propositional attitude (Perner, 1991). That is, a belief involves a propositional attitude (Perner, 1991).

Poststimulus seems to be especially important for considering specificity of the ERP differentiations cast doubt on the idea that reasoning about beliefs is automatic. Nevertheless, it remains possible that there is a specialized region of cortex responsible for thinking about beliefs, and not just a representation itself (i.e., photograph of a past situation). That is, a belief involves a propositional attitude (Perner, 1991). That is, a belief involves a propositional attitude (Perner, 1991). That is, a belief involves a propositional attitude (Perner, 1991). That is, a belief involves a propositional attitude (Perner, 1991). That is, a belief involves a propositional attitude (Perner, 1991).
Povinelli and Eddy (1996) wondered whether mental understandings are unique to humans.

- So they trained 4- to 5-year-old chimps to beg food from only one of two people—the one who had food to give.
- Then they tested whether they would beg for food only from people who could see them. In each trial, one person could see the chimp, whereas the other either had her back turned, was blindfolded, covered her eyes with her hands, had a bucket on her head, had her eyes closed, or was looking up in the air.
- Only when the experimenter had her back turned did the chimp quit begging.
- In contrast, 3-year-olds never gestured to people with buckets on their head.
Where might a “theory of mind” come from?

- **Attention to faces**
  - Faces are a rich source of input about others’ mental states
  - When do infants begin to pay attention to faces?
    - After they learn that faces have high cue validity for emotions?
    - At birth?
Evidence for domain-specific learning mechanisms

- **Johnson et al. (1991)**
  - Discovered that **newborns** visually track regular schematic faces for longer than they do a scrambled or black face.
Evidence for domain-specific learning mechanisms

- Sensitivity to faces is present before infants understand the meaning of different facial expressions
  - Between 5 and 7 months, infants notice common emotional expressions in faces and voices
  - By 12 months, they prefer to look at smiling faces vs. fearful or angry faces
Evidence for domain-specific learning mechanisms

- Newborns prefer to look at faces judged as attractive by adults versus not-so-attractive faces
- This preference affects 12-month-olds’ behavior
  - Langlois et al. 1990: same woman wore either an attractive or unattractive mask
    - Infants responded with more pleasure, more engagement, and less withdrawal when the woman wore the attractive mask
    - The key was that the woman herself did not know which mask she was wearing
Evidence for domain-specific learning mechanisms

- Neural mechanisms (in the right fusiform gyrus) underlying face perception and recognition in infants have been found to be similar to those found in adults.
- Infants (like adults) recognize a face faster if the face is initially presented in the left visual field (to activate the right hemisphere)
- Prosopagnosics (who can identify inanimate objects but not faces) show damage to brain areas (such as right fusiform gyrus) that are activated by faces in infants
Recent Criticisms

- Although early attention to faces may give infants an advantage in learning about humans, face preferences may reflect experience and general information-processing features.
Recent Criticisms

- Infants have been shown to prefer faces with normal arrangements vs. scrambled features
- But this may reflect their preference for upright Ts and figures with closed contours
Recent Criticisms

- Experience also plays a role in face recognition
- Early on, infants are more sensitive to differences in monkey faces than older infants, suggesting that the face processing system is at least fine tuned by experience
Recent Criticisms

- The fusiform gyrus is also recruited in non-face recognition tasks, such as learning to recognize novel shapes
People Concepts

- Do we think about people in the same way that we think about inanimate objects?
  - In some ways, NO: Belief-Desire reasoning appears to rely on distinct brain mechanisms that fail to develop fully in autists and non-humans
  - In some ways, YES: Much of what we know about beliefs and desires comes from what we can see in faces, and face processing relies on neural regions that are also used in object recognition
Number Concepts

- **Numerical equality:**
  - Sets of objects that differ in appearance can be equal in number
Numerical Equality

- Piaget’s studies initially suggested that children fail to recognize numerical equality, leading them to fail the number conservation task.
Numerical Equality

- But Wynn’s studies of infant addition and subtraction showed that even babies recognize when number has been changed
Not just for small numbers either
Numerical Equality

- McCrink and Wynn (2004) found that babies as young as 9 months could recognize impossible addition and subtraction events.
Number Concepts

- **An Hypothesis:**
  - Numerical equality can be recognized through two different mechanisms—estimating and counting,
  - Estimation is an innate ability,
  - Exact counting must be learned.
Estimation

- Beyond a small number, people can only approximately quantify objects without counting.
- To estimate, people and other animals seem to rely on a 'number sense', i.e., a sense of numeric magnitude.
Number Sense

- **Which is more--4 or 6 oranges?**
  - Children’s sense of the relative sizes of the numbers between 1 and 10 are so approximate that they typically fail this question until around age 5 (when they can count just fine).
  - For many years, children’s sense of numbers—like the sense of rats, pigeons, and chimps—is approximate and progressively underestimates the magnitudes of large numbers.

- Evidence? Size and distance effects in numerical judgments.
Size Effects

4
9

19
14
Distance Effects
Estimation

- The neural mechanisms for estimating appear in the intraparietal sulcus across several species, including humans.
Counting

- Counting is more difficult and is learned relatively slowly
  - Most 3-year-olds can count ten objects.
  - Most 6-year-olds can count to 100.
  - There are cultural differences in the counting level attained by young children.
But do counting children understand counting?

- Simply reciting a list of numbers while touching objects is not necessarily real counting
  - For example, duck-duck-goose is like the counting procedure, but it’s based on different principles
# Counting Procedures

## (a) Incorrect counting

<table>
<thead>
<tr>
<th>Number stated:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointing:</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Objects:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## (b) Unusual but correct counting

<table>
<thead>
<tr>
<th>Number stated:</th>
<th>3</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointing:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objects:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Principles of Counting

- **One-to-one correspondence:**
  - Each object should be labeled by a single number word.

- **Stable order:**
  - The numbers should always be recited in the same order.

- **Order irrelevance:**
  - Objects can be counted left to right, right to left, or in any other order.

- **Abstraction:**
  - Any set of discrete objects or events can be counted.

- **Cardinality:**
  - The number of objects in the set corresponds to the last number stated.
Cardinality

- **Wynn’s Give-a-Number Task**
  - Children who can count past 10 are given a pile of objects and asked to give \( N \) objects
  - Over 18 months (3 to 4.5 years), skill develops rapidly
    - One knowers
    - Two knowers
    - Three knowers
    - Cardinality
Number Concepts

• Like concepts of people, concepts of number have a uniquely human aspect that is slow to develop (counting) as well as an aspect that is innate and shared with other species (estimating)
Space Concepts

• Specific brain areas seem to be devoted to the processing of spatial information.
  ● Represent space relative to oneself (Egocentric representation)
  ● Represent space relative to the external environment (Allocentric representation)
Egocentric Representations

- As soon as infants can reach, they show they can code spatial location
  - They prefer to reach for close vs far objects
- Forming a bigger mental map of the world starts with the self and how things look to you
  - During the first year, when infants find they can reach an object on the right, they will continue to reach to the right when they are rotated
  - Once children can move on their own, they begin to form non-egocentric mental maps
Benson & Uzgiris (1985)
Non-egocentric Representations

- **Landmark-based representations**
  - 12-month-olds (and rats) use landmark locations but not landmark indicators (Hermer & Spelke, 1996)
Non-egocentric Representations

- **Dead reckoning**
  - ability to keep track continuously of one’s location relative to one’s starting point in the absence of landmarks
  - even adults are not very good at dead reckoning
  - children in some cultures are very good at dead reckoning for mysterious reasons
**Scale Errors**

- When interacting with toy objects, children normally realize that the small toys aren’t real.
- But after interacting with large toys, object concepts can interfere with spatial reasoning.

Deloache, Uttal, & Rosengren (2004)

**Fig. 1.** Three examples of scale errors. (A) This 21-month-old child has committed a scale error by attempting to slide down a miniature slide; she has fallen off in this serious effort to carry out an impossible act. (B) This 24-month-old child has opened the door to the miniature car and is repeatedly trying to force his foot inside the car. (C) This 28-month-old child is looking between his legs to precisely locate the miniature chair that he is in the process of sitting on.
Scale Errors
Scale Errors

Scale Errors:
Car
Scale Errors

Scale Errors:
Chair
Time Concepts

- Research shows that 3-month-olds can detect a repetitive sequence of events over time and expect the sequence to continue.
- By 12 months, infants can detect the order of events they have seen only once.
- By the age of 5, children can learn to estimate the duration of periods lasting three to thirty seconds.
Time

- Estimating how long ago a certain event occurred, say Christmas, is not very well developed until about the age of 9.
- Children as young as 5 years old can reason and make logical inferences about time, as in predicting that a doll that “fell asleep” last will wake up last.
Causal Concepts

- By 6 to 20 months, infants perceive causal connections among some physical events, such as the collision of a moving object with a stationary object.
- Eleven-month-olds can expect larger object to exert greater forces than small ones.
- Infants as young as 1 year seem to be able to distinguish between causally connected and irrelevant actions in a sequence.
Causality

- By 2 years, children can start to understand more subtle causality, whereas 1-year-olds cannot.
- By 3 to 5 years, children begin to search for causes when no cause is apparent.
- Unlike 3- to 4-year-olds, who don’t see the point of magic tricks, children of 5 years are fascinated because they do not understand the causal mechanisms behind the trick.