Language and Mind
HONR 218L

Class #4
How Language Helps Us Think
Views from Spelke & Jackendoff

In what ways are humans smarter?
Cognitive Achievements in Humans and other Animals

<table>
<thead>
<tr>
<th>Widely Observed</th>
<th>Uniquely Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Find &amp; recognize food</td>
<td>• Art/science of cooking</td>
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<tr>
<td>• Play fighting</td>
<td>• Competitive games w/ elaborate rules</td>
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<tr>
<td>• Navigate through a world full of</td>
<td>• Development of science (attempt to</td>
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<tr>
<td>obstacles</td>
<td>explain why the physical world works</td>
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<tr>
<td>• Organize familial or social</td>
<td>the way it does)</td>
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<tr>
<td>groups</td>
<td>• Development of laws and political</td>
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<tr>
<td></td>
<td>institutions to interpret &amp; enforce them</td>
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</tbody>
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What Makes Us Special?

What Makes Humans so Smart?

• Spelke considers 2 possibilities, both of which make reference to core knowledge systems

• A presupposition of both possibilities is that animals have specialized systems that develop in infancy and provide the core of mature abilities

  – Perceptual systems
  – Motor systems
  – Cognitive systems
What Makes Humans so Smart?

Possibility #1

• The Core Cognitive Systems of Humans are Unique to Humans

  • Similar to Descartes’s answer:
    – Humans: the only animal endowed with reason
    – Reason is the source of all distinctive cognitive achievements of humans
    – Example: Natural understanding of Euclidean geometric principles enables development of astronomy, optics, physics

Evidence against Possibility #1

• Many core cognitive systems have been explored, and (so far) none of them seem to be unique to humans
  – Object Mechanics
  – Natural Geometry

Methodological Question: How do we figure out what babies know?

• Preferential Looking Paradigm
  – Infants prefer to look at novel displays over familiar ones

• Reaching Tasks
  – Infants prefer to reach toward locations that have more of what they want rather than less

Object Mechanics: 5-month old babies know that objects exist even when you can’t see them

Results:

*Infants look longer at the 1-puppet screen, showing they represent 2 puppets in their minds

Important later manipulations:
The same result obtains even if the shapes, colors, and spatial locations of the objects in both displays are new
Object Mechanics:
5-month old babies know that objects exist even when you can’t see them

But so do:
Adult rhesus monkeys
1-day-old chicks

Object Mechanics:
Human infants fill in the surfaces and boundaries of partially occluded objects

- 4-month olds perceive the unity of a moving, center-occluded object
- Movement (common motion of discontiguous parts) is a crucial factor

Natural Geometry

- Humans
  - Both blind and blindfolded children able to deduce the geometric relationships between objects experienced one-at-a-time

- Non-humans
  - Bees compute geometric relationship between hive, food source, and solar azimuth
  - Tunisian ants make a beeline for home after long tortuous treks

Newborn chicks do this too
Evidence against Possibility #1

So...

What Makes Humans So Smart? Possibility #2

• Although the core cognitive systems of humans are the same as those of other animals...

• Language—which is unique to humans—allows humans to combine information from different core systems

Methods for navigating

Geometric

"At the northeast corner"

*rats
*human infants
*adult humans

Methods for navigating

Geometric

"At the northeast corner"

*rats
*human infants
*adult humans

Object Landmark

"At the cylinder"

*rats
*human infants
*adult humans
Methods for navigating

<table>
<thead>
<tr>
<th>Geometric</th>
<th>Object Landmark</th>
<th>Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;At the northeast corner&quot;</td>
<td>&quot;At the cylinder&quot;</td>
<td>&quot;Northeast of the cylinder&quot;</td>
</tr>
</tbody>
</table>

*T* rats  
*human infants*  
*adult humans*  

Toddlers (1.5 to 2 years old) are able to encode the location of the hidden object with respect to the geometric shape of room (left of a short wall).

But toddlers are unable to use the color of the wall to encode a location best described as "left of a black wall".

Explanation: the length of a wall is part of the geometry of a room, but the color of a wall is not. The geometric system can’t talk to the system that represents the colors of objects.

Limitations of Core Systems of Knowledge

- **Domain Specific**: represent only selection of entities in child’s environment
- **Task Specific**: guide only actions/thoughts relevant to child’s life
- **Encapsulated**: processes of each are separate from the other systems
- **Isolated**: representations from each system do not readily combine

Enter human language

“…system that has none of the limits of the core knowledge systems…”

“…a unique system for combining flexibly the representations they share with other animals…”

You can create an expression “left of the black wall” that allows you to combine representations from both the geometric and object representation systems.
Distinct Property of Natural Language

- Compositional Semantics: ability of a speaker to apply meanings of a set of words and rules for combining them to create and understand new combinations from the meanings of their parts.

- "...natural languages can expand the child’s conceptual repertoire to include not just the preexisting core knowledge concepts but also any new well-formed combination of those concepts."

Evidence that language is the crucial factor in adult success

- If you interfere with adults’ ability to produce language, adults act just like toddlers and non-human animals!

What Makes Humans So Smart?
Possibility #2

- Although the core cognitive systems of humans are the same as those of other animals...

- Language—which is unique to humans—allows humans to combine information from different core systems.

- Crucial feature: compositional semantics

Another Example:
Number
What Makes Humans so Smart?

Possibility #1

• The Core Cognitive Systems of Humans are **Unique to Humans**

More evidence against

Possibility #1

• Many core cognitive systems have been explored, and (so far) none of them seem to be unique to humans
  
  – System for determining approximate numerical magnitudes (the “number sense”)
  
  – System for representing persisting, numerically distinct individuals

Human infants have a system for approximating numerical magnitudes

• Dehaene, Gallistel & Gelman

More on LEFT or RIGHT?
Weber’s Law

“as numerosity increases, the variance in subjects’ representations of numerosity increases proportionately, and therefore discriminability between distinct numerosities depends on their difference ratio.”
Weber Fraction Limit*

<table>
<thead>
<tr>
<th>Age</th>
<th>Weber fraction</th>
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<tbody>
<tr>
<td>6 months</td>
<td>1.5-2</td>
</tr>
<tr>
<td>9 months</td>
<td>1.2-1.5</td>
</tr>
<tr>
<td>adult</td>
<td>1.15</td>
</tr>
</tbody>
</table>

*Holds for numerosity of both dot arrays and tone sequences

Everyone can do:
- 12 vs. 6 = 2.0
- 32 vs 16 = 2.0
- 100 vs 50 = 2.0

6 month olds struggle:
- 12 vs. 8 = 1.5

9 month olds struggle:
- 12 vs. 10 = 1.2

Adults struggle:
- 12 vs. 11 = 1.09

Human infants have a system for approximating numerical magnitudes

Human infants have a system for exact numerosities of very small numbers of objects

- Infants can distinguish a picture with 2 rabbits from a picture with 3 (without counting)
- But so can adult nonhuman primates: they can distinguish 3 from 4 (as good as human adults)
How Many?
Evidence that the 2 number systems are distinct

- The exact system shows a set size limit (that is small)
- The approximate system does not
- The approximate system obeys Weber’s fraction
- The exact system does not: Infants should not be able to distinguish 3 from 2, as the Weber fraction is 1.5

What 2-year-olds cannot do

- Although they know a verbal counting routine, they miss the point that the last number is the cardinal value of the set
- Although they can distinguish 2 fish from 3 fish perceptually and they know the word “two”, they cannot point to the picture with “two fish” upon request
- If you tell them a set contains 8 fish, and then you take 4 away, they will insist that the pile still has 8 fish.
What’s difficult about the meaning of “two”?

- The exact system is a system for representing individuals, NOT sets
- The approximate system is a system for representing the cardinal value of sets, but it is imprecise
- “Two” bridges these two systems because it means a “set of individuals” with an exact cardinal value

...that provides names for exact quantities of any size

1 2 3 4 5 6 ...

Enter human language:
Most languages have an exact number system

- 1, 2, 3, 4, 5, ...
  ...
  ... 1043, 1044, 1045, 1046 ...

How do children learn “two”?

- Must learn that “two” applies just in case the array contains a set composed of:
  - an individual
  - another numerically distinct individual
  - And no further individuals
- It is learned slowly because it requires bridging across systems.
- The learning is motivated by the existence of a word for “two”
How do children learn “three”?

• Roughly the same way

How do children go from “three” to understanding terms for the exact magnitude of any large set?

• From learning “two” and then “three”, they understand…
  – that going from 1 to 2 in the counting routine corresponds to an addition of one individual to the set
  – that going from 2 to 3 in the counting routine corresponds to an addition of one individual to the set

• This provides an opportunity to generalize this discovery to all other steps in the counting routine
  – Every step in the counting routine corresponds to the addition of one individual

• But this generalization requires insight (the existence of a number system in the language is not enough)

Number Words and Counting Routine

<table>
<thead>
<tr>
<th>Age</th>
<th>Understanding of number words and the counting routine</th>
</tr>
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</table>
| 2-2.5 years    | one = “an individual” 
|                | two, three,… = “a set”/ “more than one”                 |
| 2.5-3.25 years | one = “an individual” 
|                | two = “a set of an individual and another individual”   |
|                | three,… = “a set other than two”                        |
| 3.25-3.5 years | one = “an individual” 
|                | two = “a set of an individual and another individual”   |
|                | three = “a set of an individual, another individual, and still another individual” |
|                | four,… = “a set other than two or three”                 |
| 3.5-adult      | set designated by each number word contains “one more individual” than the previous set |

What Makes Humans So Smart?

Possibility #2

• Although the core cognitive systems of humans are the same as those of other animals…

• Language—which is unique to humans—allows humans to combine information from different core systems

• Crucial feature: presence of a vocabulary and syntax for generating exact numbers of any magnitude

• **But: insight may also be required**