Language and the Mind
LING240
Summer Session II, 2005

Lecture #10

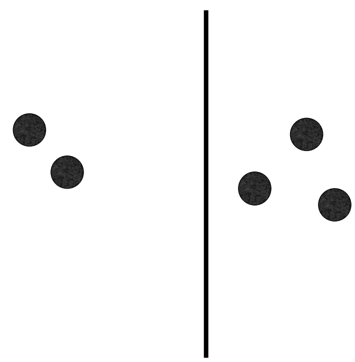
"Smartness" and Number

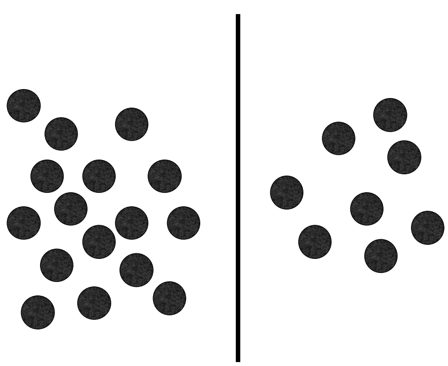
Core Knowledge Systems of Number

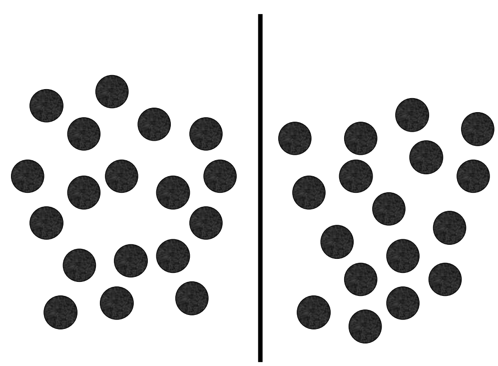
- System for representing approximate numerical magnitudes (large, approximate number sense)
- System for representing persistent, numerically distinct individuals (small, exact number sense)

Uniquely human or no?

More on the left or the 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

Age	Weber fraction
6 months	1.5-2
9 months	1.2-1.5
adult	1.15

<u>Everyone</u> 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

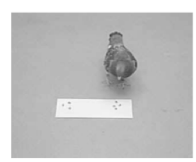
Human infants (*Prelinguistic*)

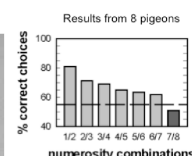
- Have a system for approximating numerical magnitudes

(Dahaene, Gallistel & Gelman)

But…

…so do pigeons, fish, rats, and other primates

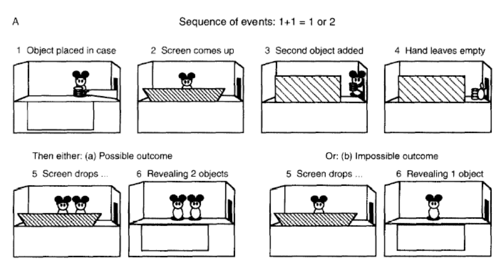




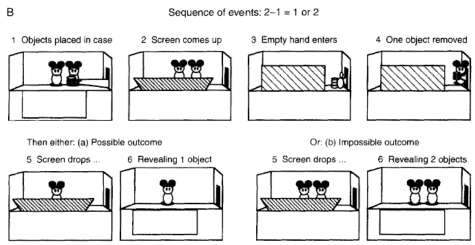
8 vs. 7 = 1.14
7 vs. 6 = 1.16

Human Infants & Small Exact Numerosities

- "Psychological foundations of number: numerical competence in human infants" (Wynn, 1998)
- Test infants with the preferential looking paradigm (logic: infants look longer at something novel)



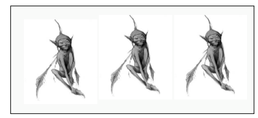
- Infants can do this with objects, number of jumps, duration of jumps - small, exact numerosities of very different things
- Infants doing very basic "addition" operation with these small numerosities



- Infants can do this with objects, number of jumps, duration of jumps - small, exact numerosities of very different things
- Infants doing very basic “subtraction” operation with these small numerosities

So Human Infants (*Prelinguistic)*

- Can represent <u>exact numerosities</u> of very small numbers of objects
- They can distinguish a picture of 2 animals from a picture of 3 without counting

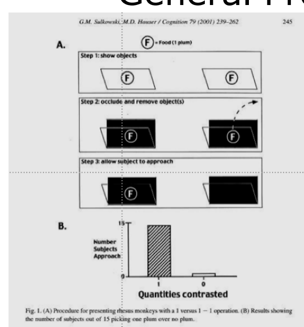


What about nonhuman (*nonlinguistic)* primates & small numerosities?

- “Can rhesus monkeys spontaenously subtract?” - Sulkowski & Hauser, 2001

- Monkeys trained to discriminate between numbers 1-4 were able to discriminate between numbers 1-9 without further training
- Shown to spontaneously represent the numbers 1-3

General Procedure



- General logic: monkeys will go to the platform they think has more food on it

Results

- Monkeys can do simple subtraction (irrespective of objects):

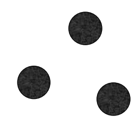
1 - 1 < 1 - 0   3 - 1 > 1 - 0
2 - 1 < 2 - 0 (even with hand waving on this side)
2 - 1 > 1 - 1   3 - 1 > 2 - 1
1 plum + 1 metal nut - 1 metal nut > 1 plum + 1 metal nut - 1 plum
2 plums - 1 plum > 1 metal nut + 1 plum - 1 plum
3 plums - 1 plum > 1 plum + 1 metal nut - 1 plum

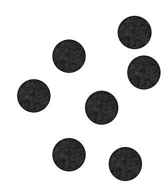
TRANSFERS (Subtraction & Addition)
2 - 1 < 1 + 1   **3 -1 = 1 + 1**
1 - 1 < 0 + 1

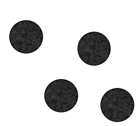
So…

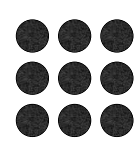
- So nonlinguistict primates are capable of performing arithmetic operations on small, exact numbers
- Also can distinguish 3 from 4, which is as good as human adults

How Many?









Amount Being Represented	How Represented
Very small numbers	"Subitizing"- up to 4; can tell what set looks like
Large approximate numerosities	System for representing approximate numerical magnitudes
Large exact numerosities	Combo of 2 above systems plus language

What human language does…

- Many languages have an *exact* number system that provides names for exact quantities of any size

1, 2, 3, 4, 5…….578, 579, 580, 581, 582…

- This bridges the "gap" between the two core systems

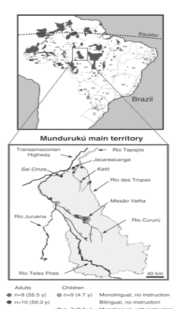
But how do we go about testing this exactly?

Pica, Lemer, Izard & Dehaene (2004)

- "Exact and Approximate Arithmetic in an Amazonian Indigene Group"
- Underlying Idea: "Exact arithmetic would require language, whereas approximation would not."

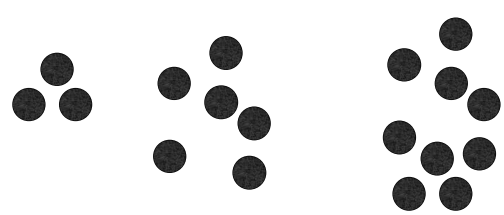
Native Speakers of Munduruku

- Only have words for numbers 1 through 5
- Live in Brazil
- 7000 native speakers
- Some are strictly monolingual
- Others are more bilingual (Portuguese) and better educated



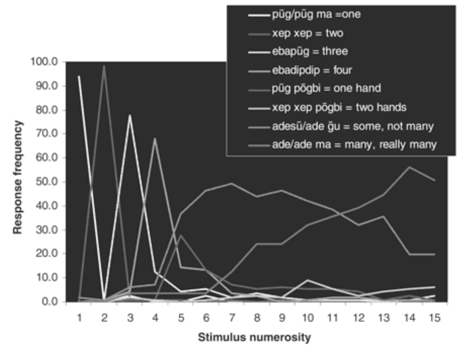
First Task: Exact Numerousities

- How many dots are present?



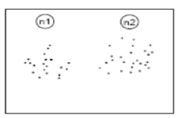
First Task Results

- 5 dots or less
  - They have numbers for 1 through 4
  - 5 = “one hand” or “a handful”
- 6 or more
  - “some”
  - “many”
  - “a small quantity”
  - Attempted precision
    - “more than a handful”
    - “two hands”
    - “some toes”
    - “all the fingers of the hands and then some more” (in response to 13)



Second Task: Approximate Numerousities

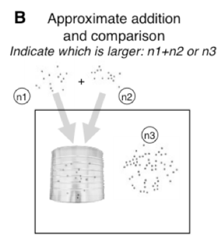
- Shown two groups of 20-80 dots and asked which quantity was larger.



Results:

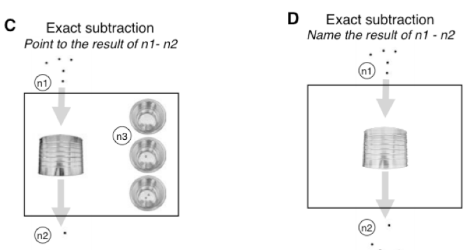
Speakers of Munduruku performed the same as the control group of French speakers. With all groups, performance improved as the ratio between the numbers compared increased.

Third Task: Arithmetic with large approximate numerousities



- Results: Everyone can do this

Fourth Task: Arithmetic with *exact* numbers



- Important: Bigger number outside language number system, but *answer* within

Fourth Task Results

- In both tasks, the Munduruku performed much worse than the control group of French speakers
- But they still performed better than chance

Fourth Task Thoughts

- Best results for Munduruku– when initial number was less than 4
- Results that were higher than chance for an initial number greater than 4 could have been a result of approximate encoding of initial and subtracted quantities

Mundukuru Thoughts

- Language not necessary within core knowledge systems (small exact or large approximate)
- But language seems extraordinarily helpful for bridging them

Gordon (2004) - the Pirahã

- "Numerical Cognition Without Words: Evidence from Amazonia"
- The Pirahã live in the lowlands of the Brazilian Amazon; about 200 people living in small villages of 10-20 people
- Trade goods with surrounding Portuguese without using counting words

Pirahã

Table 1. Use of fingers and number words by Pirahã participant. The arrow (→) indicates a shift from one quantity to the next.

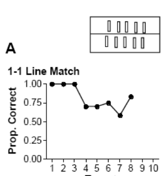
No. of objects	Number word used	No. of fingers
1	hói (= 1)	
2	hoí (= 2)	2
	aibaagi (= many)	
3	hoí (= 2)	3
4	hoí (= 2)	5 → 3
	aibai (= many)	
5	aibaagi (= many)	5
6	aibaagi (= many)	6 → 7
7	hói (= 1)*	1
	aibaagi (= many)	5 → 8
8		5 → 8 → 10
9	aibaagi (= many)	5 → 10
10		5

*This use of "one" might have been a reference to adding one rather than to the whole set of objects.

- 7 participants
- 8 experiments

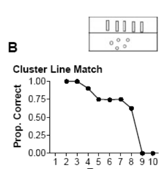
Line Matching Task

- Participants shown a horizontal line of batteries and asked to line up the same number of batteries on their own side



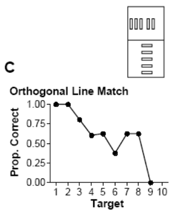
Cluster Matching Task

- Participants shown a cluster of nuts and asked to line up the same number of batteries on their own side



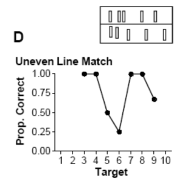
Orthogonal Matching Task

- Participants shown a vertical line of batteries and asked to line up the same number of batteries horizontally on their own side



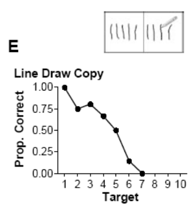
Uneven Line Matching Task

- Participants shown uneven horizontal line of batteries and asked to line up the same number of batteries on their own side



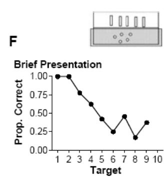
Line Draw Copy Task

- Participants asked to draw the same amount of lines on their own paper



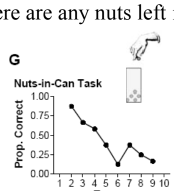
Brief Presentation Matching Task

- Participants shown a cluster of nuts for 1 second and asked to line up the same number of batteries on their own side



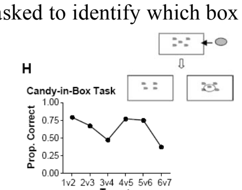
Nuts in a Can Task

- Participants shown a group of nuts for 8 seconds. Then the nuts are placed in a can. The nuts are removed one at a time and the participants are asked after each withdrawal whether or not there are any nuts left in the can.



Candy in a Box Task

- Experimenter puts candy in a box with a given number of fish drawn on the top of the box. The box is then hidden from view. The box is then brought out again along with another box with either one more or one fewer fish painted on the box. Participants asked to identify which box contains the candy.



Pirahã Conclusions

- Exact arithmetic on larger numbers that are both outside the small, exact system and outside the language is very, very hard to do

Interesting Pirahã Anecdote: Some Restriction In *Learning* To Count

"They wanted to learn this [counting] because they… wanted to be able to tell if they were being cheated (or so they told us). After eight months of daily efforts, without ever needing to call the Pirahãs to come for class (all meetings were started by them with much enthusiasm), the people concluded that they could not learn this material and the classes were abandoned. Not one Pirahã learned to count to ten in eight months. None learned to add 3+1 or even 1+1 (if regularly responding '2' to the latter of is evidence of learning – only occasionally would some get the right answer.)"

-Daniel Everett, "Cultural Constraints on Grammar and Cognition in Pirahã: Another Look at the *Design Features* of Human Language"

Gelman & Gallistel (2004) "Language and the Origin of Numerical Concepts"

"Reports of subjects who appear indifferent to exact numerical quality even for small numbers, and who also do not count verbally, add weight to the idea that learning a communicable number notation with exact numerical reference may play a role in the emergence of a fully formed conception of number."

So where are we with Whorf? "Language *Determines* Thought"

non-linguistic humans
• have **small exact** & **large approximate** representation & **can do arithmetic** (Wynn 1998)

non-humans
• have **small exact** representation and **can do arithmetic** on such small exact representations (Sulkowski & Hauser 2001)

humans without specific number language
• have **small exact** & **large approximate** representation and **can do arithmetic within** these domains **but *not* "across"** them (Gordon 2004, Pica et al. 2004)

So where are we with Whorf? "Language *Determines* Thought"

✗ • No language for <u>small exact numbers</u> = no representation for <u>small exact numbers</u>

✗ • No language for <u>large approximate numbers</u> = no representation for <u>large approximate numbers</u>

✗ • No language for <u>arithmetic operations</u> = no representation of/ability to do <u>arithmetic operations</u>

✓ • No language for **<u>large exact numbers</u>** = representation for **<u>large exact numbers</u>**

BRIDGING THE GAP between two core knowledge systems = Neo-Whorfian View (Language as Toolkit)