Ling 51/Psych 56L:
Acquisition of Language

Lecture 15

Language & Cognition

Announcements

Review questions available for language and cognition

Be working on HW6 [due 11/29/16]

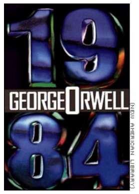
Remember to do the extra credit

Please fill out course evaluations for this class

Sapir-Whorf hypothesis

The structure of one's language influences the manner in which one perceives and understands the world.

"Don't you see that the whole aim of Newspeak is to narrow the range of thought? In the end, we shall make thought crime literally impossible, because there will be no words in which to express it…" - George Orwell, *1984*



Sapir-Whorf hypothesis

Modern example: "Could how you speak about time, could how your language forces you to think about time, affect your propensity to behave across time?" — Chen 2012, http://www.ted.com/talks/keith_chen_could_your_language_affect_your_ability_to_save_money

~5:03 - 5:50

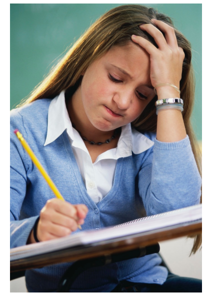
“Neo”-Whorfian question

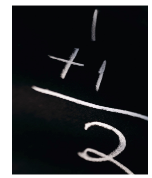
Language as a Toolkit: Does language augment our capacity for reasoning and representation (and thereby determine our perception of the world)?

Also sometimes referred to as “language as augmenter” (Wolff & Holmes 2010)

What the language toolkit can do

Language is a symbolic system that can help with cognitive off-loading.





Cognitive off-loading example (from Wolff & Holmes 2010)

FIGURE 3 | Series of gears in which the first turns clockwise. In which direction will the last gear turn?

“This problem could be solved by mental simulation; that is, by imagining the first gear turning to the right, then the second gear turning to the left, and so on. Alternatively, people might notice that each successive gear turns in the opposite direction from the previous one and generate the parity rule that ‘odd and even gears turn in different directions’. This rule, which may depend on linguistic coding, can then be applied more quickly than the laborious process of mentally rotating each gear.”

Language as a toolkit

Today:

Theory of Mind (realizing that someone can have a different point of view than you - when does this realization come, and how?)

Extra Material (*not required*):

Navigation (combining core knowledge system information)

→ geometric + landmark or color information

Number (combining core knowledge system information)

→ small, exact numbers & large, approximate numbers

Theory of mind

Theory of mind

"I know you think you understand what you thought I said, but I'm not sure you realize that what you heard is not what I meant."
— Alan Greenspan

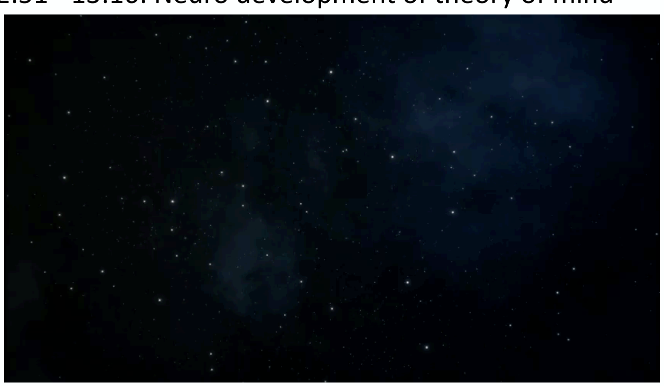
Theory of mind

https://www.ted.com/talks/rebecca_saxe_how_brains_make_moral_judgments?language=

3:28 - 3:52: Development of theory of mind

7:19 - 8:14: Neuro bases of theory of mind

12:51 - 13:16: Neuro development of theory of mind



sentential complement

Sarah thought that Hoggle had betrayed her.

The embedded sentence (also called a sentential complement here) encodes the contents of Sarah's mind.

The 'truth value' of the embedded sentence cannot be evaluated with respect to this world. It must be evaluated with respect to Sarah's mental world (what Sarah thinks).

What if a child didn't know this?

What you need to know to evaluate the truth value of these statements

Syntactic Knowledge: you know that some verbs (*think*, *believe*, *say*, …) can take sentential complements

Social Cognitive Knowledge: you know that other people can have a false belief

Bridge: you know that there is a connection between this syntactic form and the expression of potentially false beliefs

Which comes first, social or syntactic knowledge?
- Usual Pattern: Social/Conceptual ---> Linguistic
- Whorfian: Linguistic ---> Social/Conceptual

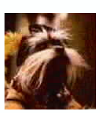
A little problem…

How do you measure children's understanding that other people can have false beliefs?

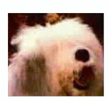
(abstracted away from their linguistic ability to represent false beliefs)

False belief task (Unseen displacement)

The child is introduced to two puppets, Sir Didymus and Ambrosius.



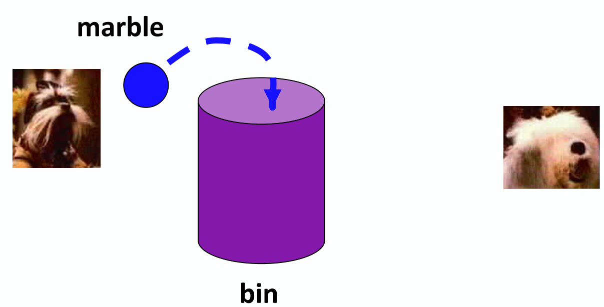
Sir Didymus



Ambrosius

False belief task (Unseen displacement)

While playing, Sir Didymus puts a marble into a bin and then goes outside (the puppet disappears under the table, for example).



False belief task (Unseen displacement)

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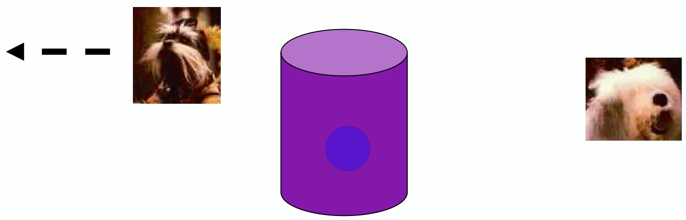
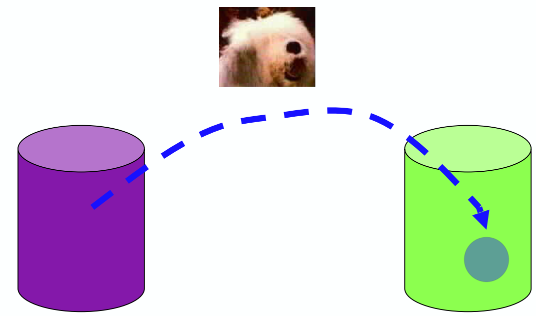


False belief task (Unseen displacement)

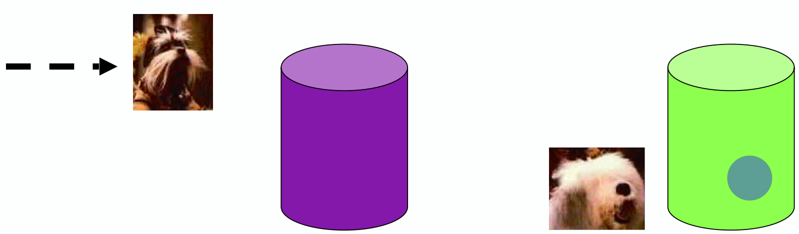
When Sir Didymus is not around, naughty Ambrosius changes the location of the marble. He takes it out of the bin and puts it in a different bin.



False belief task (Unseen displacement)

Some time later Sir Didymus comes back and wants to play with his marble. Children are then asked the critical question:

Where will Sir Didymus look for his marble?



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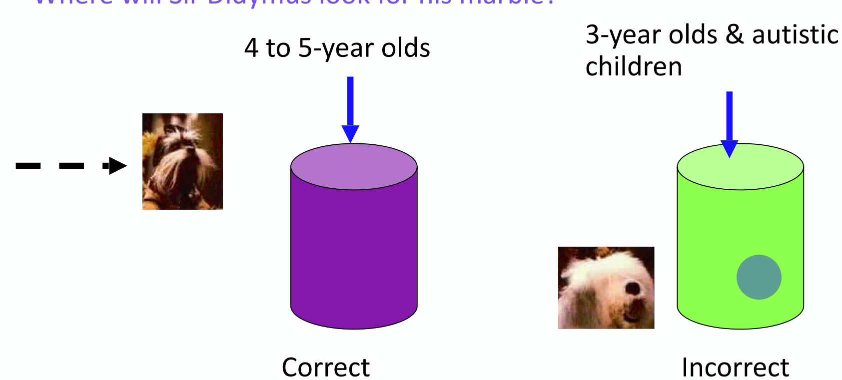


False belief task (Unseen displacement)

https://www.ted.com/talks/rebecca_saxe_how_brains_make_moral_judgments?language=

3:52 - 6:15: False belief task with 5-year-old vs. 3-year-old

False belief task (Unexpected Contents)

http://www.youtube.com/watch?v=8hLubgpY2_w

If we're looking for a language connection… [Extra]

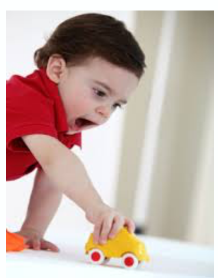
http://www.sciencedaily.com/releases/2015/07/150727095915.htm

About Kirk, Pine, Wheatley, Howlett, Schulz, & Fletcher 2015:

"…children's ability to understand the thoughts of other people when they were aged 5 was related to how mind-minded their mothers were when they were babies."

Mind-minded: Using language to label child's thought processes

Ex: If a child had difficulty with opening a door on a toy car, infant could be labeled as 'frustrated'.



If we're looking for a language connection…

At what age do children start talking about thoughts/beliefs? At what age do children first begin to use sentential complements?

2-year-olds talk a lot!

... about what they did, what they want

... about what others do

... possibly about what others say

– not about what others think

If we're looking for a language connection…

At what age do children start talking about thoughts/beliefs? At what age do children first begin to use sentential complements?

Children's comprehension of sentential complements

"Sir Didymus said he bought peaches. But look! He really bought oranges. What did Sir Didymus say he bought?"

3-year-olds: oranges (reality, not mental state)

4-year-olds: peaches (key into "*say that*")

If we're looking for a language connection…

At what age do children start talking about thoughts/beliefs? At what age do children first begin to use sentential complements?

At around four years of age, children understand that mental verbs can take a whole sentence as their object (a complement)

Sir Didymus thought that the shampoo was the toothpaste.

And the embedded sentence can be FALSE from the child's point of view, but TRUE for Sir Didymus.

Once the child has this capacity, he can represent two worlds: his own, and someone else's mental world.

This usually coincides with children's production of mental state verbs.

Testing typically developing children

De Villiers & Pyers 2002: Measures of comprehension and production of sentential complements far more correlated with children's performance on false belief tasks than any other linguistic measure.

Causation? Unclear.

"In every case, children who passed false beliefs gave us evidence that they had productive command of complementation."

How exactly do children learn that connection? One idea

- Difficult to observe: someone else's thoughts
- Easier to observe: what people say

  "She said that she ate the peach."

- Children will sometimes hear sentences like this in a context where there is overt evidence to suggest that the embedded proposition is false.
- Children can use evidence from verbs like *say* to generalize to verbs like *think* and *believe*

How exactly do children learn that connection? One idea

- Syntactic Knowledge: you know that some verbs can take sentential complements
- Bridge: you know from hearing communication verbs and from observing the world while hearing them that there is a connection between this syntactic form and the expression of potentially false propositions.
- Having learned this connection from communication verbs, you then generalize that since mental verbs also take sentential complements, their sentential complements must also potentially be false.
- Social Cognitive Result: Therefore you can contemplate other (mental) worlds.

Testing the connection in other ways and in other populations

What if you train children on communication verbs that take sentential complements? Do they improve on false belief tasks?

What if you make children use mental state verbs that take sentential complements? Do they improve on false belief tasks?

Test development in deaf children who are language-delayed vs. not

Test other primates (who are non-verbal)

Training children on communication verbs

Hale & Tager-Flusberg 2003: Children who were trained on sentential complements *("say that…")* did well on both sentential complement tests and false belief tasks. However, children trained only on false belief tasks also did well on false belief tasks.

Implication: Sentential complements not required, just extraordinarily helpful.

Making children use mental state verbs

Ornaghi, Brockmeier, & Grazzani Gavazzi 2011: During a 2-month period of intervention, children were read stories enriched with mental lexicon items. After listening to a story, the experimental group took part in language games and conversations aimed at stimulating children to use mental terms. Four-year-olds improved on false belief understanding - even though they hadn't been trained on false belief tasks. However, the control group also improved (just not as much).

Familiar Implication: Mental state verbs can be helpful for thinking about false beliefs, but they're not necessarily required.

Testing deaf children (delayed vs. non-delayed language)

de Villiers & de Villiers 2003: Oral deaf children (who are language-delayed) with normal IQ and active social intelligence are significantly delayed in false belief tasks. Performance on both verbal and non-verbal false belief tasks are delayed to the same degree. Best predicted by sentential complement production with verbs of communication or mental state, not just by general language ability.

Implication?: Language (specifically sentential complements) required for success on false belief tasks. (Maybe no one trained them explicitly on false belief tasks?)

Testing deaf children (delayed vs. non-delayed language)

Pyers & Senghas 2009: Tested two groups of learners of Nicaraguan Sign Language (NSL).

Group 1 (older): Learned an early form of NSL

Group 2 (younger): Learned a later form of NSL

Main difference: Group 2 knew many more signs for mental state verbs like *think* and *know* than Group 1

Results: Group 2 did much better on false belief tasks than Group 1, despite being younger.

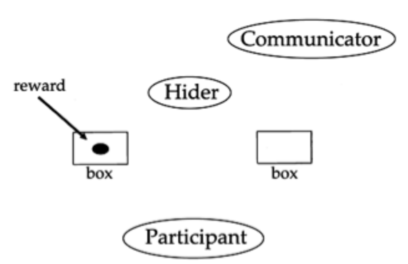
Implication?: Language (specifically mental state verbs that take sentential complements) required for success on false belief tasks. (Maybe no one trained them explicitly on false belief tasks?)

Testing other primates (who are non-verbal)

Call & Tomasello 1999: Used the same test for both children and great apes (though the great apes needed many more trials)

<u>Main Test:</u>

Communicator watches the Hider hide a reward in one of two containers and then leaves the room. The Hider switches the containers. The communicator returns and indicates which container has the reward. Participants are asked to locate the reward.

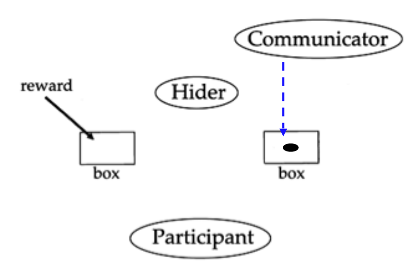


Testing other primates (who are non-verbal)

Call & Tomasello 1999: Made sure to check competency in skills needed to successfully perform the task (other than understanding of false belief)

<u>Understanding of Indication</u>
Behind barrier, Communicator watches Hider place reward in bucket. Communicator indicates bucket to participants.

(Do you understand that the Communicator picks out the location of the reward?)



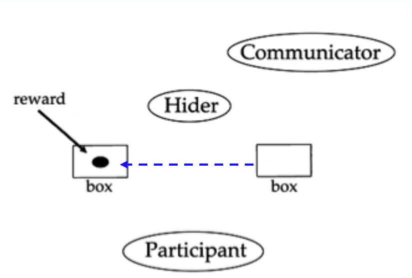
Testing other primates (who are non-verbal)

Call & Tomasello 1999: Made sure to check competency in skills needed to successfully perform the task (other than understanding of false belief)

Visible Displacement

Communicator indicates reward's location. Hider opens the container and moves the reward.

(Do you understand that the reward moves?)



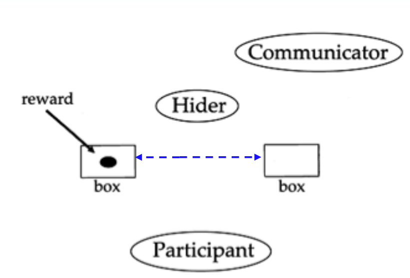
Testing other primates (who are non-verbal)

Call & Tomasello 1999: Made sure to check competency in skills needed to successfully perform the task (other than understanding of false belief)

Invisible Displacement

Same as visible but containers are switched and participants do not see the object

(Do you understand that the containers can switch places, and that means what's in them switches places, too?)



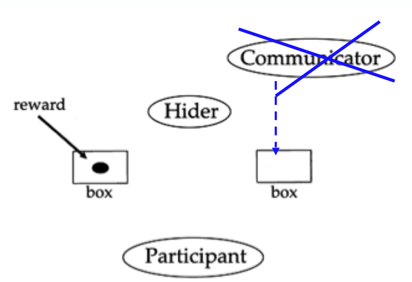
Testing other primates (who are non-verbal)

Call & Tomasello 1999: Made sure to check competency in skills needed to successfully perform the task (other than understanding of false belief)

Ignoring Communicator

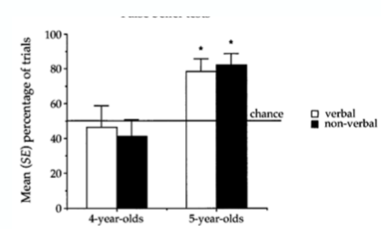
Hider hides reward. Communicator leaves. Hider switches buckets. Communicator returns and indicates bucket with reward (the wrong container)

(Do you understand the communicator can be ignored, because he may not be right?)



Testing other primates (who are non-verbal)

Call & Tomasello 1999: Children do the same on the standard verbal task and this non-verbal equivalent. (Though it takes a five-year-old to pass.)



Testing other primates (who are non-verbal)

Call & Tomasello 1999: Great apes fail spectacularly, even though they pass all the preliminary control tasks.

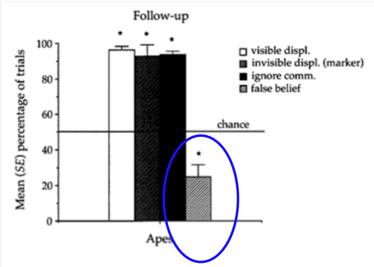


Figure 6 Mean (SE) percentage of correct trials in the three modified control tests and the false belief test during the follow up phase. * $p < .01$.

Implication: Having language (or a language-enabled brain) seems necessary. (Though maybe no one trained the apes on false belief tasks?)

Testing other primates (who are non-verbal)

[Extra]

Call & Tomasello 1999: Great apes fail spectacularly, even though they pass all the preliminary control tasks.

Ciraolo, O'Hanlon, & Doumas 2014: "…the capacity for relational reasoning can explain the differences in task performance between apes and human children, as well as the developmental trends observed in 4- and 5-year-old children."

Relational reasoning = reasoning about some object based on the role that it plays rather than its physical features alone.

Note: Relational reasoning may be helped by having language (cognitive off-loading), but doesn't require language to do.

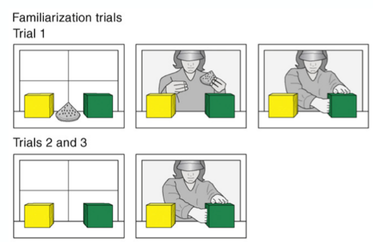
Theory of mind: Link to language is…?

Additional evidence from Baillargeon, Scott, & He 2010:

2-year-olds can pass a false belief task when they are tested indirectly. How do we test them indirectly? We can gauge their spontaneous responses (as assessed by looking time) to events they are shown. Baillargeon et al. 2010 argue that this is an easier task than requiring the children to answer a question directly using language.

Familiar implication: Language is extraordinarily helpful but not explicitly required.

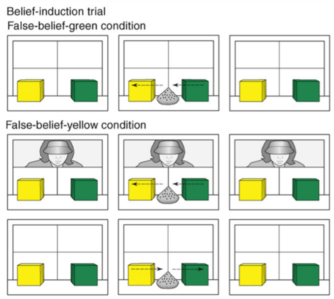
Baillargeon, Scott, & He 2010



Familiarization:

In trial 1, a toy stood between a yellow and a green box; a female agent entered the apparatus, played with the toy briefly, hid it inside the green box, and then paused, with her hand inside the green box, until the trial ended. In trials 2 and 3, the agent reached inside the green box, as though to grasp her toy, and then paused.

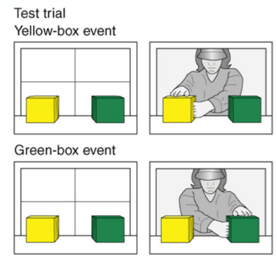
Baillargeon, Scott, & He 2010



Belief Induction:

In the belief-induction trial, the toy either moved from the green to the yellow box in the agent's absence (false-belief-green condition) or moved to the yellow box in the agent's presence but then returned to the green box after she left (false-belief-yellow condition).

Baillargeon, Scott, & He 2010

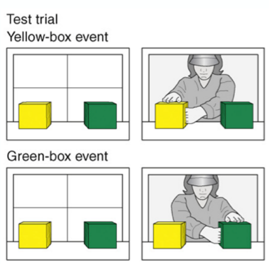


Testing:

In the test trial, the agent returned, reached inside either the yellow box (yellow-box event) or the green box (green-box event), and then paused.

In each condition, the infants expected the agent to reach where she falsely believed the toy to be hidden, and they looked reliably longer when she reached to the other location instead.

False belief younger than two



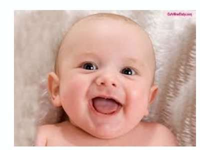
Onishi & Baillargeon 2005:
This same procedure showed that 15-month-olds have similar expectations and reactions.

Baillargeon et al. 2016: Many more examples of children under two demonstrating understanding of false beliefs in "spontaneous-response" tasks like this.

False belief younger than two

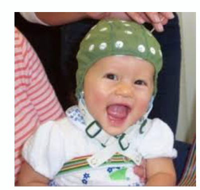
Kovács et al. 2010, Luo et al. 2009, Luo 2011a:

6- and 7-month-olds behave as if they understand other agents can have false beliefs (looking-time tasks)



Southgate & Vernetti 2014: EEG evidence from 6-month-olds

Compared to a baseline period, infants showed motor activation when an agent falsely believed a box contained a ball, but they showed no motor activation when the agent falsely believed the box contained no ball. Infants thus anticipated that the agent would search for the ball when she falsely believed it was present, but not when she falsely believed it was absent.



Indirect verbal false belief tasks at 2

Additional evidence from He et al. 2011, He et al. 2012, Scott et al. 2012: 2-year-olds can pass a *verbal* false belief task when they are tested indirectly. How do we test them indirectly but still verbally?

One way (Scott et al. 2012): Children watched a typical direct false belief scene along with an adult "subject" who was then asked where one character would look for her toy when she returned (Scott et al. 2012). Children looked longer when the adult "subject" responded incorrectly and pointed to the toy's current as opposed to original location.

Theory of mind: Link to language is…?

Language is useful for cognitive off-loading? Perhaps when children are tested directly on false belief tasks (that is, required to show their knowledge with language), having mental state verbs in their linguistic repertoire allows them to easily encode what's going on. Then, it's easier to do the task, which requires more mental work than tasks where children are tested indirectly.

But the jury is still out…(remember that the great apes were tested without language, as were the four- and five-year-olds in the Call & Tomasello 1999 study).

Theory of mind: Link to language is…?

Another idea (Lewis, Hacquard, & Lidz 2012): We often use mental state verbs (especially *think*) to indicate how certain we are about something (sometimes this is called a parenthetical endorsement).

Where did Lily go?

Lily is in the forest, I think.

Who stole the bracelet?

Hoggle thinks that Sarah is the thief.

Studies of children's spontaneous utterances suggest that this is the most common way children under age 4 use mental state verbs.

Theory of mind: Link to language is…?

Lewis, Hacquard, & Lidz 2012: Notably, in parenthetical endorsements, the complement is the focus of the communication, and is usually assumed to be true (to some degree).

Where did Lily go?

Lily is in the forest, I think.

Who stole the bracelet?

Hoggle thinks that Sarah is the thief.

Theory of mind: Link to language is…?

Lewis, Hacquard, & Lidz 2012: Children could assume in standard false belief tasks that the mental state verbs are being used as parenthetical endorsements.

Where did Lily go?

Lily is in the forest, I think.

Who stole the bracelet?

Hoggle thinks that Sarah is the thief.

In that case, it makes sense to assume the sentential complement is true (to some degree) – which is precisely how to fail a standard false belief task (where the complement is false, by design).

Theory of mind: Link to language is…?

Lewis, Hacquard, & Lidz 2012: This would mean that if children are made aware that the beliefs themselves are being questioned (which is what the mental state verbs refer to), they should do better at passing false belief tasks.

What does Hoggle think?

Hoggle thinks that Sarah is the thief.

Theory of mind: Link to language is…?

Lewis, Hacquard, & Lidz 2012: This is precisely what Lewis et al (2012) found when they tested 4-year-olds. 4-year-olds improved their performance 44% when the belief (of the characters in the story) was made more salient.

What does Hoggle think?

Hoggle thinks that Sarah is the thief.

Theory of mind: Link to language is…?

Lewis, Hacquard, & Lidz 2012: This suggests that young children know quite a bit about how to use language to encode mental states of others – it's just that they have difficulty adjusting to atypical uses of mental state verbs. (Remember: Most of the time, 4-year-olds use them as parenthetical endorsements, not as literal statements of belief. Some false belief tasks test children explicitly with the literal statement of belief.)

Who took the bracelet?

Hoggle thinks that Sarah is the thief.

parenthetical endorsement:

Sarah is the thief = TRUE to some degree.

Reasonable response: *Yeah, I think so too.*

Theory of mind: Link to language is…?

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What is Hoggle thinking?

Hoggle thinks that Sarah is the thief.

literal statement of belief:

Sarah is the thief = UNKNOWN.

Reasonable response: *Yeah, he often thinks that.*

Theory of mind: Link to language is…?

Evidence that language is necessary for adults to pass false belief tasks:

Verbal shadowing: A technique that interrupts subconscious use of language for cognitive off-loading.

Newton & de Villiers 2007:

Adults doing verbal shadowing fail false belief tasks, but adults doing rhythm shadowing can still pass them. This suggests adults unconsciously rely on language when reasoning about theory of mind.

Theory of mind: Link to language is…?

Evidence that language isn't always so necessary for adults to pass false belief tasks – it may have more to do with working memory:

Dungan & Saxe 2012:

When the verbal and rhythm shadowing are matched with respect to their demands on working memory, adults struggle to pass false belief tasks no matter which kind of shadowing they're doing.

Theory of mind: Links to executive function

Executive function (a set of cognitive processes that regulate, control and manage other cognitive processes, including inhibition, working memory, cognitive flexibility, and planning) has been shown to correlate with children's performance on theory of mind tasks (Carlson, Koenig, & Harms 2013).

Idea (discussed more thoroughly in Bradford, Jentzsch, & Gomez 2015): Children must be able to suppress their own internal representations of events (inhibition of their own perspectives) before they can reflect accurately about the mental states of others.

Theory of mind: Links to executive function

Executive function (a set of cognitive processes that regulate, control and manage other cognitive processes, including inhibition, working memory, cognitive flexibility, and planning) has been shown to correlate with children's performance on theory of mind tasks (Carlson, Koenig, & Harms 2013).

Specific evidence:
(1) Training studies of executive function lead to improved false belief performance (Kloo & Perner 2003).

(2) Individual differences in executive function predict the extent to which children benefit from direct theory of mind training (Benson et al. 2013) - children with higher executive function benefit more

Language & cognition: Recap

Neo-Whorfianism is a variant of Whorfianism that believes language augments thought, so we can think more complex thoughts.

For theory of mind, we have seen evidence for cases where language seems to enable more complex thought - or at least to enable it to happen more easily.

It seems in many cases that language is like a hammer – it's a really good tool (and probably better than a shoe) for getting the (cognitive) job done. But that doesn't necessarily mean the job can't get done without it.

Questions?

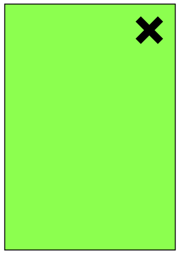
You should be able to answer all the questions on the language & cognition review questions, and all the questions on HW6.

Extra Material

Navigation

Geometric

"At the northeast corner"



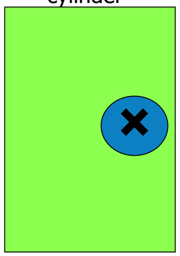
*rats

*human infants

*adult humans

(Object) Landmark

"At the (blue) cylinder"



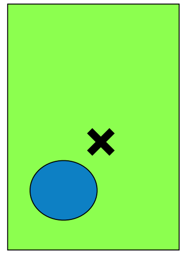
*rats

*human infants

*adult humans

Combination

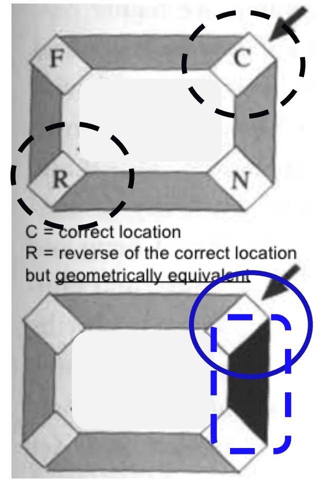
"Northeast of the (blue) cylinder"



?????

Navigation

Toddlers can find it here.



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.

Toddlers can't find it here by combining cues.

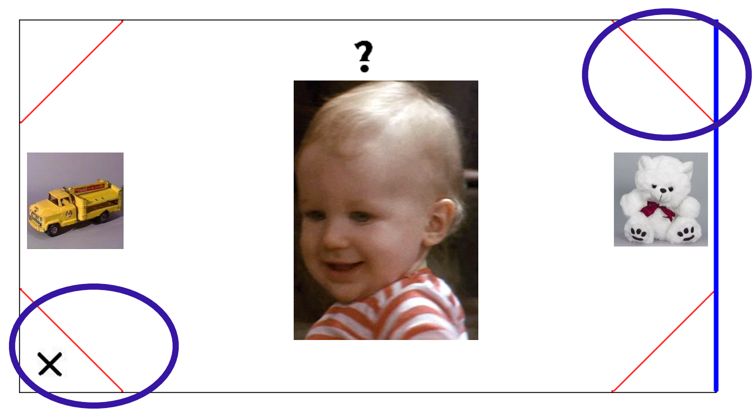
But can toddlers *really* not do it?

Maybe wall color just isn't a very salient property for toddlers. How about trying more salient landmarks? (Hermer & Spelke 1996)

"Left of the truck"?

But can toddlers *really* not do it?

Maybe wall color just isn't a very salient property for toddlers. How about trying more salient landmarks? (Hermer & Spelke 1996)



No change in navigation behavior in toddlers even with more salient landmarks (toys like truck and teddy bear).

So when does this ability develop?

Hermer-Vazquez, Moffet & Munkholm 2001: children with a high production of spatial language (like “left” and “right”) succeed. This usually happens somewhere between 4 and 5 years old.

Shusterman, Lee, & Spelke 2011: 4-year-old children can combine spatial and landmark cues when specifically told a landmark will be useful for navigation. (Ex: “The black wall can help you get the sticker.”)

Hyde, Winkler-Rhoades, Lee, Izard, Shapiro, & Spelke 2011: a 13-year-old deaf child, deprived of most linguistic input after late infancy, performs like toddlers do (very poor when cues must be combined to solve navigation).

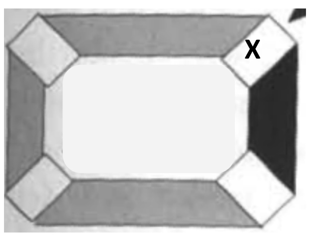
So when does this ability develop?

Implication: Language use seems integral in solving this task that requires representing information from different domains (geometry & color). Children can be prompted through language to pay attention to it, but without language, it seems difficult for humans to solve these kind of tasks.

Is language really responsible?

Hermer-Vazquez, Spelke & Katnelson 1999

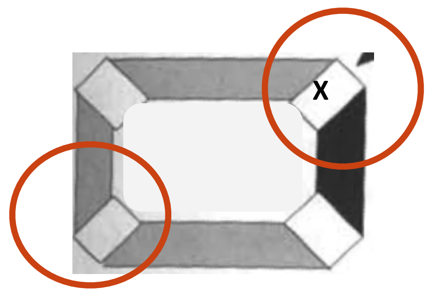
Testing adults, who were asked to verbally shadow as they performed the task. Verbal shadowing (language as meddler: Wolff & Holmes 2010) = repeating as fast as they could a passage recorded on tape. Interferes with linguistic combination abilities. [Class demo of verbal shadowing: repeat a passage while imagining that you’re giving precise directions from here to the student union.]



Is language really responsible?

Hermer-Vazquez, Spelke & Katnelson 1999

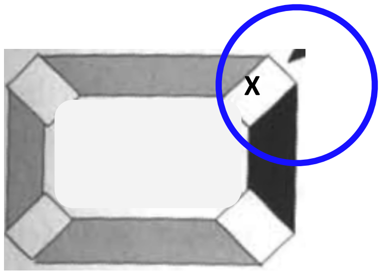
Verbal-shadowing adults behaved just like toddlers! They searched equally the correct corner and the rotationally equivalent one, seemingly unable to combine the information from geometry and color.



Is language really responsible?

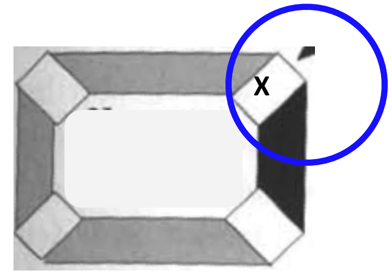
Hermer-Vazquez, Spelke & Katnelson 1999

Experiments with adults who were doing nonverbal shadowing (repeating a rhythm by clapping) did not show this result, despite the fact that the nonverbal shadowing (rhythm shadowing in this case) is as cognitively taxing as verbal shadowing. [Class demo of rhythm shadowing: repeat the clapping pattern while imagining that you're giving precise directions from here to the student center.]



Is language really *necessary*?

Rats (who don't have spatial language) can be trained to combine cues in the navigation task, though only after hundreds of trials. Language is useful (speeds things up), but not necessary?



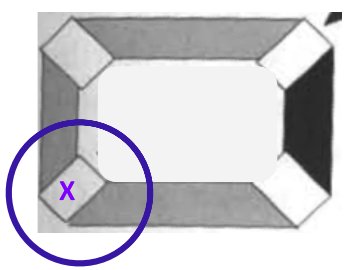
Is language really *necessary*?

Gouteux, Thinus-Blanc, & Vauclair 2001: testing Rhesus monkeys (who do not have spatial language)

Tested 3 monkeys on location "left of wall opposite the blue wall".
~50 trials each.

Two monkeys: ~85% correct
Other monkey: ~70% correct

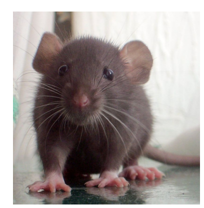
Pretty good for no spatial language!

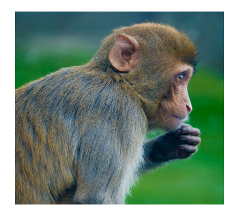


Is language really *necessary*?

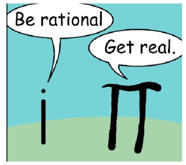
So language *does* seem to play a very important role in the ability to combine information from different core knowledge systems. (Perhaps not absolutely necessary, but extraordinarily helpful - kind of like motherese for language development.)

Or maybe rats and rhesus monkeys are just clever enough to do this without the spatial language that humans seem to rely on. Maybe humans rely on language because they have it as a tool at their disposal…





Number



5

1, 2, 3, 4, 5, 6....

6

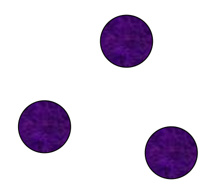
Number

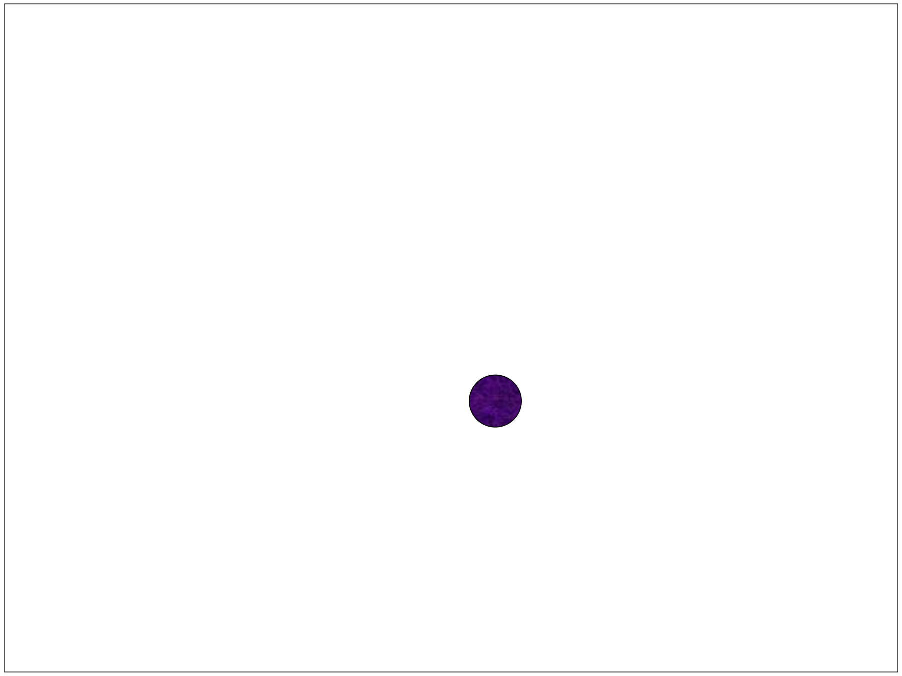
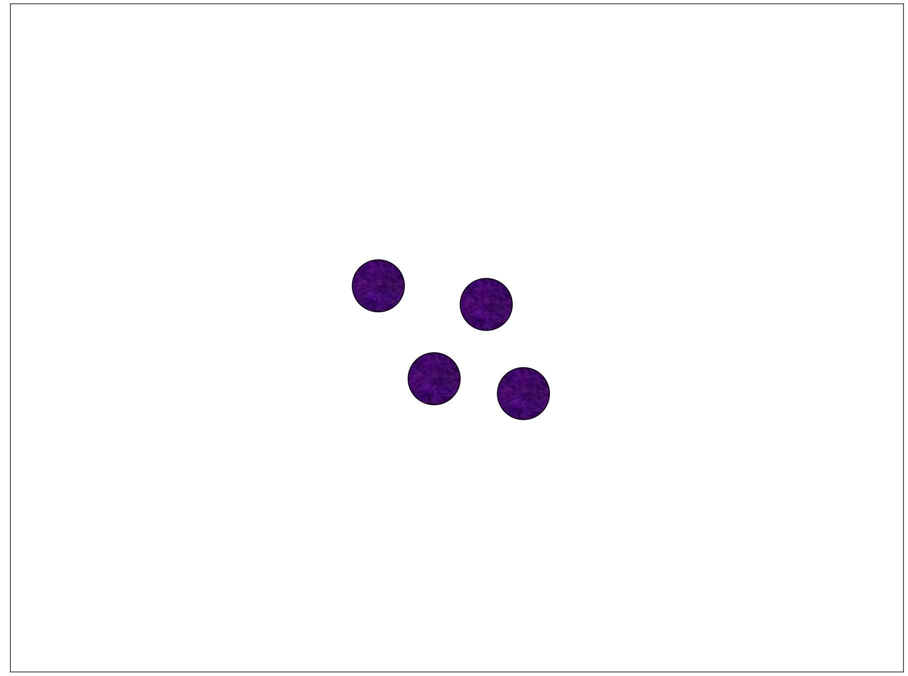
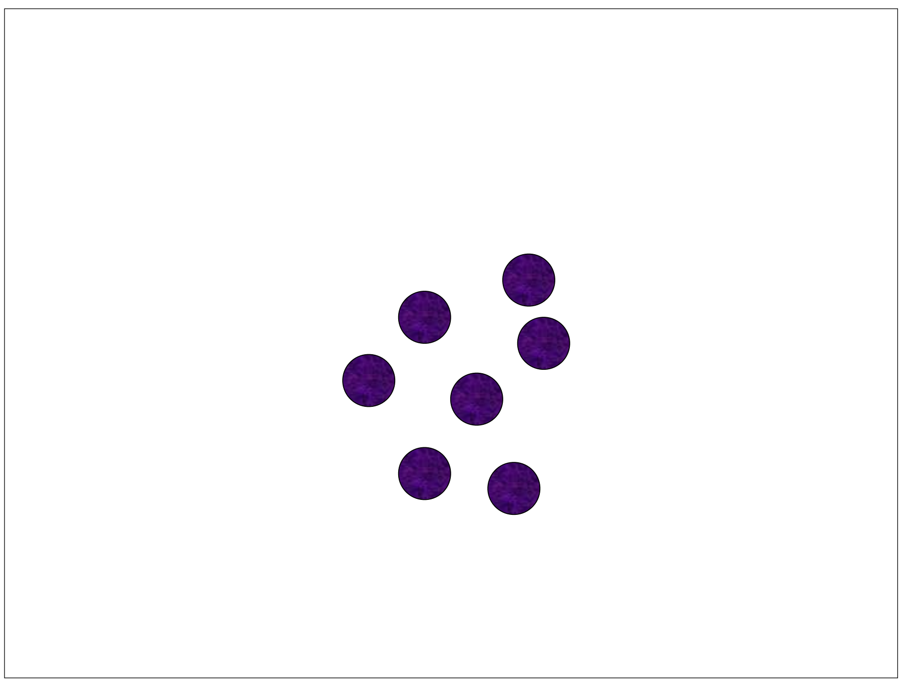
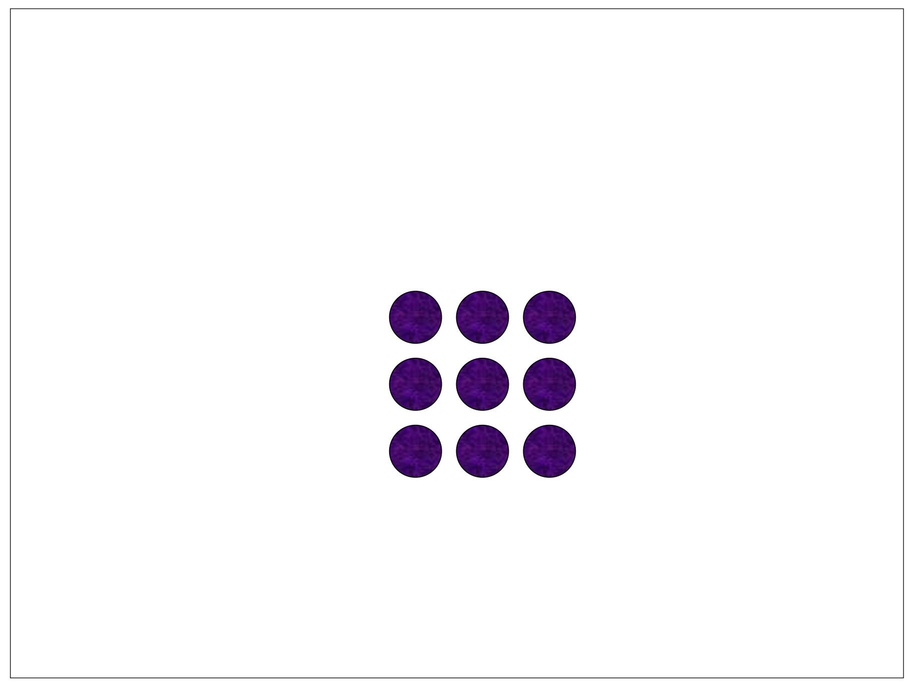
Core number systems shared by humans and other animals:

System for representing approximate numerical magnitudes
(large, approximate number sense)

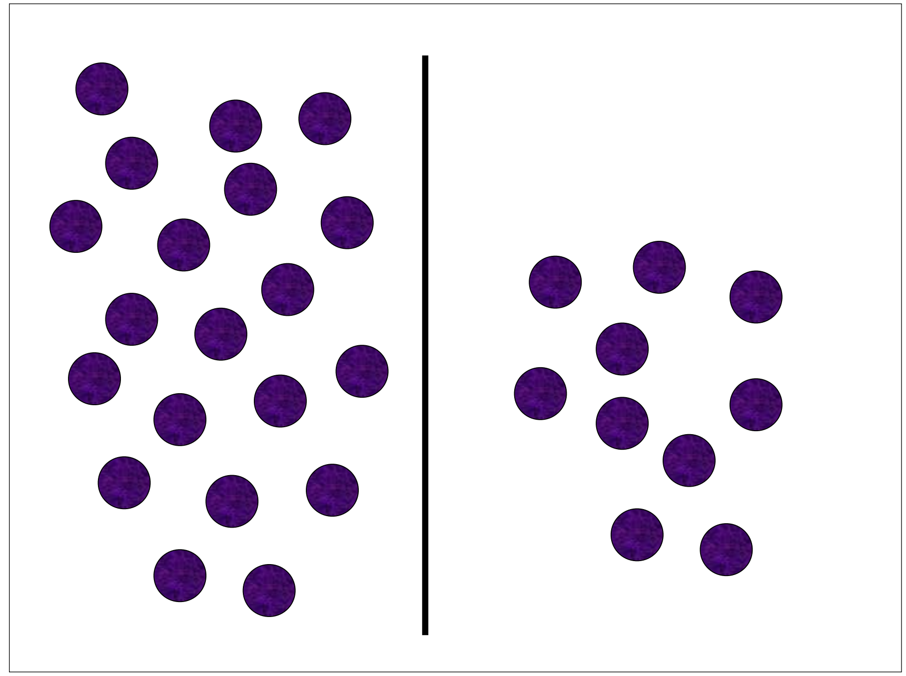
System for representing persistent, numerically distinct individuals
(small, exact number sense)

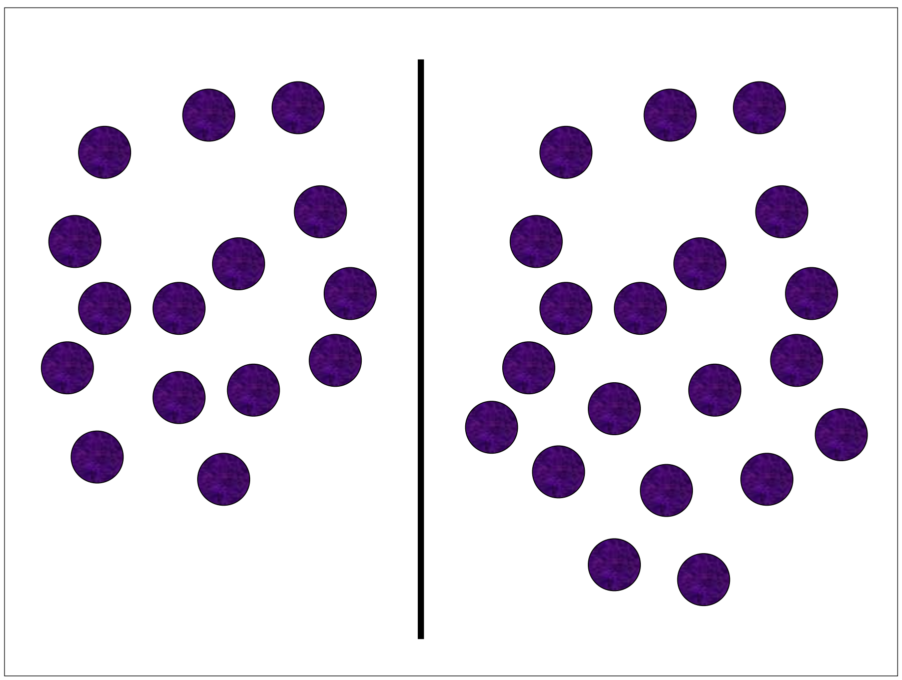
Decide fast:
How many?

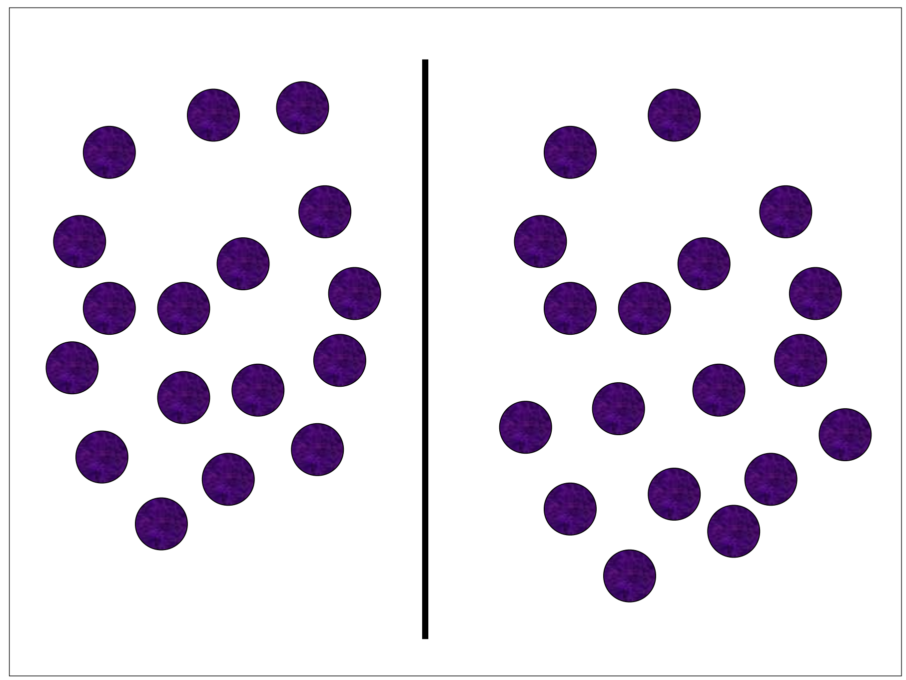


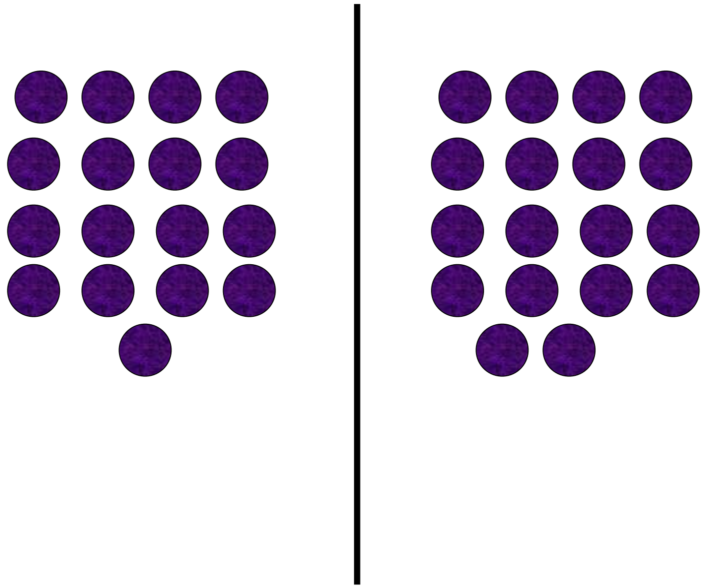





Decide fast:
Which side has more?







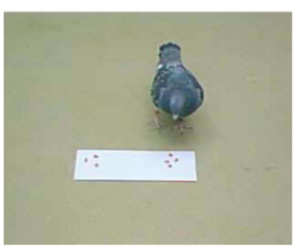


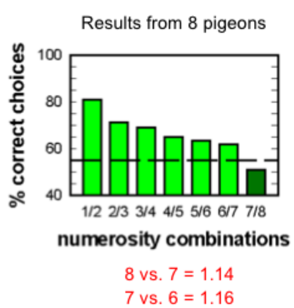
How we deal with number

Amount being represented	How represented
Very small numbers	"Subitizing"- up to 4; can tell what set looks like at a glance
Large approximate numerosities	System for representing approximate numerical magnitudes (adults at a glance can tell apart groups with a
Large exact numerosities	Combination of above systems plus language

A number sense in general isn't special

Prelinguistic infants have a system for approximating numerical magnitudes (Dehaene 1997, Gallistel & Gelman 2000), but so do pigeons, rats, fish, and other primates.





Weber Fraction Limit
for telling apart large numerosities

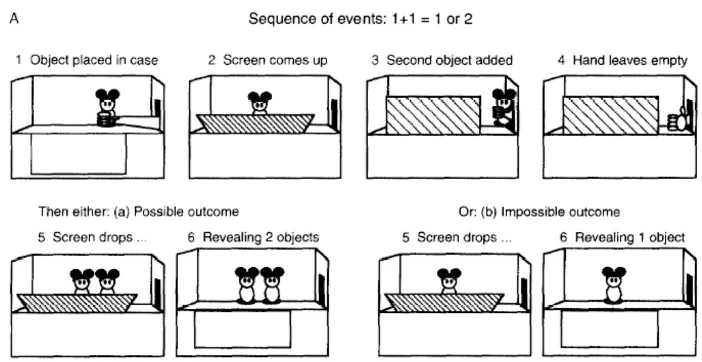
Age	Weber fraction
6 months	1.5-2
9 months	1.2-1.5
adult	1.15

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

What about small numbers?

Wynn 1998:

Testing infant knowledge using a preferential looking paradigm. Infants are surprised by the "impossible" outcome, which means they can do addition on very small numerosities precisely.



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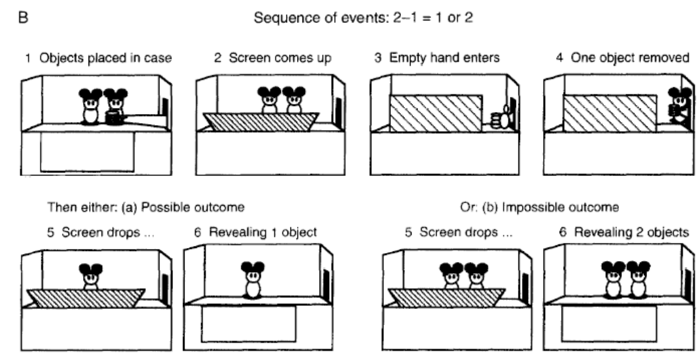


What about small numbers?

Sulkowski & Hauser 2001: Monkeys can, too

- Rhesus monkeys shown to spontaneously represent the numbers 1-3
- Test monkeys by using a procedure predicated on monkeys going to where they think food is

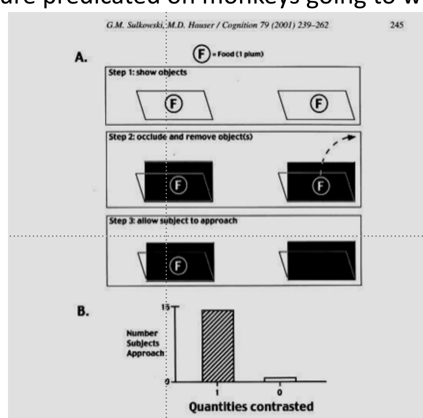
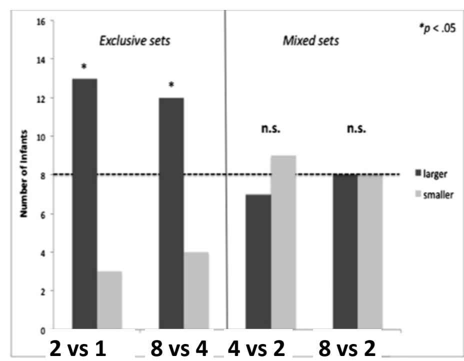


Fig. 1. (A) Procedure for presenting rhesus monkeys with a 1 versus 1 − 1 operation. (B) Results showing the number of subjects out of 15 picking one plum over no plum.

What about small vs. approximate numbers?

vanMarle 2012: 10- to 12-month-old infants have trouble doing comparisons across these two systems



"Infants choosing between sets that were either exclusively small (1 vs. 2) or exclusively large (4 vs. 8) chose the larger amount significantly more often than chance. Infants choosing between ''mixed'' sets, where one quantity was small and one was large, performed at chance. n.s., nonsignificant."

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.

Supporting evidence from Dehaene, Spelke, Pinel, Stanescu, and Tsivkin 1999: fMRI study showed that the exact number task recruited neural networks typically associated with language processing.

What human language does…

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

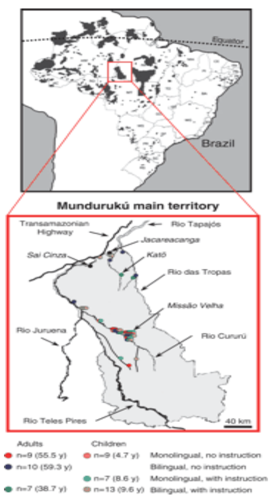
1, 2, 3, 4, 5…….578, 579, 580, 581, 582…

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

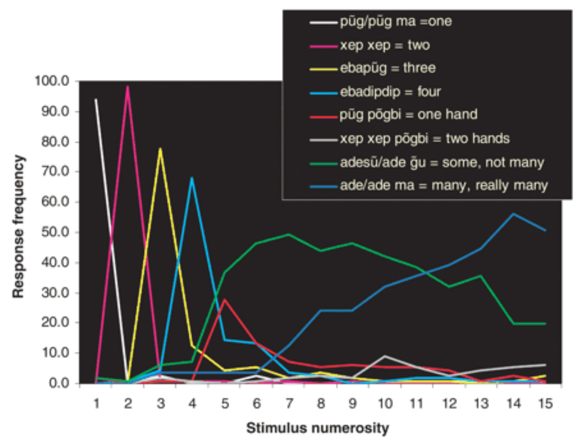
Another test of this: Look at the numerical cognition of people whose languages *don't* have an exact number system.

Languages without exact number systems

Pica, Lemer, Izard & Dehaene 2004: Munduruku speakers in Brazil who only have exact numbers for 1-5.

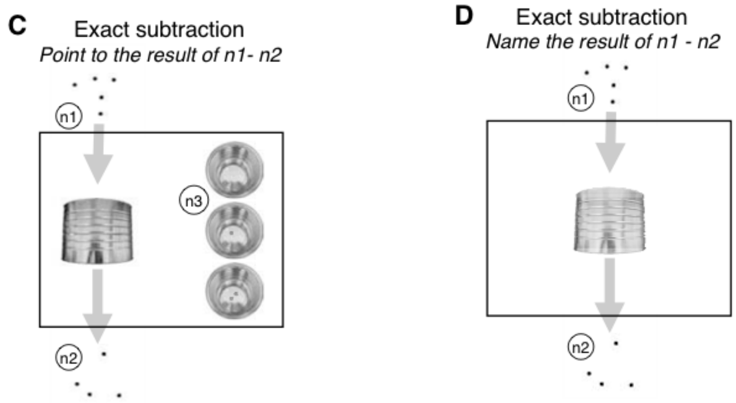


Munduruku responses when asked "how many" and shown a particular number of items



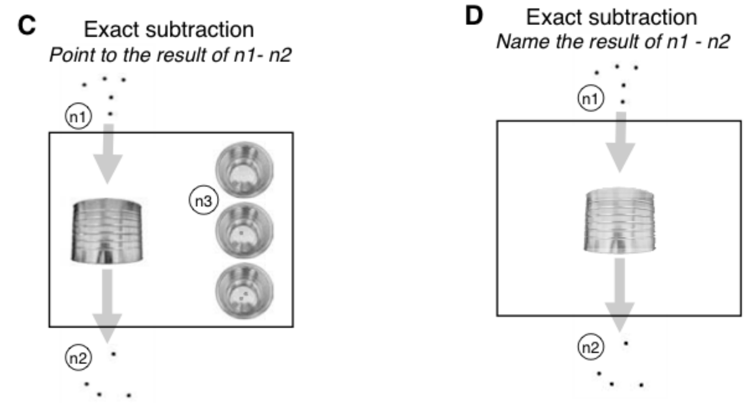
Numerosities bigger than five are "some" or "many".

Munduruku responses to exact arithmetic



Note: Even though some quantities are outside the language's number words (bigger than 5), the answer is within the number words (5 or less).

Munduruku responses to exact arithmetic



Results: Munduruku do much worse than speakers who have an exact number system (though still better than chance).

Languages without exact number systems

Gordon 2004: Pirahã speakers in Brazil who only have words for "one/two" and "many".

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

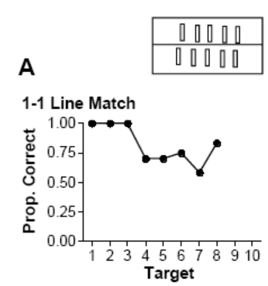
*This use of "one" might have been a reference to adding one rather than to the whole set of objects.

Languages without exact number systems

Gordon 2004: Pirahã speakers in Brazil who only have words for "one/two" and "many".

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

Shown batteries on one side of the line, and asked to line up batteries to match on the other side.

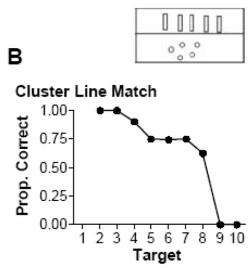


Languages without exact number systems

Gordon 2004: Pirahã speakers in Brazil who only have words for “one/two” and “many”.

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

Shown cluster of nuts on one side of the line, and asked to line up batteries to match on the other side.

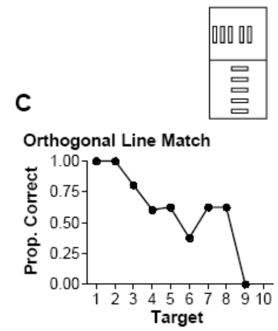


Languages without exact number systems

Gordon 2004: Pirahã speakers in Brazil who only have words for “one/two” and “many”.

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

Shown vertical line of batteries on one side, and asked to line up batteries to match on the other side.

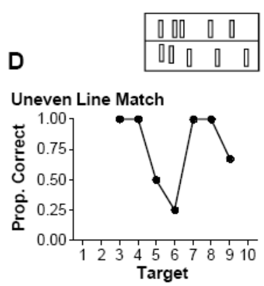


Languages without exact number systems

Gordon 2004: Pirahã speakers in Brazil who only have words for “one/two” and “many”.

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

Shown uneven line of batteries on one side, and asked to line up number of batteries to match on the other side.

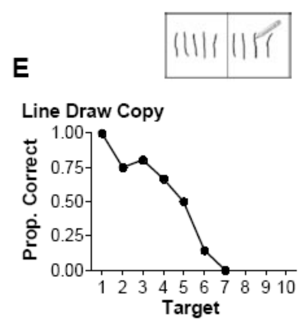


Languages without exact number systems

Gordon 2004: Pirahã speakers in Brazil who only have words for “one/two” and “many”.

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

Shown lines on one side, and asked to copy number of lines to match on the other side.

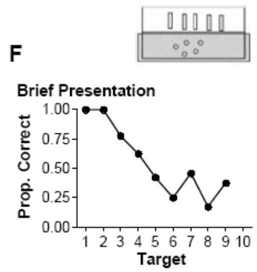


Languages without exact number systems

Gordon 2004: Pirahã speakers in Brazil who only have words for “one/two” and “many”.

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

Shown cluster of nuts on one side for one second, and then asked to match number of batteries to that amount from memory.

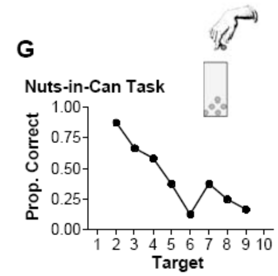


Languages without exact number systems

Gordon 2004: Pirahã speakers in Brazil who only have words for “one/two” and “many”.

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

Shown cluster of nuts, and then nuts are placed in a can. One nut is withdrawn at a time, and participant asked after each one if the can is empty yet.

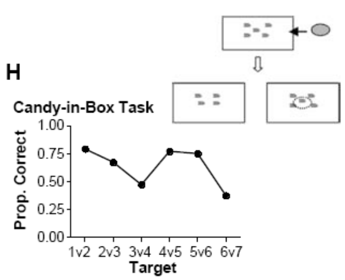


Languages without exact number systems

Gordon 2004: Pirahã speakers in Brazil who only have words for “one/two” and “many”.

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

Candy put in a box with a given number of fish drawn on the top of the box. The box is then hidden. 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.



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.”

No language for large exact numbers = no representation for large exact numbers

Languages without exact number systems

Note: English has imprecise words for numbers, too – but we also have exact words for numbers.

http://xkcd.com/1070/

JUST TO CLEAR THINGS UP:

A FEW	ANYWHERE FROM 2 TO 5
A HANDFUL	ANYWHERE FROM 2 TO 5
SEVERAL	ANYWHERE FROM 2 TO 5
A COUPLE	2 (BUT SOMETIMES UP TO 5)

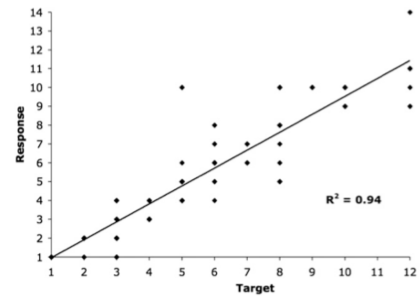
Another example: Deaf people who have not had access to a language (spoken or signed)

Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow 2011

Test population: Home-signers from Nicaragua

Spontaneous communication about number: The number of fingers the home-signers extended (y axis) as a function of the number of objects actually shown in a story they were retelling (x axis).

Home-signers seem able to track approximate numerosity.



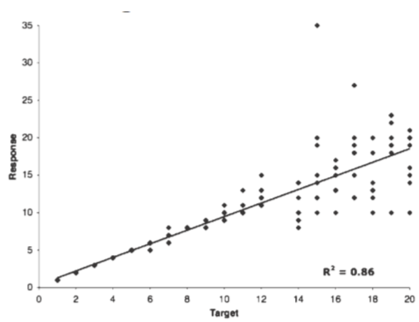
Another example: Deaf people who have not had access to a language (spoken or signed)

Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow 2011

Test population: Home-signers from Nicaragua

Asked to relate *exactly* how many objects were shown.

Home-signers have major difficulty once numbers go much above four.



Children's numerical cognition

- English children must learn number words, and it can take them a surprisingly long time to do it.

Why? It's not so easy to pick out exactly what concept numerosity refers to.

Barbara Sarnecka

(anecdote confusing numerosity with volume)
Saul (age 4;11.12) and his mother

Saul: You have 10 fingers and I have 10.

Mom: So who has more?

Saul: You.
Mom: I have more?

Saul: Yes, because yours are bigger. I mean just look at them!

Children's numerical cognition

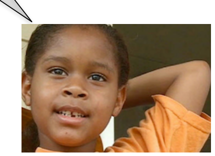
- English children must learn number words, and it can take them a surprisingly long time to do it.

Sophisticated numerical knowledge = Cardinal Principle

The last number reached when counting the items in a set represents the entire set.

Barbara Sarnecka

1, 2, 3, 4, 5, 6....there are 6!

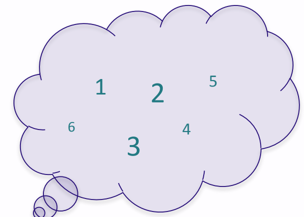


Children's numerical cognition

Children progress through different levels of knowledge on their way to discovering the Cardinal Principle (Wynn 1992, Sarnecka & Carey 2008, Sarnecka & Lee 2009).

Pre-number knowers haven't mapped any of the counting list.

1....there are 4!

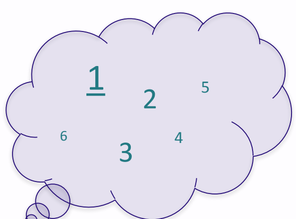


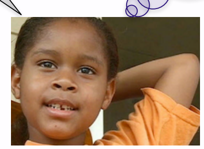
Children's numerical cognition

Children progress through different levels of knowledge on their way to discovering the Cardinal Principle (Wynn 1992, Sarnecka & Carey 2008, Sarnecka & Lee 2009).

One-knowers have only mapped 1.

1....there's 1!



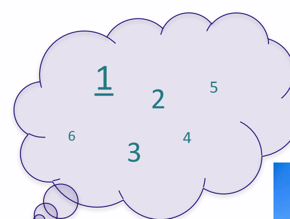


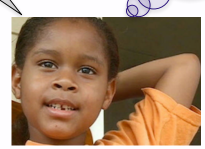
Children's numerical cognition

Children progress through different levels of knowledge on their way to discovering the Cardinal Principle (Wynn 1992, Sarnecka & Carey 2008, Sarnecka & Lee 2009).

One-knowers have only mapped 1.

1, 2....there's 5!





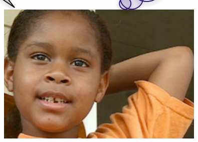
Children's numerical cognition

Children progress through different levels of knowledge on their way to discovering the Cardinal Principle (Wynn 1992, Sarnecka & Carey 2008, Sarnecka & Lee 2009).

Two-knowers have only mapped 1 and 2.

1, 2....there's 2!

1 2 5 6 3 4



Children's numerical cognition

Children progress through different levels of knowledge on their way to discovering the Cardinal Principle (Wynn 1992, Sarnecka & Carey 2008, Sarnecka & Lee 2009).

Two-knowers have only mapped 1 and 2.

1, 2, 3....there's 4!

1 2 5 6 3 4

Children's numerical cognition

Children progress through different levels of knowledge on their way to discovering the Cardinal Principle (Wynn 1992, Sarnecka & Carey 2008, Sarnecka & Lee 2009).

Three-knowers have only mapped 1, 2, and 3.

1, 2, 3....there's 3!

1 2 5 6 3 4

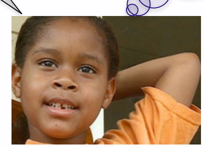
Children's numerical cognition

Children progress through different levels of knowledge on their way to discovering the Cardinal Principle (Wynn 1992, Sarnecka & Carey 2008, Sarnecka & Lee 2009).

Three-knowers have only mapped 1, 2, and 3.

1, 2, 3, 4....there's 6!

1 2 5 6 3 4



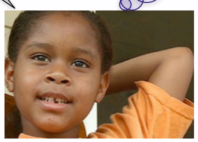
Children's numerical cognition

Children progress through different levels of knowledge on their way to discovering the Cardinal Principle (Wynn 1992, Sarnecka & Carey 2008, Sarnecka & Lee 2009).

Cardinal Principle knowers realize the mapping between numerosity and the counting list.

1, 2, 3, 4, 5....there are 5!

1, 2, 3, 4, 5, 6....



Children's numerical cognition

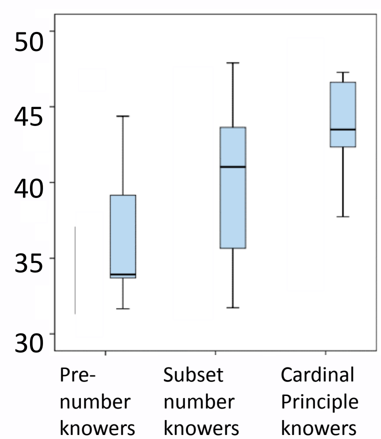
We can gauge which stage children are at using experimental methods.

Give-N Task (Wynn 1992):

"The way we play this game is: I will tell you what to put on the plate, and you put it there and sli-i-i-de it over to Kitty, like this [demonstrating]. OK, can you give one fish to Kitty?"

Children's numerical cognition

We can then get a sense of when children typically pass through the different number-knower stages.



Slusser 2010: Monolingual, High Social-Economic Status (SES) children

Children's numerical cognition

This process typically occurs in children speaking English, Japanese, and Russian between the ages of 2 and 5.

Interestingly, this same trajectory occurs in children from a farming and foraging society in the Bolivian rainforest — it just starts later, beginning around age 5 and finishing around age 8 (Piantadosi, Jara-Ettinger, & Gibson 2014).

http://www.sciencedaily.com/releases/2014/06/140618132009.htm

Using numerical knowledge

Negen & Sarnecka 2010: Tested children's non-verbal numerical cognition when they did not necessarily know the exact meaning of number words.

"Now we're going to play a *copying* game. I will give something to the anteater…(experimenter puts some items from a bowl onto his plate, and slides it to his stuffed animal)…and you give something to the bunny. You copy me and make your plate look *just like mine*."

"Now we're going to play a *remembering* game. I will give something to the bunny…(experimenter demonstrates)…and you try to remember what I gave the bunny. (Experimenter returns items to the bowl.) You give the bunny something and try to make yours *just like mine* was."

Using numerical knowledge

Negen & Sarnecka 2010: Tested children's non-verbal numerical cognition when they did not necessarily know the exact meaning of number words.

Results: Children who know more number words did a better job at replicating and remembering the number of items. Surprisingly, performance improved for all number sizes, even the ones children didn't necessarily have words for yet.

Example: Child knows "one" and "two", but improves at replicating/ remembering not only one and two, but also three, four, and five objects.

Language for numbers helps improve non-verbal comprehension and memory for numbers – may help highlight the salient concept of quantity.