Study: Math Skills Rely on Language, Not Just Logic

By Lisa Grossman ✉ February 8, 2011 | 12:00 pm | Categories: Brains and Behavior

Knowing a language that uses counting words can shape one's ability to understand large numbers.

A new study of deaf people who have made up their own hand signals to communicate shows that without number words, it's hard to keep track of more than three objects at a time.

"Learning language really shapes the way we think," said cognitive psychologist Elizabet Spaepen of the University of Chicago, lead author of a paper published Feb. 7 in the *Proceedings of the National Academy of Sciences*. "It can change the way we conceptualize something as seemingly basic as number."

Psychologists had already suspected that language was important for understanding numbers. Earlier studies of two tribes in the Amazon — one that had no words for numbers greater than five and another whose counting system seemed to go "one, two, many" — showed that people in those tribes had trouble reporting exactly how many objects were placed in front of them.

But in those cultures, which don't have monetary systems, there might be no need to represent large numbers exactly. The question posed was whether language kept those Amazonian people from counting, or a lack of cultural pressure.

To address that question, Spaepen and colleagues turned to Nicaraguan homesigners, deaf people who communicate with their hearing friends and relatives entirely through made-up hand gestures.

"They're the perfect test case for culture versus language," Spaepen said. "They're totally integrated into the economy of Nicaragua, they have jobs, they make money. But they don't learn a conventional language. They have to create one."

Homesigners in Nicaragua are famous among linguists for spontaneously creating a fully formed language when they were first brought together at a school for the deaf in the 1970s. But many homesigners stay at home, where they share a language with no one. Their "home signs" are completely made up, and lack consistent grammar and specific number words.

Over the course of three month-long trips to Nicaragua in 2006, 2007 and 2009, Spaepen gave four adult Nicaraguan homesigners a series of tests to see how they handled large numbers. They later gave the same tasks to control groups of hearing Nicaraguans who had never been to school and deaf users of American Sign Language (which does use grammar and number words) to make sure the results were not just due to illiteracy or deafness.

First, the researchers showed the homesigners ten short animated stories where numbers were central to the plot. For example, one story opened with 8 frogs on lily pads. Four jumped away all at once, and two came back one at a time.

When asked to recount the vignettes to a friend who knew their hand signals, the homesigners used their fingers to indicate the number of frogs. But when the numbers got higher than three or four, the signers' accuracy suffered.

Spaepen then showed the signers flashcards with different numbers of items like fish or beach balls on them, and asked them to report how many items were on each card. Homesigners, ASL-signers and Spanish-speakers alike were spot-on for cards with one, two or three fish, no matter how long they spent looking at the card. When they had only a few seconds with the card, all three groups guessed the exact number about a third of the time.

Given unlimited time with the cards, though, the groups whose languages had counting words gave the right number of fish almost every time. The homesigners could only give the exact number 44 percent of the time.

"The homesigners in the estimation task look like anyone else would," Spaepen said. "The thing is, they also look like estimators when they're given all the time in the world to count, or whatever you would do."

In another test, Spaepen showed the homesigners a row of one to 20 poker chips, and asked them to create an identical array. When all the chips were visible, the signers had no difficulty matching their chips one-to-one to Spaepen's. But when Spaepen's chips were covered up, the signers couldn't come up with the correct number of chips in their own array.

"The homesigners had no trouble understanding what we were asking them to do," Spaepen said. "They just couldn't do it."

Oddly, the homesigners did use their fingers to keep track of objects, the way children use their fingers to count. Spaepen thinks the signers use each individual finger to represent a unique object — the index finger is the red fish, the middle finger is the blue fish — and not the abstract concept of the number of fish.

"They can't represent something like exactly seven," Spaepen said. "What they have is a representation of one-one-one-one-one-one-one."

This might be similar to the way children learn numbers in the first place, she said. Research on child development shows that kids start by memorizing numbers as an ordered list. They can recite the numbers from one through ten, but if you ask them to give you three apples, they're just as likely to give you five or seven.

The age at which kids start connecting their ordered list to numbers of things depends a lot on how much reinforcement they have from adults. Some children learn to count by age two; others, usually from disadvantaged households, arrive at school not knowing what "two" means. The homesigners represent those disadvantaged kids taken to the extreme.

"Language input is important for everybody's representation of number, and how counting works," Spaepen said. "This isn't something you just get for free because you're human. It depends on the quality and amount of input you get. If you're not getting it in your language, you're not going to just come up with it on your own."

"I think it's a really nice result," said psychologist Peter Gordon of Columbia University, who suggested in 2004 that the Pirahã people's "one-two-many" language kept them from understanding large numbers. The study was well-designed and took care to rule out other possible explanations, he added.

"It really nailed down the role of language as opposed to culture," he said.

Video: One of the Nicaraguan homesigners telling a story in which 10 sheep stand in a pen. He incorrectly

holds up 9 fingers to describe the number of sheep. (Elizabet Spaepen, University of Chicago)

"Number without a language model." Elizabet Spaepen, Marie Coppola, Elizabeth S. Spelke, Susan E. Carey, Susan Goldin-Meadow. PNAS, Feb. 7, 2011. DOI: 10.1073/pnas.1015975108.

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Maggie 8 hours ago

When I saw the title of this article, my first reaction was, "duh." Of course math skills rely on language, without language, how could we understand math? Math is almost like a language itself, and its hard to learn a language where some words don't have an equivalent meaning in someone's first language.

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John Lucas 3 hours ago in reply to Maggie

When I was 5 or 6 yrs old I thought, "How do Chinese people think or have thoughts if they don't speak English? They must not think at all..."

Then, in my linguistics class about 10 years ago, my professor proclaimed, "Complex thought is not based on language ability."

So do you think different languages reinforce/discourage certain traits in a child's upbringing? For example, do western European languages encourage individuality whereas far-eastern languages reinforce similarity?

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John Lucas 1 day ago

“They can’t represent something like exactly 7,” Spaepen said. “What they have is a representation of one-one-one-one-one-one-one.”

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ElyasM 21 minutes ago

I think George Orwell made a similar, if unsubstantiated, observation a long time ago. Of course, he was discussing political theory, not mathematics, but the concept is the same; it is difficult to 'know' something if you lack the words to define it.

Like Reply

Shane Couzins 7 hours ago

If you want to hear more about the story of the development of the spontainous language go and listen to it from radiolab:
http://www.radiolab.org/2010/a.../

They also have a great episode about numbers. Where if I remember correctly the mention that some amazon tribes actually only have logarithmic representations of numbers:
http://www.radiolab.org/2009/n.../

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