Why Do So Many Animals Have the Ability to Do Math?
From Marc Bekoff, Psychology Today / Animal Emotions
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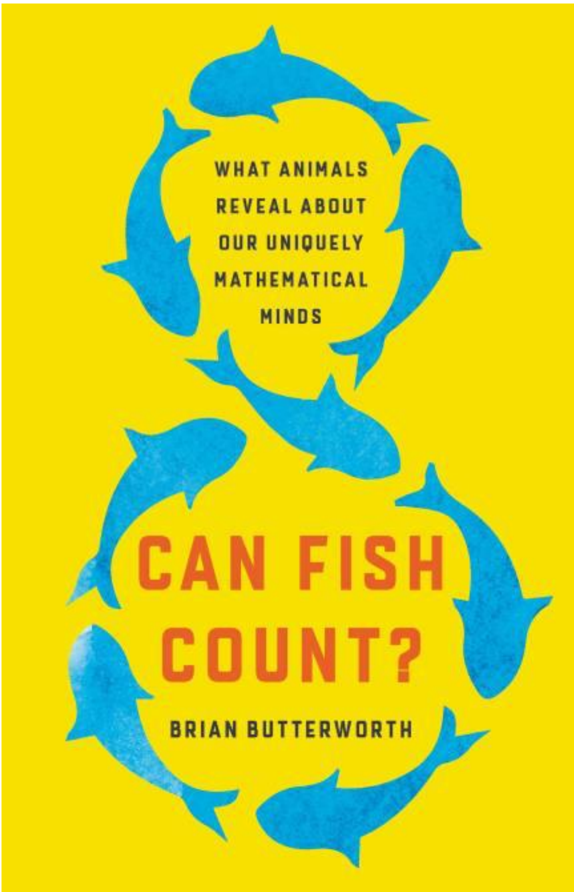
A new book challenges the myth that only a few animals have numerical skills.



I've long been interested in the numerical competency of nonhuman animals (animals) and whether they can count in their own specific ways.[1] It turns out that many animals have a well-developed numerical sense and in his new book, *Can Fish Count?: What Animals Reveal About Our Uniquely Mathematical Minds*, cognitive scientist Brian Butterworth shows that many animals seem to have inherent mathematical abilities.[2] Here's what Brian had to say about his fascinating investigation into the numerical abilities of diverse animals and how they help us make better sense of our own.

Marc Bekoff: Why did you write *Can Fish Count*?

Brian Butterworth: In 2017, Giorgio Vallortigara, Randy Gallistel, and I organised a four-day meeting at the Royal Society in London about "The origins of numerical abilities." It was partly published in the *Philosophical Transactions of the Royal Society B*. It was a great meeting, and many newspapers and magazines reported parts of it, including *The New York Times*, but I thought the science that was presented in it would be of wider interest. So, in one sense, *Can Fish Count?* is my attempt to make the work available to the general reader.

MB: How does your book relate to your background and general areas of interest?

BB: Since 1989, I have worked on the problem of how the brain processes numerical information. Initially, I studied neurological patients whose brain injury affected their numerical abilities. We discovered—or more accurately, rediscovered—that the left parietal lobe was the crucial hub for numerical processing of all types. I then asked the question: Why this region of the brain? Is it specialised from birth—i.e. inherited—or does become specialised through experience?

This region is adjacent to one of the high-level hand and finger control regions in the brain and also it is a classical "association" area, a brain region that integrates information from different modalities of input. Since numbers are intrinsically abstract—cross-modal—this seemed like a good candidate. Obviously, experience plays a big part, since we knew from our patients that damage can affect competence in many different ways, perhaps depending on the learning history of the patient.

If it's inherited, then maybe the inheritance process can go wrong, as in the case of colour blindness (colour vision abnormalities). Can there be individuals who have an inherited disability? Or perhaps a congenital disability due to early damage to this region?

Although the idea of a congenital condition was first proposed in 1974 by Ladislav Kosc, who called it "dyscalculia," we were, I think, the first to show in 2004 that there was a group of children who were impaired in very simple tasks, such as reporting the number of dots in a display. Later, we showed that this deficit in kindergarten predicted very poor arithmetic up to the age of 11 at least. And in the largest prevalence study reported (over 11,000 children in Havana), we showed that poor performance on the dots task is a highly reliable predictor of arithmetical fluency and affects about 3.5% of the population. Other studies using slightly different methods give a prevalence of about 5%. There is now work that suggests that abnormalities in the parietal lobes are associated with dyscalculia.

MB: What are some of the topics you weave into your book and what are some of your major messages?

BB: Numbers are abstract. The only thing that these three sets have in common is their threeness: three chimes of Big Ben, three coins in the fountain, and three wishes. Other animals also manage a degree of abstraction, though perhaps not as much as humans. Numbers (numerosities) are perhaps the only abstract concepts that some animals can manage.

The counting mechanism is very simple, so even small brains can do it. What is complicated and neurally expensive is choosing things to count. We can count anything, objects, sounds, abstract objects but many animals will (or perhaps can) count only adaptively relevant things: food items, mating calls (as in the túngara frog, or songbirds songs), number of competitors (e.g. lions invading a pride's territory).

There are many evolutionary advantages in being able to count and to use the results of counting in foraging, in survival, and in reproduction. For example, defending lions will only attack intruders if they outnumber them. This means comparing the number of defenders and the number of invaders. The intruders will retreat if outnumbered. A painless win for the defenders. Male Túngara frogs count the number "chucks" in competitors' advertisement calls and add one because females prefer males that make the most chucks. Most animals will go for more food given a choice, and indeed more pieces of food when the total quantity is equated.

The ability of animals to perform mathematical operations–even without being taught–also invites the question: Just where exactly do numbers come from? This is a philosophical question that goes back to Plato and indeed earlier to Pythagoras, who allegedly said all things are made of numbers. In tracing the evolution of numerical capabilities back through our recent ancestors and cousins, early humans and Neanderthals, great apes, baboons, crows and parrots, frogs and salamanders, insects, spiders, and of course fish, I shed some new light on the question.

Virtually all creatures possess an inherent mathematical mechanism, probably passed down from our most distant common ancestors. This mechanism, known as the "accumulator," provides an innate understanding of mathematics at its most basic level, and is the foundation for the more sophisticated math systems we use today. When it malfunctions in humans, dyscalculia can be the result. We have even discovered dyscalculia in fish, and are now seeking its genetic basis.

MB: How does your book differ from others that are concerned with some of the same general topics?

BB: There are several excellent books on numerical cognition, both by individual authors and in edited collections. Andreas Nieder's *A Brain for Numbers* deals with animal work, including his own excellent studies of monkey and bird brains, but it reads more like a coursebook than a book for the general reader.

My *The Mathematical Brain* (U. S.: *What Counts*) was directed to the general reader and covers similar ground, but the field has moved on a lot since 1999. For example, there is nothing in it about fish or insects, and nothing about animal brains. *The Oxford Handbook of Numerical Cognition* has three excellent chapters out of sixty on the evolutionary basis of numerical abilities. Again, this is not directed at the general reader.

References

In conversation with Dr. Brian Butterworth.

1) For more on the numerical sense of different animals see: Bekoff Marc. Free-Ranging Dogs Assess Relative Group Size by Subitizing; _____. Bears Can "Count"; _____. "My Dog Is a Genius Who Can Count. (FMRi's show that the parietotemporal cortex is involved in estimating quantity.)

2) Brian Butterworth is Emeritus Professor of Cognitive Neuropsychology in the UCL Institute of Cognitive Neuroscience, where he is currently working with colleagues around the world on the neuroscience and the genetics of mathematical abilities and disabilities in humans and other animals. He was elected Fellow of the British Psychological Society in 1993, and Fellow of the British Academy in 2002. His popular science book, *The Mathematical Brain* (U.S. *What counts?*) was a best seller and *The Dyscalculia Screener* revolutionized the identification of this specific learning disability.

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