Helping children learn to understand numbers: It's all in the way we speak to them

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Most people know how to count, but the way we master this ability remains something of a puzzle. Numerals were invented only around four to five thousand years ago, meaning it is unlikely that enough time has elapsed for specialized parts of the brain for processing numbers to evolve, which suggests that math is largely a cultural invention.

It appears to be based on an interface between vision and reasoning that we share with other animals, allowing us to "see" small numbers—up to around five—without counting. This ability—often called 'the number sense'—lays the foundations of later mathematical knowledge, but its basis is poorly understood. It has been argued that the number sense itself may be innate, but this fails to account for why learning to master the use of small numbers is such a difficult and drawn-out process in children.

Now, a formal model of the cognitive basis of counting has been reported in research published in the open-access, peer-reviewed journal *PLoS ONE*. The research was led by Michael Ramscar, Melody Dye, Hanna Poppick and Fiona O'Donnell McCarthy from Stanford University, and was funded by the National Science Foundation. Beginning with a model of the way our brains learn, the authors show how our ability to see numbers emerges naturally out of interactions between the problem of distinguishing between the size of the sets numbers describe, and the frequency with which we use different numbers. While the difficulty of distinguishing numbers increases with set size, the authors show how we talk—and think—about numbers far more often as their size decreases, and they propose that the capacity limit on our number sense arises out of these factors. While this finding challenges the view that the 'number sense' is based on an innate, dedicated system for seeing small sets, it also explains why children struggle to map numbers to words, and crucially, it shows how this process can be improved.

Numbers are never encountered alone in sets—we may see "three bears, but never a set of just "three"—so children must learn to distinguish which part of "three bears" is "three". Since learning is based on expectation—our brains learn by guessing which things lead to what—children are far better at learning to distinguish "three" if "bears" are mentioned first: "look at the bears, there are three!" If sets of "bears" come before numbers, everything the child sees will compete for relevance in her learning to expect numbers, and it soon becomes obvious that while "bear" parts are no use for discriminating between "two" and "three," two and three are. This competition is far less straightforward when "three" acts as the basis for expecting "bears." Indeed, training children using "look, there are three bears" had no effect on their number sense at all, whereas children trained with "look at the bears, there are three!" showed a 30% improvement on their ability to distinguish small sets after just one short training session.

These experimental findings provide the first evidence that the "number sense" can be improved by properly targeted training, while the computational modeling provides a formal account of why the training works, as well as offering the first formal model of how the number sense is learned, and how numerical capacity limits arise. The research team used the Rescorla-Wagner model for simulating learning and predicting the effects of training in children. This is a widely supported model of learning in the behavioral sciences, both in terms of its fit to human and animal behavior, and the amount of neuroscientific support that has been amassed for its basic mechanisms.

The development of number sense in early childhood is the best predictor educationalists have of later mathematical ability. According to the researchers, these findings are of potentially critical importance to the development of mathematical abilities in children, and they may also provide a formal basis for the development of models and interventions to help address developmental disorders, such as dyscalculia.

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