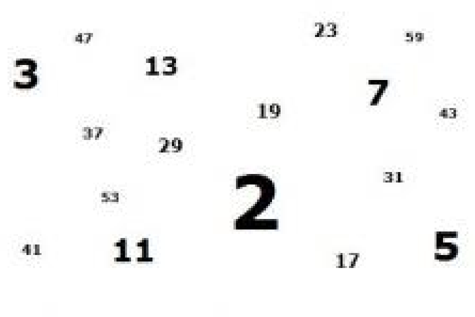
Researchers test the brain's number sense perception

October 9 2015, by Christopher Packham



Prime Numbers

Number sense hypothesis holds that the intuitive understanding of numbers is a primary visual property, like color sense or physical orientation. In nature, this refers not to any ability to count, but to visually sense the number of important objects and changes in those numbers—offspring, for instance. In humans, it also encompasses the ability to count, a sense of magnitude, number relationships, and adaptability to mathematical learning.

But what, exactly, is a number? A group of Chinese researchers tackled this deep philosophical question from a neurological perspective in a study reported in the *Proceedings of the National Academy of Sciences*. They sought to verify the invariant nature of numerosity perception in an experiment that included fMRI scanning to establish the brain structures activated in number sense.

Proceeding from the obvious assumption that numerosity is invariant to specific features like size, orientation, shape and color, they designed a test that included a number of dots within an enclosed space. To test the invariant effect of connection, they used arbitrary and irregular line segments connecting dots; there were three conditions: zero, one, and two connected pairs of dots were included in the test patterns. Subjects were shown these patterns adjacent to reference patterns that contained 12 dots unconnected by line segments. They were asked to indicate solely through visual perception which pattern contained more dots.

The researchers found that connecting dots in the patterns led to a robust result of underestimation. The researchers tested another topological invariant, the inside/outside relationship, by enclosing pairs of dots within ovals and irregular oval-like shapes. Interestingly, the results demonstrated that underestimation also occurred in this condition, and that it depended directly on the number of enclosed dot pairs in the pattern.

In another test, the researchers explored whether color grouping would affect the judgements of numerosity by participants. Instead of making connections or enclosures, the researchers colored pairs of neighboring dots red. Though this produced a visual grouping effect, the change in color produced no underestimation effect in the study participants.

To investigate the neural correlates of number sense, they assessed neural activation in the lateral intraparietal sulcus (IPS) of test participants, as this brain region has previously been associated with numerical representation. First, subjects were adapted to continuously refreshed reference patterns of 10 unconnected dots each; then, the researchers interpolated images including two pairs of connected dots. fMRI scans of this condition were compared to the reference condition, revealing a clear process of adaptation in the IPS to the new condition of connected dots. "Thus, behavioral measures as well as fMRI adaptation provided converging evidence supporting the hypotheses that the primitive units counted in numerosity perception are influenced by topological invariants," the authors write.

The researchers conclude that by taking a topological approach to number sense in the brain, the study produced evidence that numerosity as a primary visual property can be formally described in terms of topological invariants.

More information: Lixia He et al. Topology-defined units in numerosity perception, *Proceedings of the National Academy of Sciences* (2015). DOI: 10.1073/pnas.1512408112