Amazonian indigenous culture demonstrates a universal mapping of number onto space

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The ability to map numbers onto a line, a foundation of all mathematics, is universal, says a study published this week in the journal *Science*, but the form of this universal mapping is not linear but logarithmic. The findings illuminate both the nature and the limits of the human predisposition to measurement, a foundation for science, engineering, and much of our modern culture.

The research was conducted with the Munduruku, an Amazonian indigenous culture with a limited vocabulary of number words and spatial terms, little or no formal education, and little or no experience with maps, graphs, and rulers.

Munduruku adults and children spontaneously placed numbers on a line in a compressed, logarithmic function, such that smaller numbers appeared at greater spatial intervals. The study suggests that a propensity to relate numbers to space is universal, but that the mapping of successive integers and constant spatial intervals, as on a ruler, is culturally variable and linked in part to education.

The research was conducted by Stanislas Dehaene, professor of cognitive psychology at the College de France in Paris; Elizabeth Spelke, Marshall L. Berkman Professor of Psychology at Harvard University; Veronique Izard, a postdoctoral researcher in psychology at Harvard; and Pierre Pica of Paris VIII University in Paris.

"Our findings suggest that humans have a predisposition to relate two

fundamental domains of knowledge: knowledge of number and of space," Spelke says. "The Munduruku are able to place numbers on a line in a systematic way that educated adults employ as well, under certain conditions. This convergence suggests a universal relationship between numbers and space. Nevertheless, the Munduruku do not map numbers onto a line at equal intervals, as we do when we measure objects. Both universal cognitive abilities and culture-specific experiences therefore seem to contribute to the development of a linear number line and the activities that it makes possible: measurement, mathematics, and science."

The researchers studied the ability of 33 Munduruku adults and children to map numerical representations on to a line, with "1" located at the left end of the line, and "10" at the right. In tests of larger numbers, "10" was at the left, and "100" at the right. After presentation of a number stimulus, such as spoken number word in Munduruku or Portuguese, or a visual array of dots or sequence of sounds, the Munduruku indicated the number's appropriate location on the line. The test was presented on a solar-powered laptop deep in the Amazon.

In most cases, the Munduruku placed numbers on the line in a systematically compressed function, devoting more space to smaller numbers than to larger ones. Variation did exist in the amount of participants' education, and some individuals were more familiar with Portuguese than others. Those with more than three years of education tended to place numbers indicated by Portuguese spoken words at equal intervals on the line. However, those same individuals showed a compressed mapping for arrays of dots and for spoken Munduruku words, as did all of the other Munduruku participants.

Munduruku adults and children were also compared to Boston-area adults, who were given a similar set of tests. The Boston-area participants showed linear or nearly linear mappings in all the conditions

of the study when they were presented with dot arrays that were small enough to count or with number words. Nevertheless, adults in Boston also showed a compressed mapping when presented with sound sequences or with arrays of dots too large to count. These findings suggest that a compressed mapping of number onto space continues to exist in adults despite years of experience with counting, arithmetic, and measurement.

"It appears that we, as humans, can access two different methods of numerical mapping," says Dehaene. "The logarithmic, ratio-based method is the most intuitive; we inherit it from our primate evolution and we still access it in the absence of precise mathematical tools. Through education, we also acquire a linear mapping. However, this does appear to be a cultural construct."

Previous studies, conducted by the same researchers, have shown that the Munduruku are sensitive to geometry, and understand the differences between different shapes or angles.

Very young children have also been shown to access a logarithmic scale for number mapping, and animals compare numbers in accord with their ratios rather than their interval relationships. In contrast, linear numerical mapping is a uniquely human ability, not shared by animals, and develops in children between the ages of 5 and 7. Because Munduruku adults show the same logarithmic mapping as preschool children, it appears that education and culture-specific experience, rather than universal developmental processes, underlie the emergence of the linear mapping.

Source: Harvard University