Large Number Discrimination in 6-month-old Infants

Fei Xu (FEI@PSYCHE.MIT.EDU)
Elizabeth Spelke (SPELKE@PSYCHE.MIT.EDU)
Department of Brain and Cognitive Sciences
Massachusetts Institute of Technology
E10-244, Cambridge, MA 02139 USA

One of the main tasks of cognitive scientists is to characterize the initial conceptual state of a human infant. In particular, what are the innate domains of knowledge, if any? Several recent studies have documented that infants as young as 5 months are able to discriminate arrays that differ in the number of elements they contain and to perform rudimentary arithmetic operations on such arrays. Some have suggested that number is an initial cognitive domain.

Starkey & Cooper (1980) first showed that 5-month-old infants who habituate to 2 dots will dishabituate to 3 dots, and the reverse. This result has been extended to newborn infants, to more heterogeneous arrays, to sets of 4 elements, and even to elements that move around. Wynn (1992) provided the first evidence that 5-month-old infants can take into account the effects of simple addition and subtraction on small numerosities, e.g., infants represent that $1 + 1 = 2$ and $2 - 1 = 1$. Various laboratories have replicated this result.

Young infants appear to represent numbers not only of objects, but also of sounds and events (Starkey, Spelke, & Gelman, 1990; Wynn, 1995), and they appear to have some rudimentary understanding of the relation between these small numbers. Since these representations are not tied to a particular modality or a particular type of entities, some researchers have argued that infants possess a system of knowledge which pertains to number *per se* .

Nevertheless, these same studies provide evidence that infants fail on number discrimination and arithmetic tasks with set size larger than 3 or 4 (e.g., 4 vs. 6, which has the same ratio difference as 2 vs. 3), supporting the alternative hypothesis that segmentation of objects, but not number, underlies infants' successful performance. Perhaps infants use an early visual processing mechanism such as FINSTs (Trick & Pylyshyn, 1994), object files (Kahneman, Treisman, & Gibbs, 1992), or spatial models of objects to keep track of the entities in an array (Simon et al., 1995; Uller et al., 1996). That is, infants do not have a unitary representation of "2" per se but rather "an object and another object." On this account, the "limit of 3" is inherent in the underlying mechanism and infants may not represent number *per se.*

Here we report a study of young infants' discrimination of large sets of elements differing by a 2:1 ratio (16 vs. 8). Success at this discrimination would add to the claim that infants represent number, whereas failure would support the alternative hypothesis.

Two groups of 6-month-old infants were tested. Eight infants were habituated to displays with 8 dots, then tested on a new display with 8 dots and a display with 16 dots; eight infants were habituated to displays with 16 dots, then tested on a new display with 16 dots and a display with 8 dots. Several features of the experiment were designed to assure that successful discrimination would depend on number rather than other features of the stimuli that correlate with number (e.g., brightness, density of elements, and spatial frequency). First, in each habituation trial, dots were presented in a different random pattern and size of the dots varied. Second, the two test displays were equated for brightness, element size, and element density by using a 16-dot display that was twice the overall area as the 8-dot display. The element size and display were selected so as to present values equi-distant from the average value for the 8- and 16-dot habituation displays.

We found that 6-month-old infants are able to discriminate large numerosities (16 vs. 8) differing by a 2:1 ratio. After habituating to a series of displays with 8 (or 16) dots, the infants looked longer at displays with the novel number of dots (the mean looking time for the new display was 6.4 seconds and for the old display was 4.7 seconds), $F(1, 15) = 5.002$, $p < .05$.

Thus we provide the first evidence that the "limit of 3" observed in previous work doesn't appear to be a limit on the set size infants can represent, but on the accuracy of these representations: when a 2:1 ratio of set sizes is used, large set sizes are discriminated.

This finding could be explained in two ways. First, infants possess a single system for representing number, supporting discrimination of both large and small arrays. Second, infants may possess distinct systems for representing small and large numbers: an object individuation system in the first case and a number estimation system in the second case. Current experiments are attempting to distinguish these possibilities.

References

Starkey, P. & Cooper, R. (1980) Perception of numbers by human infants. Science, Vol. 210, 28, 1033-1034.

Starkey, P., Spelke, E.S., & Gelman, R. (1990) Numerical abstraction by human infants. Cognition, 36, 97-128.

Wynn, K. (1992) Addition and subtraction in infants. Nature, 358, 749-750.