Detection of Number or Numerousness by Human Infants

Starkey *et al.* (*1*) reported that 7-month-old infants prefer to look at a collection of objects that corresponds numerically to a sequence of sounds. They interpreted their results as indicating that infants match the number of objects in the visual display to the number of sounds in the auditory sequence and that infants have mechanisms for detecting information about number. Starkey *et al.* acknowledge that their results may reflect numerousness discrimination (discrimination of more numerous from less numerous discrete quantities) rather than anything numerical. This possibility is minimized, however, because it is mentioned late in the report, whereas both the title and abstract imply numerical ability. The distinction between numerousness and numerical deserves further elaboration; we think that the infants' performance was more likely based on numerousness than number.

Numerical ability can be regarded as a continuum that includes counting as well as the more advanced ability to perform operations (such as addition or subtraction). A previous attempt to describe this continuum (*2*) excluded numerousness discrimination because it represents a simple perceptual ability that bears no obvious relation to number. Numerousness discrimination is fairly common in many species of birds, as well as in rats and monkeys, but is rarely viewed as evidence of numerical ability in these species (*2*). Human infants are also capable of numerousness discrimination, but their performance seems to be based on encodings of small, discrete quantities that are not ordered in magnitude (*3*). The fact that infants can match such encodings across modality does not require the conclusion that these encodings involve either the cardinal or ordinal properties of number.

We do not think that numerousness discrimination belongs on the continuum of numerical ability. A better candidate for the low end of the continuum is "subitizing," which is the consistent assignment of a unique response (for example, a verbal label or lever press) to a small array of discrete elements (*4*). Although it has been argued that subitizing is a developmental precursor to counting and other advanced numerical abilities (*5*), numerousness discrimination does not seem to be a precursor to anything on the numerical ability continuum.

These criticisms do not detract from the overall importance of the data reported by Starkey *et al.* By their use of a cross-modal procedure, they have expanded our understanding of the range of abilities of human infants. The question, however, is what manner of ability they have observed.

HANK DAVIS
MELODY ALBERT
RODERICK W. BARRON
Department of Psychology,
University of Guelph,
Guelph, Ontario N1G 2W1, Canada

References and Notes

1. P. Starkey, E. S. Spelke, R. Gelman, *Science* **222**, 179 (1983).
2. H. Davis and J. Memmott, *Psychol. Bull.* **92**, 547 (1982); *Animal Learn. Behav.* **11**, 95 (1983).
3. R. G. Cooper, Jr., in *Origins of Cognitive Skills*, C. Sophian, Ed. (Erlbaum, Hillsdale, N.J., 1984), pp. 157–192; M. S. Strauss and L. E. Curtis, *ibid.*, pp. 131–155.
4. G. Mandler and B. J. Shebo, *J. Exp. Psychol.: Gen.* **111**, 1 (1982).
5. D. Klahr, in *Mechanisms of Cognitive Development*, R. J. Sternberg, Ed. (Freeman, New York, 1984), pp. 101–139; E. von Glasersfeld, *Arch. Psychol.* **50**, 191 (1982).

16 July 1984; accepted 25 January 1985

Davis *et al.* (*1*) conclude that our experiments on the ability of 7-month-old infants to detect intermodal correspondences between the number of items in a visual array and the number of drumbeats they hear (*2*) do not demonstrate a numerical ability. They suggest that the infants responded to numerousness but not to number. Their argument has two premises. The first is that numerousness discrimination "represents a simple *perceptual* ability that bears no obvious relation to number" [(*1*), our italics]. The second is that numerousness discrimination is too imprecise to render true numerical abstractions (*3*).

With respect to the first argument, Davis *et al.* offer no perceptual mechanism to account for our findings. We do (*4*). Detection of a correspondence may depend on a perceptual process relating a pattern of sound to a simultaneous pattern of visual acuity. With each sound, infants might scan from one object to another and perceive a sound-object correspondence only if they encounter a new object with every sound. Such a mechanism would not allow infants to detect correspondences between nonsimultaneous sounds and objects. Should infants be able to first watch a display of X items, then listen to sequences of X and Y drumbeats and choose the number sequence that corresponds to that in memory, the claim that they are restricted to a perceptual mechanism is ruled out. Since our infants did match the number of items they first saw with those they later heard, they demonstrated an ability to detect numerical correspondence, even when they had to work from memory.

True, infants of 7 months do not have a full range of numerical abilities. But that they respond to one-to-one correspondence cannot be dismissed. The presence or absence of one-to-one correspondences forms the foundation of mathematical relations, including counting and the ability to define cardinal and ordinal number. Infants' abilities as revealed by our experiments could form a component numerical skill that contributes to the development of more complex number concepts.

Are infants' responses to numerical displays too imprecise? By 7 or 8 months, infants can discriminate visual sets of one element from sets of two, sets of two from sets of three, and sets of three from sets of four, but not sets of four from sets of six. The numerical differentiations the babies make are too precise for Davis *et al.*'s mechanism of numerousness discrimination, a mechanism by which infants would make gross discriminations between sets of few and many elements (*3*). Further, if babies are judging relative numerousness, they should be able to discriminate four from six as easily as two from three, on the basis, perhaps, of a common ratio difference in brightness or length of display (*5*).

PRENTICE STARKEY
Medical Research Council, Cognitive Development Unit, 17 Gordon Street, London WC1, England
ROCHEL GELMAN
ELIZABETH S. SPELKE
Department of Psychology, University of Pennsylvania, Philadelphia 19104

References and Notes

1. H. Davis, M. Albert, R. W. Barron, *Science* **228**, 1222 (1985).
2. P. Starkey, E. S. Spelke, R. Gelman, *ibid.* **222**, 179 (1983).
3. H. Davis and J. Memmott, *Psychol. Bull.* **92**, 547 (1982); *Anim. Learn. Behav.* **11**, 95 (1983).
4. P. Starkey, E. S. Spelke, R. Gelman, *Cognition*, in press.
5. P. Starkey and R. G. Cooper, Jr., *Science* **210**, 1033 (1980).
6. Prepared while R.G. was a fellow at the Center for Advanced Study in the Behavioral Sciences, Stanford, California, and supported by the Alfred P. Sloan Foundation, the Spencer Foundation, and an NIHHCD postdoctoral fellowship. E.S.S. was a Fulbright fellow at the CNRS, Laboratoire de Psychologie, Paris. New research reported here was supported by NIH postdoctoral fellowship MH 07949 to P.S., NIH grant HD 13248 to E.S.S., and NSF grant BNS-80-04881 to R.G.

7 March 1985; accepted 10 April 1985