When Do Children Learn the Concept of Numbers?

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Abstract

According to Galister, Gelman, and Cordes [1] the cultural history of the real numbers began with the positive integers. Kronecker is often quoted as saying, "God made the integers; all else is the work of man," by which he meant that the system of real numbers had been erected by mathematicians on the intuitively obvious foundation provided by the integers. Weise [2] poses the question what role does language play in numerical thinking? and maintains that numerical thinking developed in a pattern of co-evolution of number concepts and counting words, indicating that language played a pivotal role in the emergence of systematic numerical cognition in humans. Weise [2] proposes an evolutionary scenario: we can think of the co-evolution of number concepts and counting sequences as a development in four main stages. Stage 1 starts with iconic representations of cardinality. These representations can be non-verbal (like notches), or verbal, that is, constituted by words. At stage 2, the elements of some verbal iconic representations (that is, words) appear in a stable order, supported by their correlation with body parts, in particular with fingers, that are also used for cardinal icons. At stage 3, this stable order supports indexical links between individual words and individual cardinalities. At stage 4, these indexical links give rise to dependent links: a counting sequence is born. The pattern of association can now be generalized to cover non-cardinal as well as cardinal contexts, supporting a full-blown, unified number concept.

Introduction

Butterworth [3] claims that counting makes the first bridge from the child's innate capacity for numerosity to the more advanced mathematical achievements of the culture into which she was born. The least mathematical of cultures enable their members to do much more than the infant. They can keep track of quite large numerosities counting with special number words or body-part names; they can do arithmetic beyond adding or subtracting one from small numerosities which they will need for trading or for ritual exchanges. Butterworth [3] also maintains that though it seems very easy to us adults, learning to count takes about four years from two to six. Children start around two years old, progress in stages until about 6 years old when they understand how to count and how to use counting in a near adult manner.

Lipton and Spelke [4] perform experimentation and conclude that early in human development, numerical discrimination is approximate in nature and shows a ratio signature limit. Moreover, infants' numerical representation increases in precision over the infancy period, prior to the onset of language or symbolic counting.

According to Izard, et al. [5] by the age of 4.5 to 6 months infants are able to discriminate between numbers differing in a 1:2 ratio when presented with arrays of dots, sequences of sounds or sequences of actions. According to Starkey et al (cited in Davis et al., 1985), 7 months old infants prefer to look 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. Davis et al. further contend that 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 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. 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. 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.

Davis, et al. [6] 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 drum- beats they hear do not demonstrate a numerical ability. They suggest that the infants responded to numerousness but not to number.

According to Rips, Asmuth, and Bloomfield [7], many investigators believe that children learn the meaning of the positive integers ("1," "2," "3,") by gradually connecting the first three or four number terms with sizes of sets. "One" comes to denote sets containing exactly one object. Awhile later, they learn that "two" denotes sets containing exactly two objects, and so on, for "three" and, perhaps, "four." At this point, however, children arrive at a key insight: the next term in the count sequence refers to the size of sets containing one more object than the size denoted by the preceding term. They further maintain that Children must learn that number terms in phrases like three bears denote the numerosity of a collection. Since they can't learn this connection one-by-one for all the positive integers, they must at some point come to recognize a general connection between the sequences of numerals and numerosities. In this respect, children's learning of numerals seems to differ from that of chimps, who never manage the generalization.

According to Wynn [8], in order to understand the counting system-that is, to know how counting encodes numerosity-children must know the meanings of (some of) the number words. They must also know, at least implicitly, that each word's position in the number word list relates directly to its meaning-the farther along a word occurs in the list, the greater the numerosity it refers to. Without this knowledge, though children might understand the meaning of a given number word, they would not understand how counting determines which number word applies to any given collection of counted entities. Thus children's developing knowledge of the meanings of the number words is a central part of their understanding of the counting system.

Wynn [8] further maintains that the problem that children must solve is that of mapping number concepts onto words. In this, children are faced with the problems inherent to any word-learning task-from an infinity of logically possible meanings, they must somehow infer the correct meaning of a word. This is made more difficult for children by the fact that the number words do not refer to individual items, or to properties of individual items, but rather to properties of sets of items. Yet when we count, we assign a number word to each item, so the child sees an individual item labeled "one," another "two," another "three," etc. Given children's

tendency in such situations to take novel words as names for kinds of individual objects or their properties, it would seem an especially difficult hurdle for children to learn that the number words refer to properties of sets of entities.

According to Riem and Durkin [9] recent research into early number knowledge has focused on the child's ability to perceive numerosity (i.e. manyness) in the environment. Surprisingly little research has been concerned with the context in which children encounter and use the words which label numerosity. Yet the numbers 'one', 'two', 'three' and so on are words which children first hear in the speech of others who are attempting to communicate about sets of everyday objects. It is argued that the acquisition of early number words is located in the course of social interaction, rather than in the independent cognitions of a mini scientist.

According to Brooks, Jia, et al. [10] a distributive representation also has been implicated as part of the conceptual foundation of numerical competence. They maintain that originating with work of the philosophers Frege (1986) and Russell (1919), the idea that one-to-one correspondence is a central feature of the number concept has been held by many scholars. Piaget and Szeminska (1941, cited in Brooks, Jia, Braine, & Dias, 1998) used the number conversation task as a measure of numerical competence: this task examined whether young children understand that two sets of objects placed in one-to-one correspondence are of the same numerosity and remain so despite superficial perceptual transformations. Although preschool-age children typically fail at the number conversation task, other researchers have shown that children at a young age have an implicit understanding of the one-to-one correspondence principle which underlies their ability to count. A canonical feature of the counting routine is that each object to be counted is paired with a unique number word. Gelman and Meck (1983, 1986, cited in Brooks, Jia, Braine, & Dias, 1998) observed that preschool-age children recognize that one-to-one correspondence between numbers and objects is an obligatory characteristic of correct counting.

According to Feigenson, et al. [10] in habituation studies, which rely on a preference for novelty, infants see repeated presentations of a fixed number of items and then are tested with a novel number. An increase in looking time to the novel number suggests that infants discriminated the numerosities. In most of the number habituation studies, the stimuli were sets of visually presented, two-dimensional individuals. For example, Starkey and Cooper (1980, cited in Spelke, 2002) showed 4- to 7-mont hold infants repeated presentations of two dots. During this habituation phase, infants' looking time decreased as they grew bored with the repeated displays. After habituation, infants were tested with two dots vs three. Infants increased their looking to the novel numerosity, but not to the familiar one. The pattern was symmetrical for infants habituated to three dots and tested with two. A two dot versus,

three discrimination has also been shown in newborns. However, infants' success with larger numerosities appears limited, as Starkey and Cooper (cited in Spelke, 2002) found that infants failed to dishabituate to the change between four and six.

Final Remarks

Numerical thinking developed in a pattern of co-evolution of number concepts and counting words, indicating that language played a pivotal role in the emergence of systematic numerical cognition in humans. It is believed that numbers were of integer type and humans gradually developed maniputable real numbers. Infants' numerical representation increase in precision over the infancy period, prior to the onset of language or symbolic counting. Many investigators believe that children learn the meaning of the positive integers ("1," "2," "3,") by gradually connecting the first three or four number terms with sizes of sets. The problem that children must solve is that of mapping number concepts onto words. In this, children are faced with the problems inherent to any word-learning task-from an infinity of logically possible meanings, they must somehow infer the correct meaning of a word.

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