## Language and counting in animals: Stimulus classes and equivalence relations

Ronald J. Schusterman
*Institute of Marine Sciences, Long Marine Laboratory, Santa Cruz, Calif. 95060*

Several of the issues raised by Davis & Pérusse (D & P) regarding numerical competence in animals have counterparts or parallels with animal language research. Indeed, this point was made more than two decades ago when Ferster (1964) attempted to teach the meaning and use of symbols comprising a mathematical language to two chimpanzees. The parallels between the quantitative and language abilities of animals and children have their roots in the metatheoretical, theoretical, and empirical issues currently being raised by comparative psychologists (e.g., see Premack 1986; Terrace 1985). The metatheoretical and theoretical issues appear to be primarily concerned with problems of definition and questions about the continuity of the traits between nonhumans and humans, that is, whether language ability and numerical ability are unique to humans. On the practical and empirical side, the training and testing variables associated with each of these cognitive skills in animals are very similar. For example, both skills depend greatly on subjects being given experience with a wide range of referents or stimulus values of a given category (broadly defined) from which "labels," "tags," "codes," or "names" can be abstracted, generalized, or made equivalent. Furthermore, animals must learn the "rules of the game" in order to qualify as early contenders in demonstrating their abilities to deal with a number system and/or a language system.

D & P are correcting an important deficiency in the field of comparative cognition by delineating different numerical processes. They do this by establishing sets of operations, criteria, and performance levels of numerical processes along an ever-challenging continuum of cognitive requirements. It seems clear from their review that animals (and children) relying on "relative numerousness judgments" and "subitizing" are not using or manipulating an abstract code as they must if they are to have a "concept of number." In terms of a behavioral analysis, each set or class of discriminative stimuli would have to develop into a structured network of stimulus equivalences before a species or an individual would be considered capable of an abstract notion of numerosity. Premack (1983) has recently pointed out that for species that do not have an abstract code, language training is unlikely to instil such a code in the animals (although such training may enhance an animal's ability to use it if such an animal has a genetic predisposition to see abstract, perceptual relationships or second-order relationships). As D & P's target article also clearly indicates, however, an animal's numerical coding or thinking appears to be rooted primarily in perception and memory, that is, a code that depends on imaginal representations (subitizing) rather than on quantitative abstractions (a concept of numbers).

Although I agree with many aspects of D & P's schema for analyzing the cognitive skills necessary for demonstrating numerical competence in animals and children, I disagree with their notion that basic principles of mathematics (e.g., reflexivity, symmetry, and transitivity) are not a necessary component of the concept of number. Rather, I am in accord with Gelman and Gallistel (1978) regarding the idea that number concept (and I might add its counterpart in language – referential meaning – see Savage-Rumbaugh 1986) must include equivalence relations between symbols (cardinal numbers or words, etc.) and objects and events. Such equivalences include the principles of reflexiveness, symmetry, and transitivity. Significant comparative psychological work has already begun in this area. For example, Sidman and his colleagues (Sidman & Tailby 1982; Sidman et al. 1982) have already shown in conditional discrimination tasks that although normal five-year-old humans have no difficulty with symmetrical relations, both adult rhesus monkeys (*Macaca mulatta*) and adult baboons (*Papio anubis*) have great difficulty reversing the relation "if *a*, then *b*" to if *b*, then *a*" without additional training. As a hypothetical example, they would have had difficulty reversing the relation "if the word *ball*, then the object 'ball'" to "if the object 'ball,' then the word *ball*." This finding has been overlooked by D & P and by other researchers working in the area of comparative psychology; (e.g., Roitblat 1987; see also Roitblat: "The Meaning of Representation in Animal Memory" *BBS* 5(3) 1982.]), but without additional research on symmetrical relations (as well as on transitivity) Sidman's findings do not tell us to what extent this failure of Old World monkeys to show equivalent relations between stimuli reflects training variables or species-specific constraints. Since "symbolic" or "arbitrary" matching to sample paradigms have been consistently used in artificial language learning experiments (e.g., Schusterman & Krieger 1984), as well as in numerosity experiments (e.g., Ferster 1964), it is tempting to draw the conclusion that cognitive skills which are basic to *both* the concept of number and referential meaning in animals may be studied profitably with the same procedural model (see Sidman et al. 1982).

Within the context of paired-associate learning and conditional discrimination paradigms, D & P have correctly pointed out that there is a major pitfall when one places emphasis on teaching animals merely to associate cardinal or binary numbers or any other so-called symbol with numerical stimuli (e.g., different numbers of objects). The same cautions apply when psychologists use a variety of symbolic match-to-sample paradigms to get their animal subjects to associate the symbols with objects and events and then appear to imply that their animal subjects (be they parrots, chimpanzees, dolphins, or sea lions) are therefore capable of referential meaning. I will elaborate a bit on this point.

In the area of artificial language comprehension in dolphins (*Tursiops truncatus*), Herman et al. (1984) have, in my opinion as well as in the opinion of others (see e.g., Hoban 1986), prematurely used the term "word" in their description of signs and their associated referents. Although it is true that dolphins and sea lions (*Zalophus californianus*) can correctly choose a ring or a pipe when given a "ring" sign or a "pipe" sign, it has not yet been demonstrated that they can choose the correct signs for ring and pipe when presented with these referents. Thus, stimulus equivalence (at least in terms of symmetry) has yet to be shown for these species. According to Schusterman and Gisiner (1988), the referential meaning of the dolphin and sea lion symbols has not been as well established as that of the chimpanzee lexigrams used in the artificial language research program of Savage-Rumbaugh (1986).

In experiments on numerosity in animals, a similar problem arose with Ferster's (1964) failed attempts to teach chimpanzees to master the language of mathematics. As mentioned earlier, the chimpanzees learned an elaborate association between binary numbers and numerical stimuli but did not acquire the ability of "true" counting in the human sense. Ferster might have achieved this goal if he had systematically trained his chimpanzees first to associate binary or cardinal numbers with numerical stimuli and then trained them on a similar task in which the numbers were symbols for numerical stimuli and numerical stimuli were the meanings of the numbers. Finally, if the chimpanzees acquired transitive relationships in the domains of both number symbols and numerical stimuli ("if $3 > 2$ and $2 > 1$, then $3 > 1$" or "if $x_x x > x^x$ and $xx > x$, then $x^x x > x$"), and these skills were transferable to different situations and modalities, then I believe Ferster would have had chimpanzees that were capable of "true" counting.

Language and quantitative abilities have much in common and a comparative analytic approach like that of Sidman, which considers stimulus classes and equivalence relations in a variety of taxa, will greatly facilitate our understanding of these cognitive skills.