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Review

Abstract concepts: Data from a Grey parrot

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ABSTRACT

Do humans and nonhumans share the ability to form abstract concepts? Until the 1960s, many researchers questioned whether avian subjects could form categorical constructs, much less more abstract formulations, including concepts such as same-different or exact understanding of number. Although ethologists argued that nonhumans, including birds, had to have some understanding of divisions such as prey versus predator, mate versus nonmate, food versus nonfood, or basic relational concepts such as more versus less, simply in order to survive, no claims were made that these abilities reflected cognitive processes, and little formal data from psychology laboratories could initially support such claims. Researchers like Anthony Wright, however, succeeded in obtaining such data and inspired many others to pursue these topics, with the eventual result that several avian species are now considered "feathered primates" in terms of cognitive processes. Here I review research on numerical concepts in the Gray parrot (*Psittacus erithacus*), demonstrating that at least one subject, Alex, understood number symbols as abstract representations of real-world collections, in ways comparing favorably to those of apes and young human children. He not only understood such concepts, but also appeared to learn them in ways more similar to humans than to apes.

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1. Introduction

In the early twentieth century, little scientific interest existed in cognitive processes, even in humans. As a consequence, the study of such processes in nonhumans was also not a viable pursuit. Thus, until the so-called "cognitive revolution" of the 1960s, both ethologists and psychologists, with few exceptions (notably in Europe, e.g., Herz, 1928, 1935; Koehler, 1943), were likely to see nonhumans, and particularly birds, as simple automatons, incapable of complex cognitive processing. Indeed, the term "avian cognition" was considered an oxymoron (see review in Pepperberg, 2011).

Ethologists did accept that birds had to have some understanding of divisions such as prey versus predator, mate versus nonmate,

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food versus nonfood, or basic relational concepts such as more versus less, simply in order to survive. Ethological research, however, was mostly interested in issues such as "fixed action patterns" (e.g., Tinbergen, 1951)—innate, instinctual behavioral sequences that seemed indivisible and that, once begun, could not be stopped until they ran to completion. Such sequences were initiated by external stimuli known as "releasers," and even removing these releasers mid-stream had no effect. Moreover, because objects that only approximated the releasers might set the behavior in motion, nonhumans were considered incapable of recognizing substitutions or reacting to change of any sort.

Similarly, psychologists concentrated on issues such as stimulus–response chains, where almost all behavior could be explained in terms of histories of positive or negative conditioning to increase or decrease, respectively, behavior toward some external situation. The rules underlying behavior were thought to be the same whatever the species (Skinner, 1938), and species differences were expected to arise only in the speed and extent of acquisition of these rules (for interesting discussions of these ideas see Bitterman, 1965, 1975). The focus was ostensibly on learning, but not in the sense of information processing, remembering, problem solving, rule and concept formation, perception, or recognition: learning was seen as behavior simply being *shaped* by the association of external stimuli and their consequences. Scientists eschewed discussions of issues such as thought, mental representations, or intentional actions (Pepperberg, 1999, 2011).

By the 1960s, however, researchers began to realize that the behavior patterns of their subjects (human or nonhuman) could not be fully explained by current paradigms (e.g., Breland and Breland, 1961). After realizing that even *human* actions were neither as pre-wired nor as amenable to shaping as once thought, a small group of researchers began to examine nonhumans in the same manner, suggesting a continuum between human and nonhuman abilities (e.g., Hulse et al., 1968). Psychologists such as Herrnstein started examining issues of concept formation in pigeons (e.g., Herrnstein and Loveland, 1964; Herrnstein et al., 1976), and those like Anthony Wright pushed what was then the edge of the envelope to examine so-called "abstract concepts" of same-different (e.g., Premack, 1978); he and his colleagues (Santiago and Wright, 1984; Wright et al., 1984a,b; see also seminal work from the Zentall lab, e.g., Edwards et al., 1983) tried to separate out issues of same-different from those of match-to-sample and nonmatch-to-sample and whether subjects were responding on the basis of novelty or other aspects of the task rather than the abstract concept. Specifically, a subject that understands same/different not only knows that two nonidentical blue objects are related in the same way as are two nonidentical green objects—in terms of color—but also knows that the relations between two nonidentical blue objects and two nonidentical square objects are based on the *same* concept but with respect to a *different* category, and, moreover, can transfer this understanding to *any* attribute of an item (Premack, 1978, 1983). Inspired by the research of scientists like Wright and Zentall, my own studies on Gray parrots showed their capacity to understand concepts of category and of same-different (Pepperberg, 1983, 1987a)—and of the absence of same-different (Pepperberg, 1988)—at levels comparable to those of nonhuman primates.

Once Wright, his collaborators, and colleagues helped demonstrate that abstract concept formation was a legitimate area for study in nonhumans, many of us followed their lead to examine other abstract concepts as well. One path that my laboratory took involved the study of a Gray parrot's number concepts. To succeed on number concepts, the bird would have to reorganize how objects were categorized in its world. Specifically, an object would not only be, for example, something to eat or manipulate, or of a specific color or shape, but also would have to be *labeled* with respect to its membership within a quantifiable set, if exact number competence were to be shown. Could a nonhuman acquire that level of abstract understanding? I was hardly the first to study number concepts in nonhumans or even birds, but was the first to examine whether an avian subject could use human number labels symbolically and referentially, to identify exact quantities (see Pepperberg, 2012b). I likely would not have done so had others like Wright not led the way.

Numerical abilities involve many issues. Even for humans, some researchers still disagree on what constitutes various stages of numerical competence; which are the most complex, abstract stages; what mechanisms are involved; and even what is enumerated (for a detailed review, see Carey, 2009). And considerable discussion exists as to the extent to which language—or at least symbolic representation—is required for numerical competence, not only for preverbal children but also for primitive human tribes and nonhumans (e.g., Gordon, 2004; Watanabe and Huber, 2006; Frank et al., 2008). If language and number skills require the same abstract cognitive capacities, then animals, lacking human language and, for the most part, symbolic representation, should not succeed on abstract number tasks; an alternate view is that humans and animals have similar simple, basic number capacities but that only humans' language skills enable development of numerical representation and thus abilities such as verbal counting and addition (see Pepperberg, 2006b; Carey, 2009; Pepperberg and Carey, 2012).

But what if a nonhuman had already acquired a certain level of abstract, symbolic representation? Could such abilities be adapted to the study of numerical competence? Again, with the inspiration and encouragement from colleagues such as Wright, I decided to find out. Here I begin by discussing briefly the background studies with my Gray parrot, Alex, then review the accumulated data that demonstrate the extent of abstract number competence he achieved.

2. Alex's non-numerical capacities

When I first began numerical work with Alex in the 1980s, he had already achieved competence on various tasks once thought limited to young children or at least nonhuman primates (Pepperberg, 1999). Through the use of a modeling technique, roughly based on that of Todt (1975), Alex learned to use English speech sounds to referentially label a large variety of objects and their colors; at the time he could also label two shapes ("3-corner" for triangles, "4-corner" for squares; later he identified various other polygons as "*x*-corner"). He understood concepts of category: that the same item could be identified with respect to material, color, shape, and object name (e.g., "wood", "blue", "4-corner", and "block"). He had functional use of phrases such as "I want X" and "Wanna go Y", X and Y being appropriate object or location labels. He was acquiring concepts of *same*, *different*, and *absence*—for any object pair he could label the attribute ("color", "shape", and "matter") that was same or different, and state "none" if nothing was same or different; he was also learning to view collections of items and state the attribute of the sole object defined by two other attributes—e.g., in a set of many objects of which some were yellow and some were pentagonal, to label the material of the only one that was both yellow *and* pentagonal (Pepperberg, 1999). But could he form an entirely new categorical class consisting of quantity labels?

3. Alex's early numerical abilities

As noted above, to succeed on number concepts, Alex would have to reorganize how he categorized objects in his world. He would have to learn that a new set of labels, "one", "two", "three", etc. represented a novel classification strategy; that is, one based