

Mechanisms of *same/different* concept learning in primates and avians

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Abstract

Mechanisms of *same/different* concept learning by rhesus monkeys, capuchin monkeys, and pigeons were studied in terms of how these species learned the task (e.g., item-specific learning versus relational learning) and how rapidly they learned the abstract concept, as the training set size was doubled. They had similar displays, training stimuli, test stimuli, and contingencies. The monkey species learned the abstract concept at similar rates and more rapidly than pigeons, thus showing a quantitative difference across species. All species eventually showed full concept learning (novel-stimulus transfer equivalent to baseline: 128-item set size for monkeys; 256-item set for pigeons), thus showing a qualitative similarity across species. Issues of stimulus regularity/symmetry, generalization from item pairs, and familiarity processing were not considered to be major factors in the final performances, converging on the conclusion that these species were increasingly controlled by the sample-test relationship (i.e., relational processing) leading to full abstract-concept learning.

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The purpose of this article is to compare the ways in which rhesus monkeys, capuchin monkeys, and pigeons learn a similar *same/different* (S/D) task and the abstract S/D concept. The individual species data has been published in considerably greater detail than presented here (see Katz and Wright, 2006; Katz et al., 2002; Wright et al., 2003). The present analyses cut across the species results to show what we believe are general principles in how these species (and presumably other species) learn an abstract S/D concept when they are trained and tested with an expanding training set of distinctive picture stimuli. In addition to showing that these species do have the cognitive capacities to learn an abstract S/D concept, we show the training and testing stimulus sets so that readers can judge the distinctiveness of the test stimuli from the training stimuli. We also do a meta-analysis on the successive acquisitions by the animal species and present human similarity ratings of the stimuli which (in our opinion) converge on the conclusion that in these experiments generalization is not a primary factor in explaining the high level of transfer that is shown following training with large stimulus sets. Before

presenting these analyses and results we discuss our rationale for studying abstract S/D learning, choice of species, training and testing procedures, and abstract-concept criteria.

The ability to judge two things as either the *same* or *different* has a special role in the development of abstract cognitive thinking (e.g., equivalence, conservation of area, volume, and number: Daehler and Bukatko, 1985; Marcus et al., 1999; Piaget and Inhelder, 1969; Siegler, 1996). Such abstract thinking forms the rudimentary basis of mathematical operations based on equivalence. Learning elementary equivalence relationships can provide the basis for more complex strings of equivalent operations involved in novel sentence construction and novel sequences of mathematical operations (e.g., Chen and Mo, 2004; Smith et al., 1992). This generalization of equivalence carries forward into adult years and apparently forms the “very keel and backbone of our thinking” as James (1950) proclaimed more than one hundred years ago (p. 459).

Like all abstract concepts, the S/D abstract concept is a rule about relationships (e.g., identity) among stimuli and is in sharp contrast to so-called “natural” concepts (e.g., water, trees) based upon common features that unify categories of objects. Abstract concepts transcend any individual features of the stimuli and depend instead upon the relationship between the stimuli being judged. The ability to judge relationships that transcend stimulus features is thus considered higher-order learning.

Humans are arguably the most adept species at learning abstract concepts and other feats of intelligent processing. Other

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animal species have long been considered less adept at learning abstract concepts and less intelligent. There is a long tradition from Darwin (1859) and Romanes (1892) to compare intelligence of different species and more recently to use concept learning abilities of different species as a measure of intelligence or general cognitive ability (e.g., D'Amato et al., 1985; Herman et al., 1989; Herrnstein, 1990; Premack, 1978, 1983a,b; Thomas, 1980, 1996; Thompson, 1995; Thompson and Oden, 2000). Some species (e.g., pigeons) have been thought to be totally deficient in abstract-concept learning, whereas others (monkeys, dolphins, etc.) have been considered only partially deficient relative to humans. Abstract-concept learning and abstract thinking may be dependent upon specially evolved cognitive (brain) structures or cognitive “modules” to perform these higher-order cognitive tasks (e.g., Cosmides and Tooby, 1994; Geary and Huffman, 2002; Gigerenzer, 1995, 1997; Hermer and Spelke, 1996; Wagner and Wagner, 2003).

Despite claims that some species are deficient in their ability to learn abstract concepts, recent technological and procedural advances in testing animals have enabled us and others to show that some species originally thought to be deficient in abstract-concept learning actually *do* have this ability (e.g., Bhatt and Wright, 1992; Bovet and Vauclair, 2001; Katz and Wright, 2006; Katz et al., 2002; Pepperberg, 1987; Wright et al., 1984a, 1990, 2003). Among some of the advances in testing concept learning have been improved procedures for testing a species capacity for concept learning. These include aspects of the training and testing procedures as well as performance criteria on transfer tests.

In our opinion, a subject that has learned an S/D concept ought to be able to perform as accurately with novel stimuli as with training stimuli. Anything less, then it is hard to say what is controlling behavior because some of the behavior, some of the time, is being controlled by item-specific cues (e.g., features of the training stimuli or training pairs) and not by the relationship between each item pair. Thus, we consider a finding of partial concept learning, where transfer performance is between chance and baseline performance an inconclusive result. Nevertheless, any claim of concept learning (partial or full) needs to be based upon performance with stimuli that have never been seen before (i.e., novel) and are as distinctive from the training stimuli as possible. The necessity that the stimuli be novel—is obvious. If transfer stimuli are repeated, then learning has the potential to confound transfer. One cannot escape this confound by conducting transfer trials in extinction (because all presentations produce a history of reinforcement), or by simply reporting what happened on the first presentations of a small number of transfer stimuli (because there will be little if any statistical power).

Another factor that may be critical in adequately testing whether some species has the ability to learn an S/D abstract concept is what the subjects actually do in the task (i.e., what is controlling behavior). We have found that when small numbers of training stimuli are used, subjects typically learn the correct response to each individual stimulus pair (item-specific learning) rather than the S/D relationship between the stimuli of each pair (relational learning). In tasks with simultaneously presented arrays of *same* or *different* stimuli, subjects could use emergent

patterns from a whole array (e.g., regularity of a matrix of *same* stimuli) rather than the S/D relationship between stimulus pairs. (These issues will be further discussed later.)

In consideration of these issues, we used pairs of stimuli in our S/D concept-learning experiments. We used picture stimuli that were multidimensional and distinctive from other pictures in a large stimulus pool, so that similarities within and across trials would be less likely to confuse our subjects. A large pool of distinctly different picture stimuli also means that there were plenty of novel stimuli for transfer testing. As to the size of the training set, we wanted to begin with a sufficiently small set to insure that all subjects (particularly pigeons) could learn the task. At the same time, we wanted to insure that all subjects would base their decisions upon the relationship between the stimuli and not over-learn individual item pairs. Therefore, we would eventually need a large set in order to train with many exemplars of the S/D concept. These considerations led us to make the training set a parameter of the experiment. We began training with a small set of eight stimuli. Following learning and transfer testing, we expanded the set, trained and tested again, then cycled through expansion-training-testing several more times. This regime allowed us to expand the training set virtually without limit, should more exemplars be needed to resolve whether the limit would be partial concept learning or “full” concept learning where transfer was equivalent to baseline performance. In our view, only if transfer can be shown to be equivalent to baseline (and both performances are above 80% correct), can one be reasonably sure that the subjects are basing their choices on the relationship between the transfer stimuli just as they were with the training stimuli. We have used the term “full” concept learning for such cases so that it will be contrasted with partial concept learning where transfer is at a level between chance and baseline (Katz et al., 2002; Wright, 1991; Wright et al., 1984b, 2003).

We trained and tested three species for S/D abstract-concept learning: Rhesus monkeys (*Macaca mulatta*), capuchin monkeys (*Cebus apella*), and pigeons (*Columba livia*). Rhesus monkeys (an old-world monkey species) are the standard laboratory monkey and human model for much of the cognitive neuroscience research. Rhesus monkeys have previously shown full S/D abstract concept with a large set of 210, 35-mm slides (via carousel projectors) and a response lever (Wright et al., 1984a,b).



Fig. 1. Trial displays for the three species. A touch/peck to the bottom picture was correct on *same* trials (left display). A touch/peck to the gray rectangle (white on black screen in the actual task) was correct on *different* trials.

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