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COMPARATIVE COGNITION IN MARINE MAMMALS: A CLARIFICATION ON MATCH-TO-SAMPLE TESTS

When considering the intelligence of various animal taxa, cetaceans are often included in the forefront and considered by some to be comparable to primates in cognitive ability. In comparative psychology, higher order learning abilities such as language acquisition and abstract thought are often considered to be exclusively human traits. Much recent research has been designed to test these abilities in diverse animal taxa, including marine mammals (*e.g.,* Schusterman *et al.* 1986). Attention has been focused on experiments designed to determine the ability of animals to form abstract concepts, involving the generalization of a particular problem-solving strategy on the basis of experience with a few examples of a particular problem. The strategy learned from certain situations should transcend the specificity of the problems themselves.

Within an ecological context, the ability to acquire concepts carries with it far-reaching implications. Instead of treating each environmental stimulus as a unique event, a tremendous economy in information processing is attained if an animal can organize certain stimuli as members of a single class. For instance, foraging efficiency, navigational skills, and predator recognition could all be improved provided an animal could generalize capabilities learned by solving a particular problem. In a sociobiological framework, such improvements may also take place in individual, kin, and species recognition, as well as assessing the suitability of mates and the size and aggressiveness of potential opponents. Specifically, abstract concepts such as *same/different,* relational concepts such as *larger than/smaller than,* and perceptual concepts such as *animal/non-animal,* or *fish/non-fish* should allow an animal to increase its own fitness, by adapting rapidly to changing environmental conditions.

At present, laboratory experiments are the principal way to test an animal for its ability to acquire concepts [but see Cheney and Seyfarth (1990) for imaginative field techniques in the study of animal cognition]. Perhaps the most common procedure is the matching-to-sample (MTS) paradigm. In a visual MTS experiment, the subject must choose a stimulus which is visually identical to a sample stimulus. After exposure to the sample, the animal is given a choice of comparisons (usually two) from which to choose. Choosing the correct comparison stimulus (S+) results in reinforcement, while selection of the nonidentical comparison (S−) is not reinforced.

Researchers conducting MTS experiments often assume that an identity relation between sample and comparison exerts control over the subject's choice behavior, that is, the subject is applying an abstract "sameness" concept to the problem. Instead, such identity relations may be learned initially as conditional discriminations (or *if . . . then* rules). The major difference between the conditional relation and true identity matching lies in the fact that in a conditional relation, the sample and correct comparison may not be viewed as equivalent. Through experience with additional examples of matching stimuli, however, a concept of "identity" or "sameness" may emerge. Emergence of this concept is often referred to as generalization of identity matching. In order to demonstrate generalized matching, the subject must immediately and with a high degree of accuracy match identical pairs of stimuli in novel situations. This is tantamount to being able to solve any novel problem of this particular type, regardless of specific aspects of the stimuli used.

Recent experiments demonstrate some degree of generalized identity matching in non-human animals. However, explanations other than the animal having acquired an abstract identity relation between sample and comparison may account for the rapid positive transfer shown in these studies. The experimental designs in tests for concept formation must take into account confounding factors such as the effects of exclusion, which may provide misleading results.

Earlier critics attributed successful matching performance of pigeons to such factors as stimulus generalization or attendance to absolute stimulus properties (Carter and Werner 1978). In identity generalization experiments with pigeons, two factors have been reported as being important in their performance (Holmes 1979). First, novel stimulus presentation was found to disrupt matching performance, especially when two novel comparisons were presented. Second, generalization showed a marked improvement when one of the comparison stimuli was familiar to the animal (*i.e.,* a previously learned stimulus). Recent research in the area of "exclusion" (McIlvane *et al.* 1987; Schusterman *et al.,* in press) confirms the fact that conditional relationships may appear to form almost immediately when the subject is placed in a test situation involving both novel and familiar comparison stimuli.

In order to illustrate how a subject might seemingly transfer an identity relationship to novel problems, consider the following experiment—the subject in this case is taught to match geometric shapes, and after a period of training, has learned the following conditional relationships: if the sample stimulus is a square, then the correct comparison is a square; if the sample is a triangle, then triangle is the correct comparison. A transfer test might be set up in the following way—the sample stimulus, as well as the correct comparison, is a novel shape (circle), and the incorrect comparison is either a square or a triangle. The subject is likely to respond correctly to the circle-shaped comparison; however, it is not clear that an identity relation is the controlling factor in this particular instance. Rather, the subject is likely responding to "not triangle" or "not square" when presented a sample which is likewise neither a triangle nor a square. A simple test to determine whether the animal is responding in this fashion would consist of presenting a novel sample (*e.g.,* circle), and two novel comparisons (*e.g.,* circle and hexagon) on the same trials. In this case, there is no basis for the use of exclusion and consistently correct responding would be indicative of concept formation. Analysis of this type of problem indicates that choices of a novel S+ on a MTS trial frequently depend on eliminating the familiar S− as a choice. Responding to the correct (novel S+) stimulus in a test for identity generalization may thus be controlled not by the identity relationship between the sample and the comparison, but by the different experimental histories of the novel S+ comparison and the familiar S− comparison (Dube *et al.* 1992).

In recent work, Herman *et al.* (1989) and Pack *et al.* (1991) report successful transfer of visual identity matching in a bottlenosed dolphin (*Tursiops truncatus*) and a California sea lion (*Zalophus californianus*), respectively. Based on the effects of exclusion, however, alternate explanations may exist which account for the animals' "quick" or "immediate" transfer of an "abstract relationship." A novel test stimulus given to the dolphins was usually presented along with a familiar stimulus, which may have signalled the dolphin to exclude the familiar S− in the presence of a novel sample. Alternatively, the dolphin may have chosen novel comparisons in the presence of novel samples without focusing on the identity relation between the sample and the S+.

In one respect, the Pack *et al.* (1991) study introduced test stimuli in the same manner as Herman *et al.* (1989) did with the dolphin—singly at first (for two "partial" transfer tests), and then in pairs (providing no familiar comparisons) for an additional four tests. As in the case of pigeons, performance on "partial" transfer tests by the sea lion and dolphin exceeded that of completely novel tests. Here again, the effect of exclusion provides what is perhaps a more parsimonious explanation than abstract concept formation. We should also point out that Pack *et al.*'s (1991) sea lion never made a correct response on trial one of a novel identity problem, which is considered the most stringent test of transfer (Wright *et al.* 1988, Herman *et al.* 1989).

Ongoing identity matching experiments with two California sea lions at our laboratory also suggest that exclusion can play a major role in the way that the animals solve initial identity problems. We believe that in any test for identity generalization, test stimuli must be introduced in pairs, in order to negate the effects of exclusion or the possibility of the animal responding on the basis of a novel-novel relation rather than an identity relation. We agree that the use of first trial data is also necessary for any clear-cut interpretation of *spontaneous* generalization or transfer of the identity concept. Therefore, a large pool of test stimuli is required for an accurate assessment of trial-one performance, in order to avoid possible effects of repeated reinforcement (or non-reinforcement) on the subject's performance.

Without standardizing laboratory MTS tests of transfer relations, there are alternative interpretations of supposed abstract concept formation. This certainly does not mean that sea lions and dolphins are incapable of such cognitive processes [for instance, Herman *et al.*'s (1989) dolphin chose the correct comparison 10 out of 12 times on first trials on a subsequent transfer test (exp. 3)], but more rigorous analysis may help clarify the issues and lead to a better understanding of comparative cognition in marine mammals.

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