

Equivalence class formation and cross-modal transfer: testing marine mammals

Ronald J. Schusterman¹, David Kastak² and Colleen Reichmuth²

¹ *Departments of Psychology and Biology, California State University, Hayward, California 94542, U.S.A., and Long Marine Laboratory, 100 Shaffer Road, Santa Cruz, California 95060, U.S.A.*

² *Long Marine Laboratory, 100 Shaffer Road, Santa Cruz, California 95060, U.S.A. E-mail: kastak@cats.ucsc.edu*

Summary

Several investigators have recently demonstrated cross-modal performance and stimulus equivalence in bottlenose dolphins and California sea lions, respectively. These abilities were previously thought to exist only in linguistic humans. We discuss the ramifications of such cognitive capabilities in the natural histories of marine mammals, and suggest that individual and kin recognition, rather than language, are the mediators of equivalence class formation.

Key words: cross-modal performance, equivalence class, functional class, matching-to-sample, stimulus equivalence

Introduction

We do not know precisely how most marine mammals learn to locate, track and capture their prey, navigate in the open ocean, or recognize individuals, but some cognitive capacities may be involved. Imagine, for instance, a sea lion pup on a crowded rookery learning to recognize its mother soon after birth (see Schusterman *et al.*, 1992). Very early in its training the pup may fail to discriminate adequately and find itself confused in an encounter with an aggressive female. Within a short time, however, the pup develops a class or concept of "mother" that is relatively invariant and that excludes all other adult female sea lions. This training likely came about through the association of the characteristics of the pup's mother (sound, smell, touch, and sight) with very powerful reinforcers (milk, the action of

suckling, protection, warmth). As Wasserman and DeVolder (1993) have recently pointed out, concept learning concerns a many-to-one mapping of stimuli to responses. Thus, several different members of a stimulus class (the sound, smell, touch and sight of the mother) would then be associated with the same response: "mother". In the laboratory it has been found that perceptual categories, in which stimulus members resemble one another physically, can be formed by a variety of nonverbal animals and children. Breadth of learning, that is, responding to novel examples of a category, is directly related to the number of examples used for training a given category (Bhatt, 1988).

However, demonstrations of the ability of nonhumans to sort perceptually *dissimilar* stimuli into the same class are rare. This is, in

Sensory Systems of Aquatic Mammals (1995)

R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (editors)

De Spil Publishers, Woerden, The Netherlands ISBN 90-72743-05-9

fact the problem faced by an infant sea lion: it must learn to recognize its mother based on a variety of perceptual cues, only one of which (e.g., an acoustic cue) need be present at a given time for successful recognition to occur (Schusterman *et al.*, 1992; Trillmich, 1981). Most human subjects, on the other hand, are easily able to sort stimuli into classes based on relationships that exclude physical resemblance. The classes are formed on the basis of common function or common context or association. Until recently it had been believed that only verbal humans were capable of placing dissimilar stimuli into the same class, because they possessed the ability to code their world linguistically. They could transform dissimilar stimuli into a common code by making them meaningfully similar via their language mediating abilities. In contrast, since non-humans and infants do not have language they are thought to be unable to place stimulus members that have little or no physical resemblance into common functional or contextual classes (Hayes, 1989). Recently, however, Schusterman and Kastak (1993) demonstrated that a California sea lion (*Zalophus californianus*) can place a variety of shapes having no physical resemblance into the same category. Thus, we now have powerful evidence for a cognitive mechanism (functional or equivalence class formation) by which individual recognition through a variety of modalities might occur. Indeed, individual recognition across a variety of sensory modalities may be the critical developmental requirement in group living animals such as California sea lions. This type of recognition gives rise to the refinement of cognitive skills facilitating equivalence class formation. The same skills that enable the pup to represent its mother's distinctive odor and visual appearance when it has only heard her voice may later enable the mature sea lion to recognize its sisters through their

relationship with their mother and each other. There is evidence that captive California sea lions exhibit such kin recognition (Hanggi and Schusterman, 1991), and it is reasonable to hypothesize that this ability depends on the formation of equivalence classes (Schusterman and Kastak, 1993).

Cross-modal transfer, stimulus equivalence and matching-to-sample (MTS)

Sea lions, harbor seals, and walrus can do many things with their facial vibrissae, including using them to ascertain the shape and size of objects (Dehnhart, 1990; Kastelein, 1988). Imagine that a sea lion's whiskers, or a primate's hands are used to determine the shape and/or texture of an object without the aid of vision. It may do this by matching that sample object with an identical comparison object instead of choosing a nonmatching comparison (different shape and texture). This procedure is called identity matching-to-sample (IMTS). If an animal should learn to match with a number of training stimuli, then immediately transfer its learning of identity matching to novel identity relations we may conclude that the animal has passed a test of reflexive identity (Kastak and Schusterman, 1994). Such concepts can be demonstrated in a number of sensory modalities including tactile, visual, auditory, gustatory, and olfactory. If the same results could be achieved with animals who had been trained on tactile stimuli and tested with identical visual stimuli, then the animals would have demonstrated a tactile/visual cross-modal reflexive identity.

Although cross-modal object matching of the type just described has been found in nonhuman animals, the results and interpretations of such studies have been problematic (see Ettliger and Wilson, 1990, for a review). Positive results provide evidence of cross-modal recognition (that is, an object

perceived in one modality is identified in another), and cross-modal matching, in which samples and comparisons are of different modalities. However, there have been no unequivocally successful studies which examined the performance of animals on cross-modal object matching problems in which samples and their corresponding comparisons showed little physical resemblance. In fact, until a recent study by Bush (1993), the ability to transfer such arbitrary relations across modalities had not been shown even in human children (Cairns and Coll, 1977; Cote and Schaefer, 1981; Solso and Raynis, 1982). Matching in this type of problem depends on training that establishes the choice of comparison B conditionally upon sample A and is called arbitrary matching-to-sample (AMTS). Because the sample object and the comparison object are dissimilar they can only be linked associatively. For example, the sample A might be accessed tactually (without visual access) while the comparison B might be accessed visually (without tactile access). Comparing the transfer abilities of subjects doing tactile/visual cross-modal tasks using the IMTS paradigm versus the AMTS paradigm should enlighten us about the role associative learning plays in the development of stimulus equivalence based on different perceptual experiences.

Sidman and Tailby (1982) used a series of behavioral tests to determine whether conditional relations established with a MTS format were also equivalence relations. The criteria they used were the properties of reflexivity (discussed above), symmetry and transitivity. Symmetry tests the ability of an animal to recognize the bidirectionality of the sample-comparison relation. Thus, after AB training, the animal is tested for BA matching. Associative transitivity tests require three stimuli. If the animal is trained to

perform AB and BC matching, then transitivity is demonstrated by untrained AC matching. After training on a subset of conditional relations (AB and BC), a subject demonstrates equivalence if the symmetrical (BA and CB), transitive (AC), and equivalence (CA) relations emerge without direct training.

Using AMTS and IMTS paradigms Schusterman (1990) presented a simple model based on Sidman and Tailby's (1982) concept of stimulus equivalence to test the notion of acoustic/visual/echoic cross-modal stimulus equivalence in bottlenosed dolphins. In light of the recent demonstration of a California sea lion passing stimulus equivalence tests (Kastak and Schusterman, 1994; Schusterman and Kastak, 1993) and recent findings by Harley *et al.* (this volume) and Herman and Pack (1992) on echoic/visual cross-modal recognition by bottlenose dolphins, it is reasonable to extend the paradigm of stimulus equivalence to the study of marine mammal perception. Bush (1993) tested 6 and 7 year old children on cross-modal matching-to-sample, and concluded that the conditional relations generated across modalities can satisfy the criteria for equivalence relations.

However, many investigators believe that there is a fundamental difference in cross-modal matching ability between humans and nonhumans or nonverbal humans. It can be argued that the type of cross-modal performances demonstrated by infants and non-humans is categorical (Ettlinger and Wilson, 1990, Sepehr *et al.*, 1988). That is, success in these tasks may have been due to the categorization of perceptual characteristics of the test stimuli (flat or round edges, corners, overall duration, etc.) rather than on physical identity (of shape to shape) or analogy (of temporal acoustic sequences to vi-

sual patterns). Because most animal studies use an identity format in which perceptual categorization remains uncontrolled, it is difficult to compare the cross-modal performances of humans and non-humans. Within humans, however, the rates of learning cross-modal vs. within-modal tasks do not appear to be different, and improvements in cross-modal performance are directly related to improvements in within-modal performance (Hulme *et al.*, 1983; Milner and Bryant, 1970). These results strongly suggest that the two processes are not fundamentally different. Consequently, unequivocal evidence of non-human cross-modal abilities rivaling those of verbal humans will emerge only from an arbitrary cross-modal task in an equivalence paradigm. Such attempts are likely to be most successful in species with highly developed multisensory skills, particularly those in whose survival depends on such abilities as individual recognition.

If some marine mammal species are capable of forming cross-modal equivalence classes (by treating all members of a class as equivalent regardless of modality) then it is reasonable to propose equivalence as a mechanism through which many natural problems are solved. Equivalence class formation thus provides a model allowing examination of the aforementioned pup's behavior. If equivalence does play a role in the recognition of individuals, then its study also provides a useful basis with which to examine other facets of social cognition (for example, alliance formation in dolphins) in addition to ecological learning (navigation or prey capture). Detailed laboratory investigations of cross-modal matching ability are the logical first steps in elucidating such mechanisms.

Acknowledgements

Financial support during the preparation of this manuscript was provided by grant number N00014-92-J-1970-P00 from the Office of Naval Research to RJS as well as a grant from the Center for Field Research (Earthwatch). We thank Murray Sidman for many thought provoking discussions about equivalence relations.

References

- Bhatt, R.S. (1988) Categorization in pigeons: Effects of category size, congruity with human categories, selective attention and secondary generalization. Ph.D. thesis: Iowa City: University of Iowa.
- Bush, K.M. (1993) Stimulus equivalence and cross-modal transfer. *The Psychological Record*, 43, 567-584.
- Cairns, S.E. and Coll, P. (1977) The role of visual imagery in visual, tactual and cross-modal matching. *British Journal of Psychology*, 68, 213-214.
- Coté, J.J. and Schaefer, E.G. (1981) Perceptual processing strategies in the cross-modal transfer of form discrimination: A developmental study. *Journal of Experimental Psychology*, 7, 1340-1348.
- Dehnhardt, G. (1990) Preliminary results from psychophysical studies on the tactile sensitivity in marine mammals. In: *Sensory Abilities of Cetaceans: Laboratory and Field Evidence* (Eds. Thomas, J.A. and Kastelein, R.A.). Plenum Press, New York, 435-446.
- Ettlinger, G. and Wilson, W.A. (1990) Cross-modal performance: behavioural processes, phylogenetic considerations and neural mechanisms. *Behav. Brain Res.*, 40, 169-192.

- Hanggi, E.B. and Schusterman, R.J. (1990) Kin recognition in captive California sea lions (*Zalophus californianus*). *Journal of Comparative Psychology*, 104, 368-372.
- Hayes, S.C. (1989) Nonhumans have not yet shown stimulus equivalence. *J. of the Experimental Analysis of Behav.*, 51, 385-392.
- Harley, H.E., Xitco, M.J. Jr. and Roitblat, H.L. (1995, this volume) Echolocation, cognition, and the dolphin's world. In: *Sensory Systems of Aquatic Mammals*. (Eds. Kastelein, R.A., Thomas, J.A. and Nachtigall, P.E.). De Spil Publishers, Woerden, The Netherlands.
- Herman, L.M. and Pack, A.A. (1992) Echoic-visual cross modal recognition by a dolphin. In: *Marine Mammal Sensory Systems* (Eds. Thomas, J.A., Kastelein, R.A. and Supin, A.Ya). Plenum Press, New York, 709-726.
- Hulme, C., Smart, A., Moran, G. and Raine, A. (1983) Visual, kinaesthetic and cross-modal development: relationships to motor skill development. *Perception*, 12, 477-483.
- Kastak, D. and Schusterman, R.J. (1994) Transfer of visual identity matching-to-sample in two California sea lions (*Zalophus californianus*). *Animal Learning and Behavior*, 22, 427-435.
- Kastelein, R.A. and v. Gaalen, M.A. (1988) The sensitivity of the vibrissae of a Pacific walrus (*Odobenus rosmarus d.*), Part 1, *Aquatic Mammals*, 14, 123-133.
- Milner, A.D. and Bryant, P.E. (1970) Cross-modal matching in young children. *Journal of Comparative and Physiological Psychology*, 71, 453-458.
- Schusterman, R.J. (1990) Stimulus equivalence and cross-modal perception: A testable model for demonstrating symbolic representations in bottlenose dolphins. In: *Sensory Abilities of Cetaceans: Laboratory and Field Evidence* (Eds. Thomas, J.A. and Kastelein, R.A.). Plenum Press, New York, 677-683.
- Schusterman, R.J., Hanggi, E.B. and Gisiner, R. (1989) Acoustic signalling in mother-pup reunions, interspecies bonding and affiliation by kinship in California sea lions (*Zalophus californianus*). In: *Marine Mammal Sensory Systems* (Eds. Thomas, J.A., Kastelein, R.A. and Supin, A.Ya.). Plenum Press, New York, 533-551. Leading Adjustment
- Schusterman, R.J. and Kastak, D. (1993). A California sea lion (*Zalophus californianus*) is capable of forming equivalence relations. *The Psych. Rec.* 43, 823-839.
- Sepehr, M.M., Brown, J.V., Ettlinger, G. and Skreczek, W. (1988) The relationship between metaphoric and cross-modal abilities during development. *International Journal of Neuroscience*, 38, 53-67.
- Sidman, M. and Tailby, W. (1982) Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior*, 37, 5-22.
- Solso, R.L. and Raynis, S.A. (1982) Transfer of prototypes based on visual, tactual and kinesthetic exemplars. *American Journal of Psychology*, 95, 13-29.
- Trillmich, F. (1981) Mutual mother-pup recognition in Galapagos fur seals and sea lions: cues used and functional significance. *Behavior*, 78, 21-42.

Wasserman, E.A. and DeVolder, C.L. (1993)
Similarity- and nonsimilarity-based conceptualization in children and pigeons. *The Psychological Record*, 43, 779-794.