

How Animals Classify Friends and Foes

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Abstract

A model of stimulus equivalence, which describes how non-similarity-based categories are formed, is used to describe aspects of animal social and communicative interactions such as kinship, friendship, coalitions, territorial behavior, and referential calling. Although this model was originally designed to deal with stimulus relations in linguistic behavior, it can be readily applied to understanding the cognitive mechanisms that underlie social as well as non-social categorizations in numerous taxa. This approach provides a new, parsimonious, and experimentally based understanding of how animals without language deal with problems of classification in their environment.

Keywords

stimulus equivalence; social cognition; referential communication; aggression; kin recognition

The brain's imposition of meaning upon a jumbled array of information can be a powerful tool. One way the brain uncomplicates the world is through classification, or the division of items into categories. True classificatory behavior depends on the learned equivalence of stimuli, whether they are perceptually similar or not. Stimuli that are not perceptually similar may be classified together because

of spatiotemporal or functional relationships. Humans generally classify information linguistically; however, there are precursors to our own classifying ability that do not depend on linguistic coding. There is accumulating evidence that animals without linguistic ability can form non-similarity-based categories, and indeed use them frequently during their social and communicative encounters. One can imagine large brains evolving in animals because of the adaptive value of some aspects of reasoning. For example, animals that live in social groups may benefit by performing complex classifications that allow them to recognize not only other individuals but also relationships between individuals. The ability to gauge degrees of relatedness or association between individuals can confer increased fitness because responding appropriately in social contexts leads to increased survival and reproductive success.

We argue that a model of stimulus equivalence (Sidman, 1994) can effectively and parsimoniously describe the way nonlinguistic animals classify friends and foes. In addition to providing a framework to describe social behavior, this relational learning model can be applied to understanding how animals conceptualize nonsocial features of the environment to solve problems in nature as well as in the laboratory. Many species in different contexts may use such cognitive processes because decision making based on inferences about the future can confer a selective advantage to an individual.

THE CONCEPT OF EQUIVALENCE

The equivalence principle may be broadly defined as follows: Equivalence refers to relations between things, such as signals, objects, behaviors, or individuals, that become mutually interchangeable, or acquire the same meaning, through common spatiotemporal or functional interactions. The term stimulus equivalence appeared irregularly in the literature of the behavioral sciences until Sidman (1971) reintroduced the concept. He used this term to describe and interpret the emergence of reading comprehension in a severely retarded teenage boy. In a procedure called match-to-sample (MTS), Sidman's subject was trained to select both pictures of objects and printed names of objects (comparison stimuli) upon hearing the spoken object names (sample stimuli). Sidman found that this training generated emergent performance, that is, the appearance of sample-comparison relations that were not directly trained. For example, following the original training, printed words and pictures could serve as sample and comparison stimuli to each other in the absence of the spoken object names. The original training had generated equivalencies between the objects and written words, which, together with the spoken words, had formed three-member equivalence classes.

A schematic diagram of Sidman's original procedure for training and testing for equivalence relations is shown in Figure 1. In this procedure, reward training of relations $B \rightarrow A$ and $B \rightarrow C$ (where arrows represent connections between sample and comparison stimuli) generated emergent performance on relations that were not explicitly trained. A variant of this procedure trains two sequential relations, $A \rightarrow B$ and $B \rightarrow C$. The re-

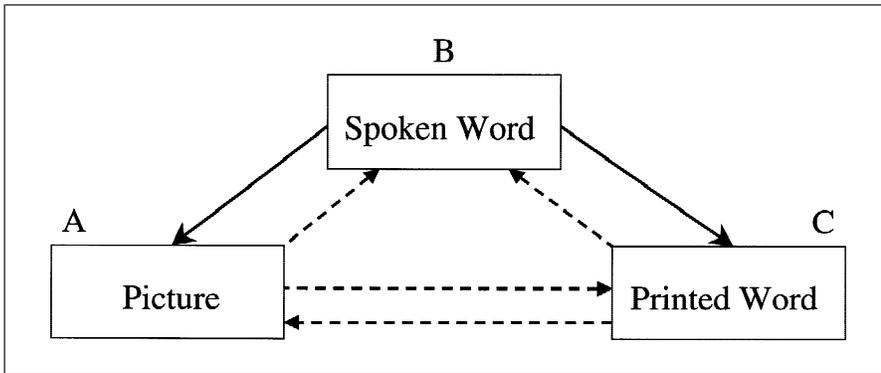


Fig. 1. Schematic summary of Sidman's (1971) experiment. For example, following the mapping of the spoken word "car" (B) onto the corresponding picture (A), and the mapping of the same spoken word onto the printed word C-A-R (C), by reward training (shown by solid arrows), novel, symmetrical relationships (shown by dashed arrows) emerged. The picture (A) and the printed word (C) were spontaneously connected by their equivalence ($C \rightarrow A$) relationship.

lations that emerge from this training are analogous to the algebraic properties of reflexivity (i.e., matching $A \rightarrow A$, $B \rightarrow B$, etc.), symmetry (matching $B \rightarrow A$ and $C \rightarrow B$), and transitivity (matching $A \rightarrow C$). Subjects demonstrating such emergence are said to have passed the test for Sidman equivalence (Sidman, 1994).

Although there is substantial evidence in humans for the emergence of Sidman equivalence, the evidence for such processes in other species is not as strong. However, results from laboratory studies of classical and operant conditioning with animals show that they are capable of classifying stimuli in ways that, although not always structured in terms of the Sidman equivalence test, nonetheless allow mutual substitutability (Zentall, 1998). Furthermore, field studies indicate that some nonhuman primates classify acoustically different calls into the same functionally meaningful category (Cheney & Seyfarth, 1990). These findings of emergent relations, from both lab and field studies, indicate that animals can form a common representation of physically different stimuli, which in turn suggests that they are capable of Sidman equivalence.

ANIMAL EXPERIMENTS IN EQUIVALENCE

Some of the specific properties of Sidman equivalence have been carefully documented in animals. Reflexivity, or generalized identity, has been demonstrated with relative ease in chimpanzees, bottlenose dolphins, and California sea lions. Evidence for symmetrical connections between stimuli has been more difficult to establish (see Zentall, 1998). However, in laboratory experiments, some evidence for symmetry has been found, in tasks in which one of the events entering into the relation is biologically important (e.g., food). There is also evidence for associative transitivity using Pavlovian procedures. The best evidence for transitivity in MTS has been found with nonhuman primates and with a California sea lion. We first showed the emergence of complete Sidman equivalence in a nonhuman animal by establishing three-member classes (A, B, and C) in a visual MTS procedure with a California sea lion (Schusterman & Kastak, 1993); subsequently, the same sea lion transferred the relations it acquired between equivalence-class members from MTS to

two-choice simple discriminations (Schusterman & Kastak, 1998). In the training phase of the simple discrimination procedure, two comparisons (one from each of two three-member classes) were presented simultaneously in the absence of a sample stimulus. Responses to one of the two comparisons were consistently reinforced. In transfer tests using the two remaining members from each class, the subject consistently responded to members of the class to which the correct training comparison belonged. The only response cue in the transfer tests was the reinforcement history of the three-member class itself; thus, the subject responded in a general way to each equivalence class rather than specifically to individual class members. Unlike the animals in any previous or subsequent tests of Sidman equivalence, the sea lion who showed emergence of Sidman equivalence had already demonstrated a facility to infer reflexive relations with many of the stimuli that were used (Kastak & Schusterman, 1994). We believe this was a very important factor in the sea lion's successful performance because reflexive learning is a necessary prerequisite to form equivalence relations.

Vaughan (1988) used a variation of the simple discrimination procedure in which stimuli were presented to pigeons successively instead of simultaneously. Responses to one set of stimuli (slides of trees) were reinforced, whereas responses to a second set of stimuli (also slides of trees) were not reinforced. Following repeated reversals of the reinforcement contingencies, it became clear that the pigeons were classifying the stimuli into two categories that corresponded to the initial two sets arbitrarily defined by Vaughan. It is likely that equivalencies between members of the same category had emerged; however, this would

have been more clearly demonstrated if the pigeons had shown interchangeability among members of each of the two classes in an additional context such as an MTS procedure. Furthermore, if each category could be expanded by mapping one novel stimulus to one familiar member of each category, and if immediate transfer of each new stimulus to each of the other members of its respective category could be demonstrated, Vaughan's idea of equivalence being generated by a reversal procedure would have been strengthened. Sidman, Wynne, Maguire, and Barnes (1989) did precisely this using a variant of the procedure just described. They demonstrated that 2 human subjects were capable of

forming equivalence classes within the framework of a simple discrimination task. Thus, at least for some human subjects, the categories formed in a simple discrimination reversal procedure are equivalent to the classes generated by MTS training. Figure 2 is a schematic summary of this type of experiment using numbers and letters to make up each of the two classes.

We recently obtained results with 2 sea lions that link the type of emergent performance obtained in a simple discrimination (Vaughanian equivalence) with the type of emergent performance shown in MTS (Sidman equivalence), thus supporting the broad equivalence model explaining how animals

might form non-similarity-based concepts (Sidman, 1994; Zentall, 1998). Following a reversal procedure using 10-member sets of "numbers" and "letters" (outlined in Fig. 2a), both sea lions showed evidence of Vaughanian equivalence by performing significantly better on number-letter simple discriminations in the last 5 trials of a 10-trial reversal block than on the first 5 trials. Changing the reinforcement contingencies for one member of a class was thus sufficient to change subsequent responding to remaining class members.

In this task, the sea lions' correct responses were reinforced with two different fish, capelin and herring, that were mixed or uncorrelated with numbers or letters.

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Fig. 2. Schematic summary of the equivalence procedure derived from Vaughan (1988)—panel (a)—and Sidman, Wynne, Maguire, and Barnes (1989)—panels (a), (b), and (c). Each row of stimuli represents a potential trial in which one choice is correct (denoted by "+") and one choice is incorrect (denoted by "-"). A simultaneous discrimination procedure using repeated reversals generates the classes "letter" and "number" in (a), following criterional learning of letter discriminations (upper panel) and subsequent reversal to number discriminations (lower panel). This process is repeated until rapid acquisition of the reversed contingencies occurs. The diagram in (b) shows transfer of these classes into a match-to-sample (MTS) procedure in which letter samples (center column) are discriminative for responses to letters and number samples (center column) are discriminative for responses to numbers. In (c), the classes are expanded following training of a novel stimulus onto one member of each class in an MTS procedure (upper panel). Following this training, new relationships emerge between the novel stimuli "K" and "11" and the remaining members of each class (lower panel).

However, in the next reversal experiment, capelin was correlated with responses to one class (e.g., letters) and herring was correlated with responses to the other class (e.g., numbers), in what is termed a differential outcome effects (DOE) design. The results are shown in Figure 3, and indicate nearly perfect responding by the 2nd trial of a 10-trial reversal block, a substantial improvement in performance relative to the non-DOE condition. These results indicate that representing the outcome of a choice by the same biological event (type of fish) facilitated formation of Vaughanian equivalence classes. In a continuation of the DOE design, the sea lions were transferred to an MTS procedure, as shown in Figure 2b. On novel stimulus pairings, their performance was almost perfect. After this experiment, a novel letter was mapped onto a single,

familiar letter, and a novel number was mapped onto a single, familiar number by MTS training, as shown in Figure 2c; transfer to all other letters and numbers emerged full-blown for both sea lions. The sea lions also showed near-perfect transfer when the newly mapped stimuli were later tested in the reversal procedure. Such results indicate that nonhuman animals are capable of transferring equivalence relations formed under one set of conditions to a novel set of conditions. These results bolster an expanded view of stimulus equivalence by including responses and reinforcers, as well as discriminative and conditional stimuli, as class members. This view provides a proximate mechanism that allows an understanding of how animals chunk information to better cope with social and communicative encounters.

SOCIAL INTERACTIONS, REFERENTIAL COMMUNICATION, AND EQUIVALENCE

When an animal such as an antelope hears a sound produced by a predator, it will sniff and search visually for the predator's location. Thus, a prey animal frequently learns the equivalence between the sound (A), sight (B), and scent (C) of a predator. These separate but interchangeable visual, acoustic, and olfactory stimuli become linked together to form a representation of the predator. Each of these signals thus takes on the meaning of the object (the predator) with which it is connected. By accessing and integrating information from multiple sources rather than treating each source as distinct, the antelope becomes more efficient at recognizing predators and taking appropriate action. This type of cross-modal equivalence has been discussed developmentally in terms of individual and kin recognition in California sea lions. After a 2-day feeding bout, a female returns to the rookery and becomes reunited with her pup following a vocal exchange between them. Auditory, visual, olfactory, and tactile stimuli combine to provide mother and pup with an accurate representation of each other. These cross-modal representations later allow the mature sea lion to recognize its sisters through their connection with their mother and each other (Hanggi & Schusterman, 1990). For instance, a sea lion may determine degrees of kin relatedness by observing affiliative interactions between its mother and its sisters.

Additionally, emergent cross-modal equivalence has been suggested by observations of vervet monkeys. The first time recorded vocalizations of a juvenile vervet monkey were played to its mother and 2 other adult females (who had

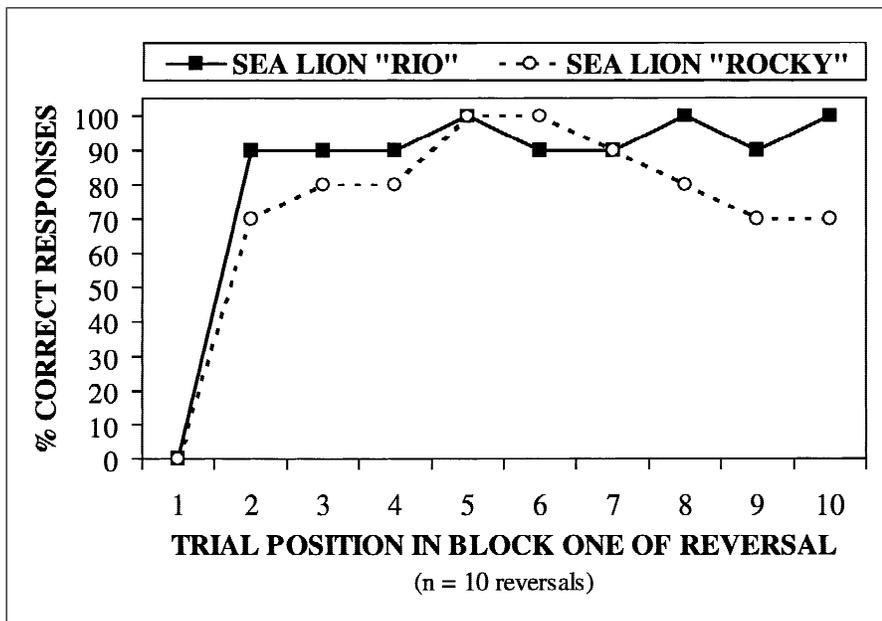


Fig. 3. Results from the repeated reversal procedure used by Reichmuth (1997) with California sea lions (as depicted in Fig. 2a). Correct responses to members of the "letter" class were reinforced with one fish type, and correct responses to the "number" class were reinforced with an alternative fish type. The first 10 trials following a reversal contained random presentation of each of 10 different letters and numbers. On the first trial of each reversal, the subjects' choices were never correct, but on the next 9 trials, performance was near perfect, indicating that the outcome of the first trial with one member of a set was sufficient to control subsequent responses to the remaining members of that set.

offspring in the group), the 2 females looked to the juvenile's mother rather than orienting to the location of the loudspeaker, indicating that they associated the juvenile's vocalizations with its mother. According to the equivalence model, the previously existing relation between the juvenile's vocalization (A), the visual and other sensory cues associated with the juvenile (B), and the frequent spatiotemporal relation between the juvenile (B) and its mother (C) resulted in the formation of a three-member class consisting of the vocalization, the juvenile, and the mother herself (A, B, C). Thus, actions of individuals and individuals themselves can be categorized as having the same meaning.

Social interactions sometimes involve classifying some individuals into "familiar" or "friendly" groups and other individuals into "novel" or "unfriendly" groups. Such concepts depend on the ability of individuals to recognize relationships between individuals, as well as higher-order relations such as those between groups of individuals. Members of different groups may be treated as equivalent in the context of violent aggressive interactions, as well as affiliative interactions such as grooming, alarm calling, foraging, and alliance formation.

Territorial male sea lions and fur seals recognize one another by their calls and subsequently group conspecific territorial males as familiar or novel. For example, male Steller sea lions become reproductively successful only after securing a territory for at least one full season. Grouping neighboring males into equivalence classes of either familiar or novel individuals appears to be critical in this process, which can take 3 or more years. Although successful males do not expend energy aggressing against familiar males, they will aggress against newcomers. This

"dear enemy" effect is unlikely to be the result of habituation to familiar males because the effect spans multiple breeding seasons, between which recovery of the aggressive response would be expected if habituation were the mechanism responsible for inhibiting aggression. Instead, the effect appears to be the result of grouping familiar males into a single class whose members are relatively interchangeable.

Male common chimpanzees form strong group identities, with all members of one class being treated similarly. Group cohesion is facilitated by grooming, food sharing, and other reinforcers. Interactions between two groups can escalate into violent confrontations, in which non-group members are attacked in ways that are qualitatively different from the types of aggression that occur between members of the same group. All members of a weak group, including females and offspring, may be attacked and killed in an incursion by males from a stronger group, whereas aggression between members of the same group is generally tempered. Even inanimate objects associated with a particular group appear to elicit reactions from other chimpanzees that are similar to those elicited by the group members themselves. Goodall (1986) reported that when patrolling males from one group found a sleeping nest built by a member of another group, they reacted aggressively to the nest, as if the nest represented the chimpanzees of the second group. Such animal behavior is analogous to humans treating symbols like statues or icons as if they are the things or events that they denote. This referentiality, in which signal and denoted object appear to have become equivalent, has been well documented in the alarm calls of vervet monkeys, prairie dogs, and other group-living animals, and in the food calls

of rhesus macaques. Investigations into animal calls using an equivalence framework indicate that there is mutual substitutability between these calls and the objects they represent; the listeners are responding to the meaning of the call, rather than to the call's structural characteristics.

CONCLUSION

Cheney and Seyfarth (1990) have proposed that social cognition is a type of intelligence that evolved specifically in response to selective pressures related to solving complex social problems. As such, it is a special-domain adaptation—a solution to specific rather than general types of problems—in which nonhuman primates communicate referentially and deal with social relationships in ways that are more complex and hierarchical than conventional associative theories of learning can describe. However, although Cheney, Seyfarth, and others do attribute some fundamental aspects of social behavior to associative learning processes, they do not suggest an alternative psychological mechanism responsible for complex patterns of emerging social behavior. The idea of domain specificity implies that the sorts of concepts an animal uses in social cognition will not readily transfer to the arbitrary tasks used in laboratory experiments of stimulus equivalence. In contrast, we suggest that Sidman's equivalence relational model has relevant applications to animal social relations and referential communication. This model provides a closer link between behavior observed in nature and laboratory studies of the acquisition of relational concepts. Further investigations into behavior observed in the field, including reciprocal relationships, role reversal in play, and re-

inforcer substitutability, should provide a better understanding of the proximal mechanisms underlying adaptive, complex social behavior and an appreciation for the sophisticated ways animals think without words.

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Note

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