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Ronald Schusterman

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Ronald Jay Schusterman **(1932–2010)** was an American comparative psychologist that contributed innovative experimental and behavioral research with humans, primates, and marine mammals from the late 1950s to the end of his life in 2010. He had a long and productive career in the biological and behavioral sciences, and his research intersected many diverse fields. He considered himself an eclectic scientist, borrowing the most useful ideas from every discipline that he encountered and blending them into a practical and synergistic approach to his studies of animal learning and behavior. Schusterman was best known for the meticulous experimental methods that he developed, refined, and applied to the research problems he explored, as well as for his dedication to searching for the most parsimonious explanations for the behaviors he observed and analyzed (Nachtigall et al. 2010).

Schusterman began his career in the 1950s working with human subjects, and also the behavior of non-human primates, including chimpanzees, gibbons, and monkeys at the original Yerkes Laboratory of Primate Biology in Orange Park, Florida (Schusterman 2010). He credited his training as a psychologist to Mortimer Fienberg at Brooklyn College, where he completed his Bachelor's degree, and Joel Greenspoon and Winthrop Kellogg at Florida State University, where he earned his Master's and Doctorate degrees. He also credited his success to lucky timing and the support of the National Science Foundation following massive American investment in young scientists – starting in 1958 – in response to the shocking successful Soviet launch of *Sputnik I.*

Schusterman shifted his focus from primates to marine mammals during a time when little was known about these animals and their behavioral and sensory capabilities. His subsequent experimental work with dolphins, seals, sea lions, and walruses spanned nearly 50 years, a period over which understanding of these animals changed dramatically. Schusterman's early studies with sea lions were spurred by his former professor Winthrop Kellogg, who had recently reported the discovery that dolphins used specialized ultrasonic sonar to orient and to detect objects under water (e.g., Kellogg 1958). Schusterman sought to determine whether sea lions similarly used echolocation to gain information about the environment. By observing sea lions in controlled environments and training them to cooperate in a variety of behavioral procedures, he eventually found that they did not echolocate (see Schusterman et al. 2000a; Rice 2010; Schusterman 2010). Ultimately, Schusterman combined sensory and cognitive assessments to

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understand how sea lions and other marine mammals acquired and used information from a variety of modalities to modify their own behavior.

Schusterman's research with primates and marine mammals covered a broad range of topics that addressed fundamental topics in animal learning, including those related to the themes of *efficiency in learning, decision-making in uncertainty,* and *emergent behavior*. Schusterman's research in these areas relied on the basic tenants of conditioning and learning theory, which he used to develop innovative and effective methods for training animals which he studied mostly in the controlled conditions of the laboratory (see e.g., Schusterman 1980). He correlated what he learned through rigorous experimentation with observations of animals in the wild to better understand how learning and sensory capabilities might be used by individuals to solve complex social and ecological problems (e.g., Schusterman et al. 2003). Especially later in his career, Schusterman worked to connect knowledge of species-typical behavior to understanding of proximal mechanisms that support cognition and communication (e.g., Schusterman et al. 2000b, 2002).

Efficiency in Learning

Schusterman was intrigued by Herb Terrace's research on *errorless learning* in pigeons (Terrace 1963), which described examples of discrimination learning that occur with few or no responses to negative stimuli. Terrace was the first to show that errors are not required for successful discrimination performance to occur, but rather that gradual fading methods can dramatically reduce (or eliminate) the number of errors needed to learn new discriminations.

Schusterman immediately followed Terrace's thread by showing that similar methods could be used to accomplish complete reversals of well-established visual discriminations in sea lions, virtually without error (Schusterman 1966; Schusterman and Thomas 1966). He found that reversals of stimulus form preferences could be accomplished by progressive dimensional changes in shapes. Importantly, Schusterman measured subtle behavioral responses as well as trial outcomes, and thus, was able to determine the transition points at which the subject's attention shifted from one stimulus dimension to the other. Like Terrace, Schusterman found that learning in these optimal conditions could occur efficiently and without errors, and that subjects could learn without frustration or other emotional responses that might bias later responses to stimuli. Schusterman used variants of errorless learning procedures in a variety of different experimental contexts over the next decades (e.g., Schusterman 1980).

In the 1980s, Schusterman and colleagues discovered that sea lions were capable of *learning by exclusion*. Exclusion learning refers to behavioral control by familiar negative stimuli, or in layman's terms, decision-making by process of elimination. This type of learning has been called by many names in the psychological literature, including "emergent mapping," "psycholinguistic inference," "disambiguation," "mutual exclusivity," and most recently "fast-mapping" (Reichmuth Kastak and Schusterman 2002a). At the time, this learning process was not well identified or described in the comparative literature, but became evident to Schusterman during his studies of complex learning and artificial language learning in sea lions (Schusterman and Krieger 1984).

During learning of conditional discriminations, or *if .... then* associative rules, Schusterman found that sea lions could immediately relate two new items when they were paired with a familiar or incorrect alternative (Kastak and Schusterman 1992; Schusterman et al. 1993). He further saw, as did others working independently in the fields of human behavior analysis and psycholinguistics, that this type of problem solving strategy generated "learning outcomes"; that is, that after exposure to problems that could be solved by an exclusion strategy, new associations were eventually established that could be performed in the absence of familiar alternatives. In this way, new conditional discriminations could be acquired virtually without error. This was an important and effective training procedure, but also, critical to interpretations of relational learning in animals (Kastak and Schusterman 1992). The principle of exclusion improves our understanding of what individuals know about what is *not* correct, and how that knowledge can induce new stimulus relationships. The exclusion principal was evident in Schusterman's studies of artificial language learning by sea lions, enabling him to argue that linguistic competence was not a prerequisite for apparent object labeling.

Efficient learning and teaching strategies for animals were also evident in Schusterman's research with learning sets. Learning sets refer to the process of learning to learn, as described originally by Harlow (1949) – where independent but similar problems are learned faster with experience. Demonstration of learning sets relies on transfer between similar successive problems. Schusterman used visual shapes to train simple two-choice discriminations with sea lions and found a decrease in the number of errors required to learn each successive problem, until eventually one trial or a few trial learning occurred when novel stimulus sets were introduced (Schusterman and Thomas 1966). Evidence of the learning-to-learn phenomenon in animals leading to nearly errorless learning of new relationships strongly influenced Schusterman's view that that learning benefited from exemplar training. As a result, he tended to use large stimulus sets and large numbers of training and testing problems in many of his experiments (e.g., Kastak and Schusterman 1994). In doing so, Schusterman prepared his animals for the types of test problems they would encounter later on, thus dampening responding influenced by trial novelty and enabling the use of trial-one (first exposure) measures of performance on transfer problems.

Decision-Making in Uncertainty

Efficiency in learning and learning without errors or frustration were recurrent themes in Schusterman's work; however, errors tell us a great deal about what animals can do, and sometimes what they cannot do. This is certainly true in assessment of sensory performance, where errors reveal the limits of sensory capabilities.

Schusterman was interested in how animals made decisions in conditions of uncertainty. Throughout many of his experiments, he used behavioral observations and performance metrics to evaluate attention, motivation, and strategy during problem solving. Due to his interest in sensory biology, he was among the early psychobiologists to conduct empirical work on signal detection theory (Schusterman 1974). His rigorous work in this area revealed a great deal about learning and behavior during difficult tasks. Over the years, he and his collaborators conducted detailed and systematic experiments to explore the role of response bias in animal psychophysics (e.g., Schusterman and Johnson 1975; Schusterman et al. 1975; Schusterman 1976).

The experiments revealed that strategies and decision making during difficult discriminations are influenced by a variety of factors, including reinforcement ratios, trial ratios, conditional probabilities within trial sequences, and response generalization. Schusterman's work helped shape our understanding of how prior experience influences decision-making in humans and other animals, and has relevance to many modern applications of signal detection theory.

Emergent Behavior

Schusterman's most important contributions to comparative cognition come from research on what some have called emergent learning or concept learning. This refers to the emergence of new or untrained behavior from logical inferences about previously learned relationships. Schusterman considered these emergent performances examples of new knowledge arising from old knowledge, or synergistic problem solving.

Schusterman's efforts, starting in the late 1970s, to teach sea lions to comprehend an artificial gestural language led him to a rigorous experimental analysis of syntax and semantics (Schusterman and Krieger 1984, 1986;

Schusterman and Gisiner 1988; Gisiner and Schusterman 1992). Following training with four *modifiers* (e.g., small, white), 14 different *objects* (e.g., ring, cone), and seven *actions* (e.g., flipper touch, tail touch), Schusterman showed that a sea lion could respond appropriately to over 7000 unique instructional sequences. Furthermore, the sea lion could answer questions about the presence or absence of particular objects in her pool, perform relational trials which required her to take one object to another, and indicate the relative size of objects. The sea lion's performance in this paradigm rivaled or exceeded that of language-trained dolphins and chimpanzees, indicating that large brains and extreme sociality were not prerequisites for highly complex associative behavior.

The results of the artificial language study clearly showed the emergence of a "slot" grammar supporting novel behavior, with apparent functional equivalences arising between signs of a given type. However, whether or not the gestural signs were truly symbols, or referential signals was difficult for Schusterman to demonstrate in this linguistic task, as the sea lions could not "name" the objects by producing the gestures used by their trainers. Schusterman suspected that general learning processes, rather than specialized cognitive abilities like language, were involved. Instead of comprehending the instructional sequences within a linguistic framework, he believed that the sea lions, and maybe other animals trained on similar tasks, were using structured sets of problem-solving rules to succeed in the comprehension tasks.

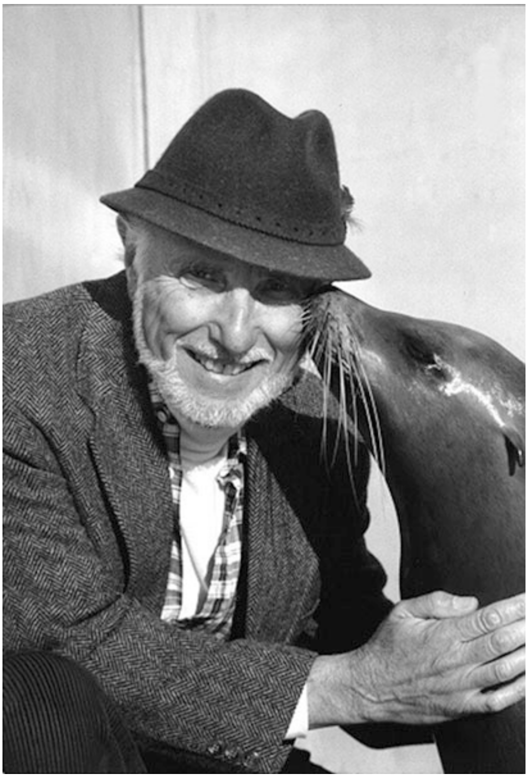
To further explore the basis of emergent behavior in animals, he and his students began a detailed series of studies on symbolic behavior, concept formation, and memory which allowed for a deeper experimental analysis of component behavior and contextual control (for review see Schusterman et al. 2002). Strongly influenced by the behavior analyst Murray Sidman, Schusterman turned to complex discrimination learning procedures to examine the conditions which promoted emergent learning. Schusterman used highly specific training procedures with sea lions to demonstrate that these animals were capable forming an assortment of abstract concepts. These included generalized *identity* matching, symbolic matching or *symmetry*, *associative transitivity*, *stimulus equivalence*, and *functional equivalence* (Schusterman and Kastak 1993, 1998; Kastak and Schusterman 1994; Kastak et al. 2001). These concepts, once formed, proved to be highly durable, lasting as many ten years (Reichmuth Kastak and Schusterman 2002b).

The sea lions' successful performances in these procedures, which are notoriously difficult for nonhuman animals, were attributed in part to Schusterman's use of large stimulus sets during training. Multiple exemplars also afforded the sea lions practice with similar problems prior to testing, and enabled "trial-one" performance measures of transfer. The sea lions' success with novel transfer problems demonstrating specific cognitive abilities provided some of the first convincing evidence that nonhuman mammals could use "rules of logic" to solve complex problems. In this sense, Schusterman was a true pioneer in the field of comparative cognition. Many of his systematic teaching methods for animals have been adopted to improve learning outcomes for language-disabled people.

Legacy

Ronald Schusterman's careful work in the laboratory to document the conditions under which animals gather and process information, and use it to solve a variety of synthetic and natural problems, leaves a strong empirical framework for the study of animal cognition. During his lifetime, he published more than 100 professional papers which continue to influence many studies in contemporary comparative psychology. Schusterman was a Fellow of the American Association for the Advancement of Science (1967), the American Psychological Association (1984), the Animal

Behavior Society (1996), the Acoustical Society of America (1998), and a founding member of the Society for Marine Mammalogy (1981). His laboratory, which Frans de Waal has called "*the strangest and most delightful animal laboratory he ever set a slippery foot in*" (de Waal 2016, p. 181) has remained at the University of California's Long Marine Laboratory since 1985.



Ronald Schusterman, Ron Schusterman and California sea lion Rocky, taken at the University of California Santa Cruz in 2003 (photo: C. Reichmuth)

Cross-References

- ▶ Artificial Grammar
- ▶ Associative Concepts
- ▶ Associative Learning
- ▶ Comparative Cognition
- ▶ Concept Formation
- ▶ Discrimination Learning
- ▶ Echolocation
- ▶ Frans de Waal
- ▶ Harry Harlow
- ▶ Intelligence
- ▶ Language Research
- ▶ Matching-to-Sample
- ▶ Neophobia
- ▶ Pinniped Cognition
- ▶ Reasoning by Exclusion
- ▶ Same/Different Learning
- ▶ Semantics
- ▶ Sign Language
- ▶ Stimulus Equivalence
- ▶ Syntax
- ▶ Transfer of Learning
- ▶ Transitive Inference

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