Language learning studies in pinnipeds: sonic production and comprehension

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The important role of learning in sound production and usage by dolphins has been well documented. Until now, however, aside from the unusual case of Hoover, the harbor seal who appeared to imitate human speech, much less has been made of experimental evidence for call production and usage learning by another group of marine mammals—the pinnipeds. In this paper, I will consider aspects of signal production as well as some issues related to signal comprehension. First, I will show that several different pinniped species demonstrate remarkable flexibility in the ways they can use and modify their vocal emissions. In general, these adaptations are related to: (1) breath control and therefore laryngeal control, and (2) control over articulatory movements of tongue, lips, mouth, and teeth.

One example of vocal learning comes from "Sprouts," now a twenty-year-old male harbor seal (*Phoca vitulina*) who is one of the main subjects of our ongoing conditioned vocalization experiments with pinnipeds. He was born into a captive colony of harbor seals at Sea World, San Diego, where he lived with his mother and other harbor seals for the first nine months of his life. At Long Marine Lab he is housed with other pinnipeds but no conspecifics. Sprouts was relatively silent until the age of seven, when he spontaneously began emitting underwater roars during the spring breeding season. The vocal displays produced by this harbor seal occur each breeding season and are associated with visual displays (which include lobtails, flipper slaps and bubble blowing). During these periods, Sprouts has attempted to copulate with a female elephant seal and several California sea lions. The underwater roar by Sprouts is a guttural growl that ramps up in amplitude over several seconds and seems to have changed little over these past thirteen years. Similar vocal displays have been reported in other breeding harbor seals both in the field and in captivity. Independent of his underwater breeding vocalizations, Sprouts was conditioned with food reward to produce an airborne growl-like sound which was placed under the control of two specific discriminative stimuli or $S_{D's}$ (a trainer's hand gesture which is produced simultaneously with the spoken word "speak"). Three years ago, the reinforcement contingencies were changed and food reward was made contingent on Sprouts emitting only relatively novel variants of his conditioned growl-like vocalization. This contingency led to a swift expansion of sounds produced following the $S_{D's.}$ Occasionally he was encouraged with a gentle touch to his jaws to move his mouth while vocalizing. As Sprouts explored which sound types resulted in reinforcement his sound emissions varied between growls, snores, sneezes, sputters, moans and clicks produced at different speeds, sounding very much like a motor boat changing speeds. During his vocal explorations the sounds became progressively more varied along the dimensions of amplitude, frequency, modulation, and rate. During the second experimental session Sprouts emitted a sound that had some vowel-like syllabic qualities (a more tonal "wa" that was produced while the mouth was moving) and selective shaping of the particular sound began until it became more tonal and a more repetitive "wa-wa-wa-wa" and this speech like sound was then placed under the control of a different discriminative stimulus. Currently, with the help of anatomists from the University of St. Andrews, Sprouts' speech-like vocalizations are being analyzed to determine correlations between jaw opening and formant frequencies.

Sprouts, the harbor seal, is an especially interesting case in terms of pinniped vocal behavior because despite being raised mostly without conspecifics, he nevertheless shows species-typical vocal behavior patterns in response to intrinsic (hormonal) as well as nonsocial environmental (photoperiod) cues. Thus, despite this apparently innate pattern of sound production, his vocal behavior is still readily accessible to modification by reinforcement contingencies, showing that both fixed and flexible vocal responses can occur concomitantly within an individual under the right set of circumstances.

In another experiment, two twelve-year-old Pacific walruses (*Odobenus rosmarus divergens*), one male and one female, housed at Six Flags Marine World in Vallejo, CA, were trained to emit several different sounds to different discriminative cues. Eventually, both walruses were encouraged through modified reinforcement contingencies to produce novel sounds and novel sound combinations both in air and under water. Both walruses emitted a variety of sounds, including knocks and soft bells under water and whistles in air which are components of the complex sonic displays male walruses produce during the breeding season. Future studies are planned to clarify the extent to which pinnipeds, in contrast to apes and monkeys, resemble humans in the capacity for vocal production learning. Such convergence in the precise control of vocal emissions may provide clues to the type of morphological, neural, and behavioral mechanisms designed for human spoken language.

From the standpoint of rudimentary language comprehension it has been argued that sea lions, like dolphins, are capable of using a slot and frame grammar which allows the individual to abstract stimulus classes from specific examples. In the second part of the paper, I will talk about how sequence training can generate emergent equivalence classes based on shared ordinal positions. Indeed, such classes of functionally interchangeable stimuli are required to account for the novelty we see in human speech. Sea lions can learn that all "adjective" signs are equivalent and that all "noun" signs are equivalent at the level of their position in a sign sequence. Sea lions learn a few instances of adjectives before nouns (e.g., "*large ball*," "*black car*"), but then readily demonstrate that the signs in one class are interchangeable in their roles as adjectives (i.e., signs representing stimulus color and size), and the signs in another class are interchangeable as nouns (i.e., signs representing different objects, people, etc.). These language comprehension studies with sea lions (and dolphins) suggest that such computational and classificatory skills existed, at the very least, in our last common ancestor with chimpanzees.