

SYLLABLE SEQUENCE PERCEPTION IN SONGBIRDS AND PARROTS

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The capacity to use recursive syntax is considered a fundamental difference between human and animal vocal communication (Hauser and Fitch, 2003). Even more fundamental, however, is the capacity to produce and perceive acoustic sequences. The sequentially complex vocalizations of songbirds have long served as a potential bridge between human language and animal vocalizations with much of the historical evidence coming from field studies (e.g., Kroodsma and Miller, 1996). Laboratory perceptual studies, on the other hand, have provided less compelling evidence that songbirds have the perceptual machinery to process complex sound sequences (Fishbein, et al, 2019; Geberzahn and Deregnaucourt, 2020; Lawson, et al, 2018; Seki, et al, 2013). By contrast, laboratory studies on one psittacine, the budgerigar (*Melopsittacus undulatus*), has revealed that this species can both produce a sequentially complex vocal repertoire consisting of multiple syllable categories and perceive changes to syllable sequence in its song (Fishbein, et al, 2019; Tu and Dooling, 2012; Tu, et al, 2011).

A major difficulty in studying sequence production and perception in birds is that cross species comparisons, in which each species is tested under identical conditions, are rarely done. Here we first showed that the complex sequential structure of the budgerigar warble song can be modeled as a 5th order Markov sequence. Then we successfully trained budgerigars and various songbirds, including canaries (*Serinus canaria*), zebra finches (*Taeniopygia guttata*), Bengalese finches (*Lonchura striata domestica*), and Cordon Bleus (*Uraeginthus bengalus*) by operant conditioning to discriminate changes in the sequential order

of various natural vocalizations as well as neutral sounds including tones, words, and syllables within a word.

Results show that budgerigars, a psittacine, can discriminate changes in the sequence of syllables in their warble and in other sound sequences. This ability matches well with the sequential complexity of their warble. Several species of songbirds tested on these sequences of sounds, and their own species-specific vocalizations, cannot discriminate these perturbations in syllable or sound sequences. Even reducing the task to its simplest level, discriminating a change in the order of two syllables, budgerigars well outperform songbirds even when both budgerigars and songbirds are tested on songbird species-specific vocalizations.

While there is a long history of efforts aimed at understanding the differences in acoustic communication between humans and birds, the focus of much of this comparative work has been on the production side (e.g., Kroodsma and Miller, 1996). Our results suggest that the limits to acoustic communication using sound sequences in birds could lie more on perceptual side. Indeed, the differences observed here between songbirds and parrots may offer hints as to how the perception of sequences evolved in the primate lineage to support the emergence of human language. It might be fruitful to focus on anatomical differences between songbird and parrot brains to identify the neural candidates that might underly these significant differences in the perception of complex acoustic sequences.

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