Meaningful Acoustic Units in Nonhuman Primate Vocal Behavior
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Introduction

A common experience to all of us who travel to foreign countries is making sense of the confusing sounds being uttered by the native speakers. Unless one can find a translator or at least a good bilingual dictionary, one often will have an extraordinarily difficult time expressing one's most basic needs for food and shelter. In such situations, we lack not only the knowledge of what the different words mean, but also an understanding of where the boundaries are for the different acoustic units within a foreign stream of speech as well. The extreme version of this Quinean problem of translation (Quine 1973) applies not only to linguists or foreign travelers, but also to those of us who wish to shed light on the vocal communication systems of other species (Hauser 1996).

Ethologists studying nonhuman animal communication systems are faced with the daunting task of dividing the vocal repertoire into different types of acoustic units (e.g. bouts, vocalizations, syllables, etc.). Specifically, how can one determine whether a sequence of temporally distinct units emitted by an animal represents a single functional unit (like meaningless syllables put together to form a word in speech), a string of functionally independent units (like words forming a sentence in speech), or something simpler such as the repetition of one small unit? A true understanding of how vocal signals are parsed must be derived from the animal's perspective: vocal signals must be parsed into the acoustic units which are meaningful in terms of eliciting specific behaviors from the intended receivers (Green and Marler 1979; Hauser 1996). Thus, an animal's behavior serves as a 'translator' for ethologists entering a species' perceptual world. Using this approach, we have learned much about the meaningful acoustic units in many avian (e.g., Podos et al. 1992; Searcy et al. 1999) and anuran vocal repertoires (e.g., Narins and Capranica 1978; Ryan and Rand 1990). Studies in these taxa have given us significant insights into how vocal behavior relates to brain design.

Like birds and anurans, many primate species produce bouts of vocalizations containing sequences of similar acoustic units and/or different sounding acoustic units (Figure 1), but we know very little about the meaningful units in primate vocal signals. Understanding how primates perceive and produce such vocalizations is important for several reasons. First, the evolution of speech and language may have involved the co-opting of capabilities that exist in extant primates (Lieberman 1984; Ghazanfar and Hauser 1999; Fitch 2000). One such capability may be to produce vocal signals that mean one thing when produced individually, but something different when recombined into sequences of sounds. Second, from a more general perspective, understanding the constraints on the perceptual and motor domains of primates' vocal behavior may provide us with insights into the species-specific perceptual world, and thus their cognitive abilities and limitations. In this chapter, we review our understanding of the meaningful acoustic units of production and perception in nonhuman primate (hereafter, primate) vocal communication. Given space constraints, a complete literature review cannot be provided here. For a list of studies relevant to this issue see Table 1.

To begin this discussion, we would like to clarify our use of the term acoustic unit. For the purposes of this review, we refer to all temporally distinct acoustic pulses as syllables. This criterion is arbitrary in the sense that it is based solely on an acoustic measure, not a behavioral one. Nevertheless, it serves as a good starting point. Our own research is aimed at refining this definition as we gain better understanding of the functional and perceptual significance of all acoustic units within primate vocal signals; i.e., determining how acoustic units are organized to form "meaningful" units from the primate's perspective.

Observations and Experiments in the Field