BRIEF REPORTS

Variability in Spider Monkeys' Vocalizations May Provide Basis for Individual Recognition

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Analysis of long-range vocalizations given by spider monkeys revealed consistent acoustic differences among the calls of individuals. Of seven acoustic measurements, four exhibited significant variation between individuals. A discriminant analysis demonstrated that two of these variables allowed correct identification of the caller 44% of the time. Including the remainder of the variables increased the percentage correctly identified to 50%. Individual identification by call structure could benefit spider monkeys, where individuals forage separately in subgroups and the interactions between specific pairs of individuals is highly variable. Acoustic recognition of callers would facilitate the choice of which subgroups to join, thus allowing individuals to manipulate the size and composition of their subgroups. In addition, the calls of mothers and offspring appeared to be similar in acoustic properties.

Key words: acoustics, identification, subgroups

INTRODUCTION

Long-range vocalizations exist in the vocal repertoires of many forest dwelling primates. These calls typically have been suggested to convey information with respect to territorial status or location of groups [Marler, 1965; Byrne, 1982; Mitani, 1985]. However, for species that forage in subgroups that are out of visual contact of each other, it could be advantageous for long-range vocalizations to contain information about the identity of the caller. In these species, such an ability might allow an individual to decide whether to join or to avoid specific subgroups, thus, manipulating the size and composition of its subgroups. For instance, a low-ranking individual might benefit by avoiding the subgroup containing a high-ranking member, thus, preventing aggression and possibly increased levels of feeding competition [Chapman and Lefebvre, 1990].

With playback experiments, Waser [1977] demonstrated that mangabey *(Cer-*

cocebus albigena) long-range calls transmit information concerning the identity of the caller, but the criteria for distinguishing callers was not determined. Marler and Hobbett [1975] studied the long-range vocalizations of chimpanzees *(Pan troglodytes)* that forage in small subgroups. They found individual differences in call structure that could provide a basis for individuals to distinguish callers. Cheney and Seyfarth [1980, 1982] demonstrated through playback experiments that vervet monkeys *(Cercopithecus aeithops)* discriminate individuals based on calls and can group callers into higher order units based on matrilineal kinship. Based on an analysis of contact calls, Macedonia [1986] demonstrated that there was an acoustic basis for individual discrimination of callers in *Lemur catta.* Pereira [1986] used playback experiments to demonstrate that mother Japanese macaques *(Macaca fuscata)* could recognize the coo calls of their juveniles. Seyfarth [1987] reviews studies of primates that have attempted to demonstrate specific acoustic differences between calls of different individuals.

The objective of this study was to identify whether structural differences exist in the calls of individual spider monkeys *(Ateles geoffroyi)* that would allow animals to identify the caller. Such identification might be advantageous for spider monkeys, given their flexible pattern of association in which subgroups frequently are out of visual contact and animals repeatedly must decide whether or not to join or avoid nearby subgroups [Chapman, in press.; Symington, 1987]. In addition, evidence suggests that individuals attempt to manipulate the size and composition of the subgroups that they enter [Chapman and Lefebvre, 1990].

METHODS

Recordings of spider monkeys were made in Santa Rosa National Park, Costa Rica between April 1987 and April 1988. The dominant habitat in Santa Rosa is tropical dry forest in which the majority of the understory plants and nonriparian trees lose their leaves in the dry season. The canopy of the forest rarely exceeds 30 m and the average size of the trees used by the spider monkeys is only 43.1 cm (diameter at breast height). To date, the spider monkey community of Santa Rosa has been studied over a 6-year period. Individual recognition of animals was possible following the darting and tagging of monkeys, either as a result of the collars and anklets placed on the animals (n = 13) or by their scars and pelage patterns (n = 22). Thirty-five of the forty-two members of community were individually recognizable. For details of the study site and the spider monkey community see Chapman and Lefebvre [1990].

We focused on a long-range vocalization called a "whinny." This call is strongly correlated with foraging activities [Eisenberg and Kuehn, 1966] and has been considered a locational call [Fedigan and Baxter, 1984]. Eisenberg [1976] described the call as a position indicator that accompanies feeding and suggested that it may serve to indicate food availability.

Recordings of whinnies were made at a distance of 30 to 45 m with a Sony TC-D5M recorder and a Sennheiser (MD 211) microphone. One observer recorded contextual information on the individuals calling using a focal animal sampling regime with a 10-minute session length. Only vocalizations given by an identifiable individual in a foraging context, while the caller was in a food tree were considered. Given the flexible social organization of spider monkeys and our small sample size, no attempt was made to control for contextual factors such as the type of fruit tree, amount of fruit, or composition of the subgroup.

Vocalizations were analyzed with a Kay 6061B Sonograph with a wide band filter. A representative sonogram is presented in Figure 1. We measured six variables for each vocalization: 1) the total call duration, 2) the number of elements of
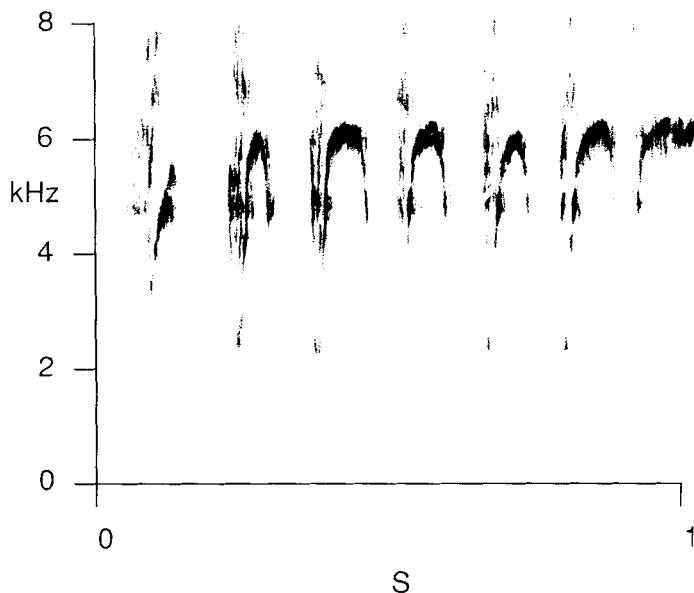
Fig. 1.   A representative sonogram of a whinny.

the call (element = one rising and falling segment of the call), 3) the duration of the first element, 4) the duration of the middle element (if the call had an odd number of elements the one closest to the middle but occurring first was selected), 5) the duration of the last element, and 6) the frequency at the inflection point of the highest frequency element in the call. These variables were selected to minimize the potential that differences between individuals could arise because of differing quality of recordings resulting from calls being taped at different distances from the animal or under different conditions. Acoustic variables were statistically examined using an ANOVA to determine if it was possible to reliably distinguish between callers. Similar results were obtained with nonparametric analyses. In addition, discriminant analysis was used to assess the reliability of identifying individuals based on all of the measures and specific subsets, following the procedures outlined by Smith et al. [1982]. Discriminant analysis reduces the number of variables and creates a number of functions which can be used to classify individual cases (calls) into groups (individuals).

RESULTS
The "typical" whinny consists of a sequence of about seven rising and falling elements strung together into a call that lasts approximately 0.90 seconds (Table I). However, there is a large amount of variability in the structure of the call. For instance, the call can have as many as 16 elements or as few as 2 and can last from 0.30 to almost 2 seconds. Some of this variability may be attributable to individual differences in the structure of the call.

We recorded 315 vocalizations from the spider monkey community of Santa Rosa. Of these, 81 were given in the appropriate context and were of suitable quality to use in the analysis of individuals. The sample represents 14 individuals (mean number of calls per individual = 6, range 4 to 10). There was no consistent difference between individuals in the duration of the call, the number of elements,

TABLE I. The Nature of Specific Acoustic Variables of the Spider Monkey Whinny and an Analysis of Whether the Variable Reliably Differed Between Individuals (Analysis of Variance and a posteriori Scheffé Comparisons)

Trait	Mean	Range	Standard error	ANOVA between individuals	Number of individual pairs distinguished
Duration	0.861	0.344–1.925	0.033	$F = 1.017$ $P = 0.445$	0
Number of elements	6.6	2–16	0.280	$F = 1.608$ $P = 0.105$	0
Duration of first element	0.130	0.091–0.159	0.002	$F = 7.173$ $P < 0.0001$	6
Duration of mid element	0.126	0.087–0.158	0.002	$F = 11.61$ $P < 0.0001$	12
Duration of end element	0.108	0.004–0.471	0.014	$F = 11.22$ $P < 0.0001$	17
Maximum frequency	810	705–897	16.92	$F = 1.600$ $P = 0.107$	0
Mean element duration	0.136	0.038–0.277	0.004	$F = 3.086$ $P = 0.001$	0

the maximum frequency, or in the mean duration of an element (Table I). In contrast, the duration of the first, middle, and last elements differed significantly between individuals and allowed the differentiation of 35 pairs of individuals (Table I).

The durations of the middle and last elements were the parameters which differed the most between individuals. Figure 2 depicts the frequency distributions of these two traits and their associated standard errors. There was little overlap in the standard errors of any two individuals, suggesting that individual recognition could be fairly reliable, based only on these two traits.

Based on a discriminant analysis, which used only the duration of the middle and last elements, calls were correctly assigned to caller on 44% of the occasions. Including the remainder of the variables only increased the percentage of calls correctly identified to 50%.

Aside from individualistic differences in call structure, one might predict that close kin may have calls that are more similar acoustically than non-kin. Figure 2 illustrates that the calls of adult females were very similar to their immature offspring. The difference between mothers and their offspring were on average less than that between all other pairwise combinations of individuals for the duration of the last element (Mann-Whitney $P = 0.04$) and marginally so for the duration of the middle element (Mann-Whitney $P = 0.09$).

DISCUSSION

The results obtained here suggest that there are consistent acoustic differences between the whinnies of different individual spider monkeys. Although this does not allow one to conclude that the animals use the features that we have chosen to identify the caller, or that they even have this capability, it does reveal that within this call there is the potential for individual recognition. The use of such information could benefit spider monkeys. In spider monkey social organization, individuals forage separately in subgroups, and the interactions between specific pairs of individuals can at times be dangerous, thus the ability to choose which subgroups to avoid and which ones to join would be advantageous. An animal could minimize interactions with potentially aggressive individuals and maximize potentially beneficial interactions.

Female spider monkeys are thought to disperse once they reach adulthood [Symington 1987] and prior to dispersal, mothers and daughters travel together. Thus, it is unlikely that the apparent similarity between the calls of mothers and
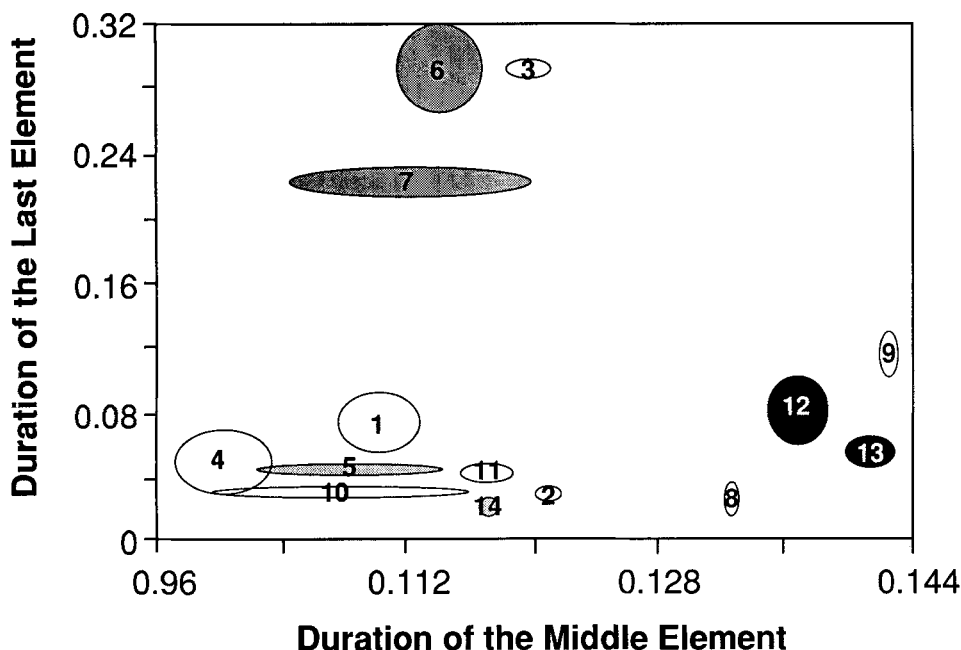
Fig. 2. A plot of the frequency distributions of the two acoustic parameters that best distinguished individual spider monkeys. The numbers represent the mean value of specific individuals, and ellipses represent the standard errors around the means in both directions. The differentially shaded ellipses represent three mother-daughter pairs in the study community. The age, sex, and dominance status of the individuals are 1) high-ranking adult female, 2) mid-ranking adult female, 3) mid-ranking adult female, 4) high-ranking adult female, 5) mid-ranking adult female, 6) low-ranking adult female, 7) immature daughter of 6, 8) low-ranking adult female, 9) high-ranking adult female, 10) low-ranking adult female, 11) low-ranking adult female, 12) immature son of 13, 13) mid-ranking adult female, and 14) immature daughter of 5.

daughters represents a mechanism to facilitate kin recognition, because immature daughters do not typically range out of visual contact of their mothers.

CONCLUSIONS

1. There are consistent acoustic differences between the whinnies of different individual spider monkeys.

2. The calls of mothers and offspring may be structurally more similar than those of less closely related individuals.

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