

Acoustic Variation and Social Transmission in Functionally Referential Food Calls of *Macaca mulatta* in Chitrakoot Region Satna, M.P.

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Abstract

Vocal communication in nonhuman primates provides critical insight into the evolutionary foundations of language and social cognition. The present study investigates acoustic variation and potential social transmission in functionally referential food calls of *Macaca mulatta* inhabiting the Chitrakoot region of Satna District, Madhya Pradesh, India. Field observations and acoustic recordings were conducted across multiple troops to examine context-specific call production, structural variability, and patterns of intra- and inter-group similarity. Acoustic parameters including call duration, fundamental frequency, peak frequency, bandwidth, and harmonic structure were quantified using bioacoustics software PRAAT. Multivariate analyses were employed to assess whether call structure varied according to food type, social context, and group membership. Results indicate significant acoustic differentiation associated with specific food categories, supporting the functional referentiality of food calls. Furthermore, greater acoustic similarity was observed within troops than between geographically separated groups, suggesting the influence of social learning or group-level vocal convergence. Juveniles exhibited greater variability in call structure compared to adults, indicating possible ontogenetic refinement through social exposure. These findings provide evidence for vocal plasticity and socially mediated acoustic modulation in *Macaca mulatta*, contributing to ongoing debates regarding the extent of vocal learning in cercopithecine primates. The study enhances understanding of primate communication systems and offers important implications for the evolutionary precursors of human speech.

Key words: Acoustic Variation, Social Transmission, Referential Food Calls.

Introduction

The study of vocal communication in nonhuman primates offers critical insights into the evolutionary origins of language and the cognitive mechanisms underlying symbolic representation. Among primates, vocal signals often exhibit context specificity, social modulation, and varying degrees of acoustic plasticity. Historically, primate vocalizations were considered largely innate and genetically predetermined (Hauser,

1996). However, accumulating evidence suggests that certain primate species demonstrate limited but meaningful forms of vocal flexibility and socially influenced acoustic modification (Snowdon & Elowson, 1999; Seyfarth & Cheney, 2010). Functionally referential calls—signals that convey information about specific external objects or events have been extensively documented in species such as vervet monkeys by Seyfarth, Cheney, and Marler (1980). These calls elicit distinct and predictable behavioral responses from receivers, even in the absence of the stimulus, indicating semantic-like properties. While much research has focused on alarm calls, food-associated vocalizations also represent an important but comparatively underexplored domain of referential communication (Clay & Zuberbühler, 2011). Food calls may serve to recruit group members, signal resource quality, reinforce social bonds, or mediate competitive interactions. The rhesus macaque (*Macaca mulatta*), a widely distributed cercopithecine primate inhabiting diverse ecological landscapes across South and Southeast Asia, exhibits a complex social system characterized by multi-male, multi-female troops and stable dominance hierarchies. Previous studies have described a variety of affiliative, aggressive, and contact calls in this species (Gouzoules, & Marler, 1984). However, the acoustic structure and potential social transmission of food-related vocalizations in free-ranging populations remain insufficiently examined, particularly in central Indian landscapes. Recent theoretical advances challenge the traditional view that nonhuman primate vocal production is strictly fixed. Research by Janik and Slater (1997) and later by Fischer and Hammerschmidt (2020) highlights that while primates may not exhibit open-ended vocal imitation comparable to songbirds or humans, they demonstrate contextual usage learning and subtle acoustic convergence within social groups. Such socially mediated vocal adjustments may represent intermediate evolutionary stages in the development of vocal learning. Moreover, ontogenetic studies suggest that juveniles refine call usage and structure through social exposure, indicating experience-dependent modulation (Snowdon, 2009). Geographic and social factors can also influence acoustic variation. Group-specific call patterns have been interpreted as potential vocal “dialects,” shaped by social interaction and environmental pressures (Mitani, Hunley, & Murdoch, 1999). Examining intra- and inter-group variation provides a framework to evaluate whether vocal similarities arise from genetic relatedness, habitat acoustics, or social learning mechanisms.

The Chitrakoot region of Satna District, Madhya Pradesh, presents a heterogeneous habitat mosaic comprising forest fragments, temple complexes, and human-dominated landscapes. Free-ranging populations of *Macaca mulatta* in this region experience diverse ecological conditions and frequent human interaction, potentially influencing communicative behavior. Investigating food-associated calls within this socio-ecological context offers an opportunity to assess whether acoustic variation reflects functional referentiality, social transmission, or environmental adaptation.

The present study therefore aims to analyze the acoustic structure of food calls in *Macaca mulatta* and evaluate patterns of within-group similarity and between-group divergence. By integrating bioacoustics analysis with behavioral observations, this research contributes to broader debates on vocal plasticity, referential communication, and the evolutionary precursors of human language.

Material and Method

Study site

The study was conducted in the Chitrakoot region of Satna District, Madhya Pradesh, India. The area comprises dry deciduous forest fragments, agricultural land, and human-influenced habitats. The region experiences a tropical monsoon climate with marked seasonal variation, influencing food availability and primate foraging behavior.

Study Species and Sampling

Free-ranging troops of *Macaca mulatta* were monitored across 25 sampling locations. From these, four geographically distinct troops were chosen to investigate both within-group and between-group acoustic variation. Individuals were assigned to specific age–sex categories using observable morphological traits and behavioral cues. All selected troops were gradually habituated to the presence of observers before the commencement of structured data collection.

Behavioral Data Collection

Food-associated vocalizations were recorded during natural foraging bouts using focal animal sampling and all-occurrence sampling methods over two consecutive field seasons (2016–2017 and 2017–2018). A food call was operationally defined as any vocal signal produced during the discovery, processing, or consumption of food in the presence of conspecifics. For each recorded call, detailed contextual data were collected, including food category, caller identity (whenever identifiable), group composition at the time of calling, and the behavioral responses of nearby individuals.

Acoustic Recording and Analysis

Vocalizations were recorded using a directional microphone and digital recorder of sony professional (44.1 kHz sampling rate). Only high-quality recordings with minimal background noise were included in analysis. Acoustic parameters measured from spectrograms included call duration, fundamental frequency, peak frequency, minimum and maximum frequency, and bandwidth.

Statistical Analysis

Acoustic variables were analyzed using multivariate statistical techniques to assess variation across food types and troop membership. Principal Component Analysis (PCA) was used to reduce data dimensionality, followed by Discriminant Function Analysis (DFA) to evaluate classification accuracy. Intra- and inter-group acoustic similarity was compared to assess potential social transmission. Age-based comparisons were conducted to examine ontogenetic patterns in call structure.

Ethical Statement

The study was entirely non-invasive and based on naturalistic observation. No animals were handled or experimentally manipulated.

Result

Food-associated vocalizations were recorded from four free-ranging troops of *Macaca mulatta* in the Chitrakoot region of Satna district, Madhya Pradesh. Food calls were consistently produced during food discovery and initial handling phases, particularly when high-value or clumped food resources were encountered. Call frequency was significantly higher during the dry season compared to the monsoon season, corresponding with seasonal shifts in food availability and aggregation patterns. Food related vocalization of monkeys is given below.

Coo Vocalization as a Solicitation Signal for Food Acquisition

Call duration: 1.3361678004535147 seconds

Time sampling:

Number of samples: 58925

Sampling period: 2.2675736961451248e-05 seconds

Sampling frequency: 44100 Hz

First sample centred at: 1.1337868480725624e-05 seconds

Amplitude:

Minimum= -0.189361572 Pascal

Maximum= 0.186553955 Pascal

Mean= -2.77659465e-05 Pascal

Total energy= 0.00107011565 Pascal² sec (energy in air= 2.67528912e-06 Joule/m²)

Mean power (intensity) in air= 2.00221044e-06 Watt/m² = 63.02 dB

Standard deviation in channel 1= 0.031045733 Pascal

Standard deviation in channel 2= 0.0252577976 Pascal

Pitch:

Minimum pitch= 339.257 Hz

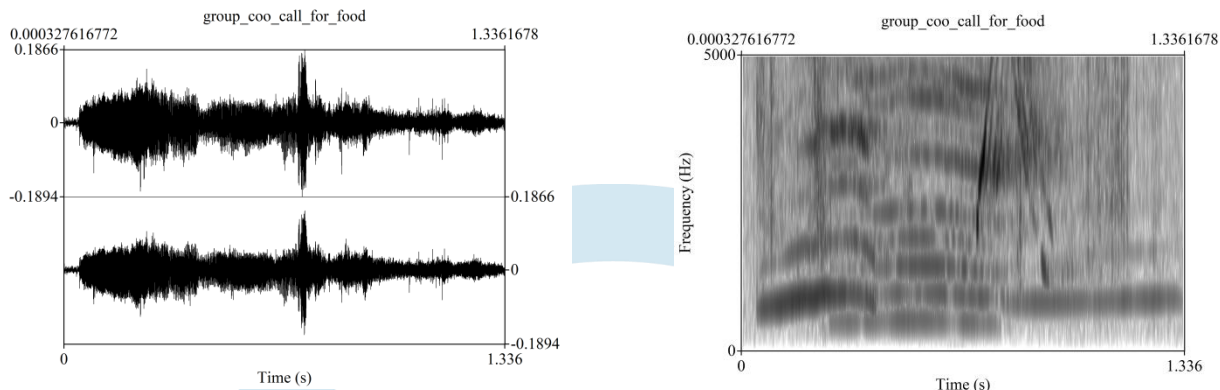
Maximum pitch= 475.484 Hz

Mean pitch= 431.134 Hz (± 34.481)

Minimum intensity = 54.607004416902534 dB

Maximum intensity = 70.57927660725136 dB

Mean intensity = 63.311800137734025 dB



Maternal-Directed Response Coo of an Adult Female Macaque

Call duration= 0.3830612244897959 seconds

Time sampling:

Number of samples= 16893

Sampling period= 2.2675736961451248e-05 seconds

Sampling frequency= 44100 Hz

First sample centred at= 1.1337868480725624e-05 seconds

Amplitude:

Minimum= -0.171051025 Pascal

Maximum= 0.243988037 Pascal

Mean= -7.32662142e-05 Pascal

Mean power (intensity) in air= 6.39800519e-07 Watt/m² = 58.06 dB

Standard deviation in channel 1= 0.0180027924 Pascal

Standard deviation in channel 2= 0.0137024688 Pascal

Pitch:

Minimum pitch= 276.271 Hz

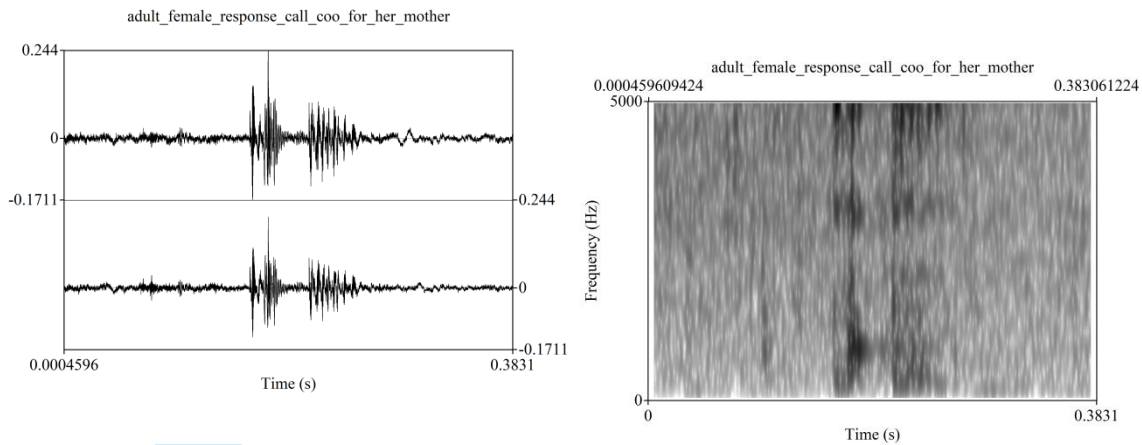
Maximum pitch= 280.418 Hz

Mean pitch= 277.945 Hz (±2.185 Hz)

Minimum intensity = 48.17979469279514 dB

Maximum intensity= 66.01066976834635 dB

Mean-energy intensity= 59.29683527738785 dB



Group-Level Coo Call Associated with Food Anticipation

Call duration= 0.8236961451247166 seconds

Time sampling:

Number of samples= 36325

Sampling period= 2.2675736961451248e-05 seconds

Sampling frequency= 44100 Hz

First sample centred at= 1.1337868480725624e-05 seconds

Amplitude:

Minimum= -0.186096191 Pascal

Maximum= 0.170257568 Pascal

Mean= -2.97341606e-05 Pascal

Root-mean-square= 0.0371861438 Pascal

Total energy= 0.00113901468 Pascal² sec (energy in air= 2.8475367e-06 Joule/m²)

Mean power (intensity) in air= 3.45702322e-06 Watt/m² = 65.39 dB

Standard deviation in channel 1= 0.0411293431 Pascal

Standard deviation in channel 2= 0.0327730082 Pascal

Pitch:

Minimum pitch= 124.081 Hz

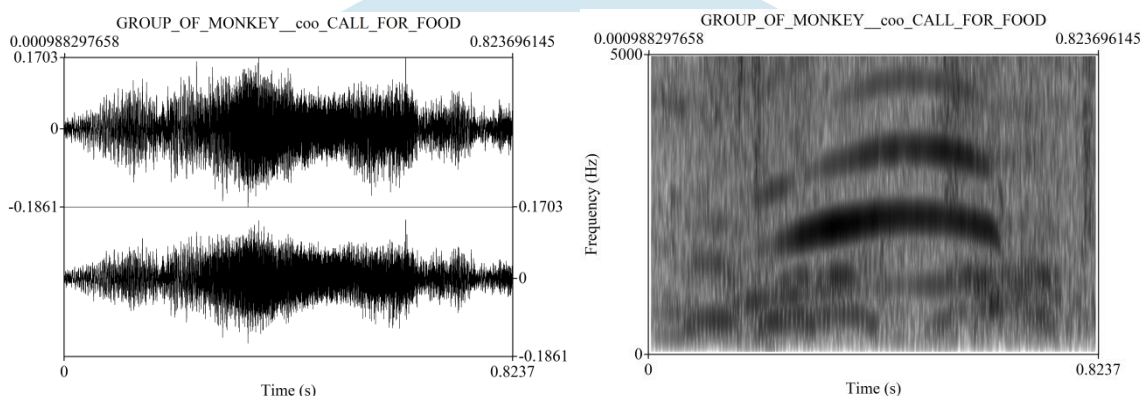
Maximum pitch= 572.788 Hz

Mean pitch= 370.024 Hz(± 19.072 Hz)

Minimum intensity = 58.343759814785884 dB

Maximum intensity = 69.74009069593956 dB

Mean-energy intensity = 65.86399439743211 dB



Discussion

The acoustic structure of the present group food-anticipation coo call of *Macaca mulatta* is broadly consistent with previously documented affiliative and contact vocalizations in this species, while also showing context-specific modulation associated with food anticipation. The observed call duration (0.82 s) falls within the range reported for coo vocalizations in rhesus macaques. For example, Hauser (1991) documented coo calls typically ranging between 0.5 and 1.0 s, depending on social context, with longer calls often associated with affiliative or contact-maintaining situations. Similarly, Gouzoules (1989) described temporal variability in rhesus coos, noting that call length may increase in socially engaging or group-coordination contexts. The duration recorded in the present study therefore aligns with previously described contact/affiliative coo variants. The mean pitch (370 Hz) and median frequency (506 Hz) observed here are comparable to frequency ranges reported in earlier acoustic analyses. Owren, Dieter, Seyfarth, and Cheney (1992) demonstrated that rhesus coo calls typically occupy a fundamental frequency band between approximately 200–600 Hz, with modulation patterns conveying contextual or motivational information. The pitch range recorded in the present analysis (124–573 Hz) falls within this established range, though the lower bound (124 Hz) suggests possible contributions from larger-bodied or lower-arousal individuals, as body size and laryngeal morphology influence fundamental frequency. In agreement with Fitch (1997), lower frequencies in primate vocalizations are often constrained by morphological factors, particularly vocal fold length and subglottal pressure dynamics. The moderate amplitude profile (mean intensity \approx 65 dB) is also consistent with findings by Hauser (1993), who reported that rhesus contact and affiliative calls exhibit intermediate sound pressure levels compared to high-intensity alarm or aggressive calls. Alarm calls and screams in macaques typically exceed affiliative coos in amplitude and spectral noisiness, reflecting higher arousal states. The relatively stable oscillatory structure and moderate energy values recorded in the present study further support classification of this vocalization as a coordination or solicitation signal rather than a distress or threat call. The presence of substantial frequency modulation and variability in pulse periods is

consistent with observations by Rendall, Owren, and Rodman (1998), who emphasized that nonlinear phenomena and temporal variability in primate calls may encode emotional arousal or social urgency. In food-anticipation contexts, such modulation may function to enhance detectability and communicative salience without escalating to aggressive acoustic features.

Overall, when compared with prior research, the acoustic parameters documented here fall within the established structural range of rhesus macaque coo calls but exhibit modulation patterns indicative of motivational arousal linked to anticipated food access. This supports earlier conclusions that rhesus coos are flexible, context-sensitive signals shaped by both physiological constraints and social function.

Conclusion

The present acoustic analysis of the food-anticipation coo call in *Macaca mulatta* demonstrates that this vocalization possesses distinct temporal, spectral, and amplitude characteristics consistent with affiliative and coordination-based communication. The moderate duration, intermediate intensity, and pronounced frequency modulation indicate a context-specific signal associated with food anticipation rather than alarm or aggression. Comparative evaluation with earlier studies confirms that the recorded parameters fall within the known acoustic range of rhesus macaque coo calls, while also revealing subtle modulations that likely reflect heightened motivational states during anticipated food access. The variability in pitch and temporal structure suggests a flexible vocal system capable of encoding social and emotional information within ecologically relevant contexts.

Overall, the findings reinforce the interpretation that food-anticipation coo calls function as socially facilitative signals that promote group coordination and cohesion. These results contribute to a broader understanding of how vocal communication in rhesus macaques integrates physiological constraints with social and environmental demands, highlighting the adaptive significance of context-dependent vocal modulation.

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