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The Spanish sparrow (*Passer hispaniolensis* Temminck 1820) nestling begging calls: call characterisation and distinctiveness

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Resumen

Llamadas de pedida del gorrión moruno (Passer hispaniolensis)

Este es el primer trabajo que describe cuantitativamente las llamadas de pedida de los pollos de gorrión moruno (*Passer hispaniolensis*). Estas llamadas presentan un alto grado de especificidad inter-individual, como lo confirman una comparación por correlación de audioespectrogramas y un análisis de funciones discriminantes. La clasificación post-hoc de este análisis erraba en la clasificación de 7 casos de un total de 72 (o sea daba una clasificación correcta del 90.3% de los casos). Las características que mejor discriminaban entre individuos eran duración de la llamada y tiempo relativo del máximo de intesidad (relative peak time).

Palabras clave: Gritos de petición, diferencias interindividuales, gorriones, características estructurales de la llamada.

Abstract

This is the first study to characterise the Spanish sparrow nestlings begging calls. The nestlings' begging calls presented high degree of inter-individual distinctiveness, Confirmed by both audiospectrogram correlations and discriminant function analysis. The *post hoc* classification miss-classified 7 cases out of 72 (making a total of 90.3% correctly classified cases). The individual call characteristics that seemed to best discriminate between nestlings were call duration and relative peak time.

Key words: Vocal begging, inter-individual distinctiveness, Sparrows, call structural characteristics.

Introduction

Altricial offspring of birds solicit food provisioning by complex begging displays, implying acoustic and visual signals (Trivers 1974, Harper 1986, Medvin et al. 1993, Kilner 1997, Kilner & Johnstone 1997, Leonard & Horn 2001b). Offspring begging as long been view as signal in a parent–offspring communication system (Trivers 1972, Godfray 1991). The vocal begging characteristics can be use as systematic characteristic for species identification (e.g. Redondo et al. 1986). However, this apparent stereotype call may have within-type structural variation (Medvin et al. 1993) that can reflect «errors» in call production or some functional variation (Owings & Morton 1998). The most important functional aspects favouring nestling vocal distinctiveness are parent-offspring recognition and offspring condition signalling (e.g. Cotton et al. 1996, Kilner 1997, Leonard et al. 1997). Parent recognition of their kin occur in situations where identification is crucial to offspring survival like in a colony (Medvin et al. 1993, Seddon & Vanheezik 1993, Nakagawa et al. 2001) or in other contexts (e.g. cooperative breeding, Barg & Mumme 1994). Nestling vocal distinctiveness could also be favoured in situations where variation in sound structure could incorporate information concerning the nutritional condition of the nestling (Price & Ydenberg 1995, Kölliker et al. 1998, Leonard & Horn 1998, Sacchi et al. 2002).

The parameters that allow the incorporation of information in vocal begging can be divided in two different types: non-structural and structural. Non-structural incorporation of information can be done by changing the intensity of sound, as in the tree swallows *Tachycineta bicolor* (Leonard & Horn 2001a); by altering the begging rate, as in the yellow-head black birds *Xanthocephalus xanthocephalus* (Price et al. 1996) or the begging latency time as in the barn swallow *Hirundo rustica* (Sacchi et al. 2002), where this variation is usually associated with changes in offspring needs. Structural variation, like call duration (Leonard & Horn 2001a, Sacchi et al. 2002) or sound frequency (Leonard & Horn 2001a, Sacchi et al. 2002) can also encode information on offspring needs and is associated with both individual signature and the expression of offspring need. Several factors such as predation (Redondo & Reyna 1988, Haskell 1994, Briskie et al. 1999) but see (Halupka 1998)) or energetic costs (Bachman & Chappell 1998) but see (Leech & Leonard 1996, McCarty 1996)) can constrain the evolution of the signal and thus the codification of the information.

The Spanish sparrow is a colonial species with highly synchronised breeding phases (Gavrilov 1963, Alonso 1982, 1984, Marques 2002). No clear relation was found between average nestling condition and the nestling vocal begging behaviour for this species. The effect of brood size in nestling begging behaviour of bi-parental was significant with the vocal begging intensity per nestling diminishing with the number of offspring in the nest. Spanish sparrow nestlings begged indiscriminately to males and females (Marques 2004).

The purpose of this study was to characterise structurally the nestling begging call of the Spanish sparrow (*Passer hispaniolensis*). We also study the distinctness of individual begging calls. Two questions where addressed. The first question concerned the individual differentiation of nestling begging calls being assessed by two different approaches: first by comparing audiospectrograms and secondly by using a limited set of audiospectrograms variables to compare the nestling begging calls. Secondly, to determine which variables would contribute most for nestling calls discrimination.

Material and methods

The study was carried out in May 2002, at Castro Verde, Southern Portugal (37° 41'N, 08° 03'W). A total of 5 Spanish sparrow nests with one nestling were monitored in the same colony. Single-nestling nests were chosen in order to ensure that the calls recorded form each nest were produced by a single individual.

The nestlings vocal reaction to the parents visits was recorded with the use of a tie clip microphone (REALISTIC electret microphone) attached to the top of the nest and connected to an audio cassette recorder (SONY WM-D6C) by a 30 m audio cable. The nestlings were thus located at a distance of approximately 10-20 cm from the microphone. Recordings were made during all day, avoiding the early morning and late afternoon periods. There was no apparent effect of the microphone in parent or nestling behaviour. Recordings started after a waiting period after the placement of the microphone to allow adults to resume their feeding activities. At the time of observation nestlings age ranged between seven and ten days (hatching day = day 1), ageing was done according to Alonso (1982) description of nestling development.

Sound analysis

Recordings were digitized with a Digi 001 sound board and Pro Tools software (Digidesign Inc.) in a Apple Macintosh G3 computer. Files were edited with SOUNDMAKER v. 1.0.4. (Riccisoft.com) software, sound files were then filtered in order to remove noise (bandpass: low 300 Hz and high 16 000 Hz) and normalized to 96 %. On average 14.6 ± 3.0 calls (ranging from 12 to 19) were used for describing the begging call. The quantitative analysis of these calls was made with the minimal number of variables that would adequately describe the dominant harmonic in an audiospectrogram of a call (bandwidth 174.85 Hz, frame length 1024 points). The structural variables considered were: the call duration (s), the peak frequency (the frequency with the highest amplitude in the call, in Hertz), relative peak time ((peak time-begin time)/duration of the call)), and the maximum and minimum frequency of the calls (in Hertz).

Measurements were made from audiospectrograms using Canary software 1.2.4. (Cornell Laboratory of Ornithology, Ithaca, NY, USA).

Statistical analyses

To assess the difference of begging calls between nestlings, correlations between all pairs of

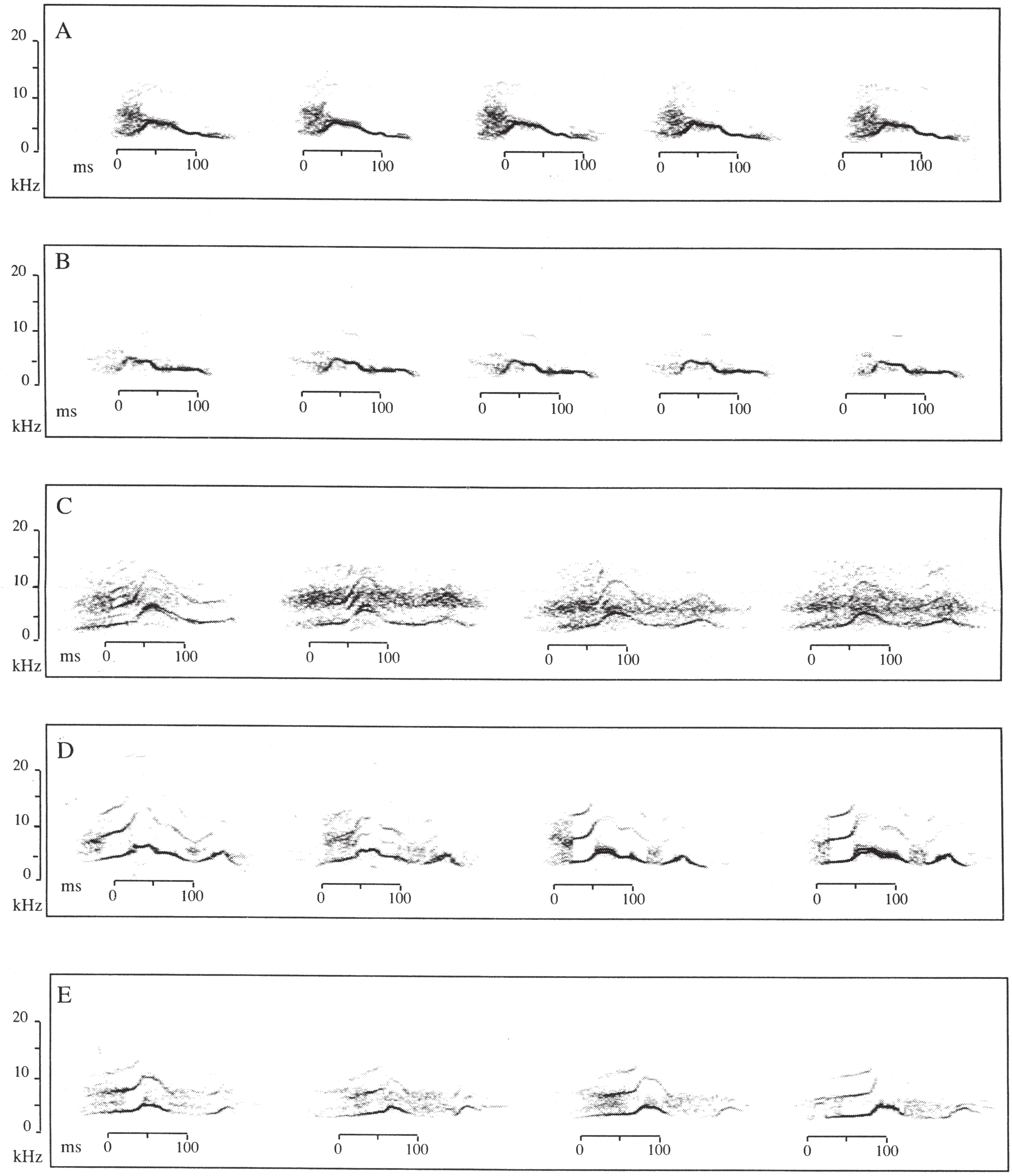

Fig. 1. Examples of the audiospectrograms from five nestlings, A to E (bandwidth 699.40 Hz, frame length 256 points, clipping level of –60dB).
Fig. 1. Ejemplos de audioespectrogramas para cinco pollos, A a E (anchura de banda, 699.40 Hz, longitud de ventana 256 puntos, nivel de «clipping» –60dB.

audiospectrograms were made using the function «audiospectrogram correlation» (Batch correlation) of Canary software v. 1.2.4. 400-ms recorded segments containing a single call from each recorded individual were selected based on sound quality. Five begging calls were used for each nestling. For each call, the peak amplitude of the call was positioned at 200 ms. An audiospectrogram was calculated for each file, and all the audiospectrograms obtained were cross-correlated in a batch correlation. The process yielded a square correlation matrix containing the correlations coefficients of every call with the rest of the calls. The average audiospectrogram correlation of intra-individual calls was then compared to the average audiospectrogram correlation of calls between-individual. Independent samples *t*-tests were used.

The aforementioned structural variables were used in a discriminant function analysis to determine if individual calls could be discriminated. This approach also allows detecting the variables that best discriminate between nestlings. Statistical analysis was performed using Statistica software (StatSoft 1996). Results are presented as mean ± SD (standard deviation).

Results

Calls characterisation

A total of 72 begging calls from 5 individuals were analysed. Spanish sparrow nestlings present a simple begging call (Figure 1). Begging calls are short in duration, with the intensity peak occurring on average at the end of the first third of the call (Table 1). The range of low and high frequency overlap.

Individuality of the calls

A visual inspection of the audiospectrograms was first conducted and clearly detected differences between individuals (Fig. 1). The audiospectrogram correlation analysis supported this empirical view and revealed that the calls from the same individual had significantly higher correlations than calls from different individuals. All nestlings presented significantly differences when compared to other nestlings (Table 2).

Discriminant function analysis revealed that the overall discrimination between individuals is highly significant (Wilks' Lambda=0.017, F (16,196)=34.64, P<0.0000). Peak frequency was removed from the analysis to avoid discriminant analysis assumptions violation, since this parameter did not present homogeneity of variances. All the considered variables presented highly significant contributions to the model (Table 3). The Partial lambda values indicate that call duration and relative peak time contribute most to the discrimination (Table 3).

All the discriminant functions were statistically significant. The first discriminant function was weighted most heavily by call duration and relative peak time (RPT), the second by RPT and low frequency, and the third by low and high frequencies (Table 4). The first 3 discriminant functions accounted for 98% of the explained variability. Apparently the first discriminant function discriminated nestlings 8 and 5 (negative values) from nestlings 3 and 4 (positive values). The second discrimination function discriminated nestling 8 from nestling 5 and nestling 3 from nestling 4. Finally, the third function discriminated 3 and 5 from 6 (Table 5, Fig. 2).

Based on this result a *post hoc* prediction on the classification of the cases was conduced. The percentage of correct classification for each nestling calls varied from 75 to 100 % and 7 out of 72 cases were miss-classified (with a total of 90.3% correctly classified cases, using the squared Mahalanobis distances from group centroids).

Discussion

This is the first study to characterise structurally the Spanish sparrow nestlings begging calls (Cramp & Perrins 1994), and the description reveals a high

	Minimum	Maximum	Mean ± SD	N
Call duration (s)	0.135	0.333	0.218 ± 0.050	72
Relative peak time %	0.09	0.671	0.336 ± 0.096	72
Low Frequency (kHz)	1 493	3 172	2 565 ± 332	72
High Frequency (kHz)	5 074	7 138	6 125 ± 515	72
Peak Frequency (kHz)	3 445	6 718	4 871 ± 819	72

Table 1. Characteristics of nestling begging calls (SD- standard deviation).
Tabla 1. Caraterísticas de las llamadas de petición de los pollos (SD- desviación típica).

	Intra-individual correlation Mean±SD (N)		Inter-individual correlation Mean±SD (N)	t-test	df	P
Nestling 3	0.827±0.024 (10)	Nestling 3 x 4	0.535±0.030 (25)	27.4	33	<0.0001
		Nestling 3 x 5	0.414±0.059 (25)	21.2	33	<0.0001
		Nestling 3 x 6	0.481±0.052 (25)	19.9	33	<0.0001
		Nestling 3 x 8	0.445±0.028 (25)	37.8	33	<0.0001
Nestling 4	0.857±0.057 (10)	Nestling 4 x 3	0.535±0.030 (25)	22.0	33	<0.0001
		Nestling 4 x 5	0.281±0.052 (25)	28.8	33	<0.0001
		Nestling 4 x 6	0.343±0.041 (25)	30.0	33	<0.0001
		Nestling 4 x 8	0.369±0.049 (25)	25.5	33	<0.0001
Nestling 5	0.566±0.069 (10)	Nestling 5 x 3	0.414±0.059 (25)	6.5	33	<0.0001
		Nestling 5 x 4	0.281±0.052 (25)	13.3	33	<0.0001
		Nestling 5 x 6	0.398±0.057 (25)	7.4	33	<0.0001
		Nestling 5 x 8	0.431±0.057 (25)	6.0	33	<0.0001
Nestling 6	0.645±0.075 (10)	Nestling 6 x3	0.481±0.052 (25)	7.3	33	<0.0001
		Nestling 6 x4	0.343±0.041 (25)	15.3	33	<0.0001
		Nestling 6 x5	0.398±0.057 (25)	10.6	33	<0.0001
		Nestling 6 x 8	0.417±0.026 (25)	13.4	33	<0.0001

Table 2. Average and standard deviation of the audiospectrograms correlations within and between nestlings begging calls (SD- standard deviation; N- number of correlations).
Tabla 2. Media y desviación típica de las correlaciones de audiospectrogramas de las llamadas de petición a nivel intra- e inter-individual (SD- desviación típica; N- número de correlaciones).

	Wilks'			
	Lambda	Partial Lambda	F-remove (4, 64)	P
Call duration (s)	0.081	0.204	62.16	<0.000
Relative peak time %	0.054	0.306	36.30	<0.000
Low Frequency (kHz)	0.031	0.533	14.02	<0.000
High Frequency (kHz)	0.020	0.802	3.94	<0.000

Table 3. Discriminant function analysis results and contribution of the variables to the overall discrimination.
Tabla 3. Resultados del análisis de la función discriminante y contribución de las diferentes variables a la discriminación total.

degree of inter-individual distinctiveness. Both the audiospectrogram correlations and the discriminant function analysis confirm this view. The audiospectrograms of the calls from each individual were significantly more correlated with its own calls than with calls from other individuals. This individuality of the begging calls was also confirmed with a discriminant function analysis of the sound variables. The individual call characteristics that seem to best discriminate between nestlings were call duration and the relative peak time. The *post hoc* classification missclassified 7 cases out of 72, supporting the reported call distinctiveness. Although, this approach is limited since the same cases were included in the

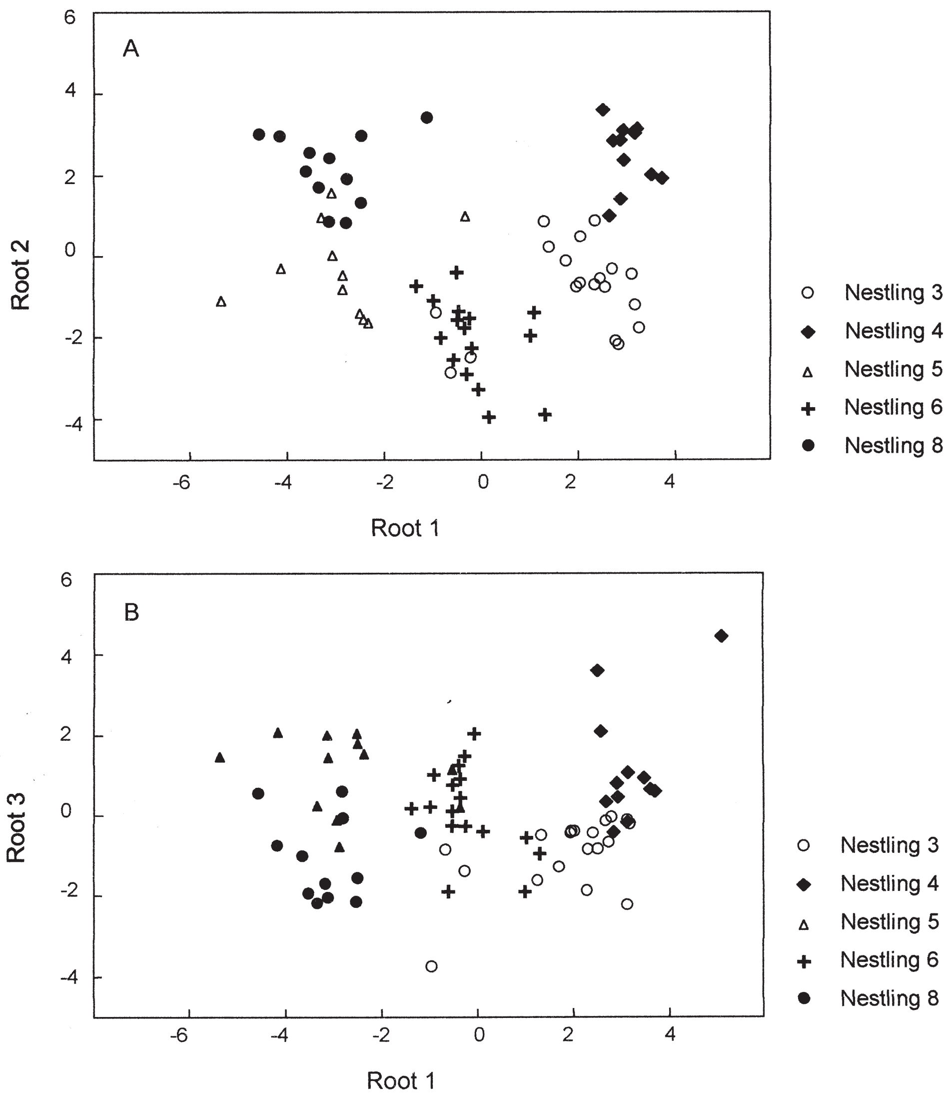

Fig. 2. Graphical representation of the discrimination between five nestlings: A -canonical scores of each call in the 1st and 2nd discriminant functions (roots) and B - canonical scores of each call in the 1st and 3rd discriminant functions.
Fig. 2. Representación gráfica de la discriminación entre cinco pollos: A- valores canónicos de cada llamada en las funciones discriminantes (raices) 1 y 2, y B valores canónicos de cada llamada en las funciones discriminantes 1 y 3.

	Standardized Coefficients			
	Functions			
	1	**2**	**3**	**4**
Call duration (s)	-0.97	-0.22	0.27	0.21
Relative peak time %	0.32	-0.85	0.49	0.02
Low Frequency (kHz)	-0.15	0.40	0.92	-0.28
High Frequency (kHz)	-0.12	0.11	-0.17	-1.04
Eigenvalue	5.81	3.18	0.75	0.21
Cumulative Prop. E. V.	0.58	0.90	0.98	1

Table 4. Variable contribution for call discrimination in each discriminant function (Cumulative Prop. E. V. - cumulative proportion of explained variance).
Tabla 4. Contribución de las variables en cada función discriminante (Cumulative Prop. E. V. – proporción acumulada de la varianza explicada).

	Means of Canonical Variables			
	Function			
	1	2	3	4
Nestling 3	1.90	-0.80	-0.85	0.41
Nestling 4	3.09	2.41	0.88	-0.17
Nestling 5	-2.72	-0.44	1.13	0.59
Nestling 6	-0.20	-2.05	0.21	-0.59
Nestling 8	-3.11	2.19	-0.96	-0.23

Table 5. Contribution of each discriminant function for the individual calls discrimination.
Tabla 5. Contribución de cada función discriminante para la discriminación individual de las llamadas.

model and for a correct validation of the usefulness of the discriminant functions a new set of cases should be considered.

The reported variability in this study suggests that the nestling begging calls might incorporate information about their need for food or information related to individual recognition, although only experimental approaches could confirm these hypotheses. Both these functional aspects could constitute adaptive advantages in the Spanish sparrow. The assessment of offspring need could favour the evolution of such a trait improving the resources distribution among siblings and thus their survival (Godfray 1995, Rodríguez-Gironés et al. 1996). This species social behaviour, nesting in large colonies (Marques et al. 2002), may also favour the inter-individual variability of the calls, through kin recognition as reported for other species (Beecher 1982, Lessells et al. 1991, Jouventin et al. 1999, Insley et al. 2003). The differences could also be due to differences in ontogenetic changes of the begging vocalisations originated by nestlings age differences. In order to test these hypotheses further studies are needed. Primarily, the ontogeny of the begging calls should be studied. Secondly, it should be determined if the variation detected encodes any information and finally it should be evaluated if parents can perceive the signal variation. Overall, the study of non-structural vocal begging variation (e.g. begging rate) on parental behaviour seems to indicate that, at least for some species, parents can perceive changes at that level (Ottosson et al. 1997, Leonard & Horn 1998, Kilner & Davies 1999). Experimental manipulation of structural features of begging call also reveal that, at least for some species, parents use particular call parameters to discriminate between nestlings (Aubin & Lengagne 1998, Lengagne et al. 1999).

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