

## **The grey parrot (*Psittacus erithacus*) as musician: an experiment with the Temperate Scale**

L. BOTTONI <sup>1,2</sup>, R. MASSA <sup>1</sup> and D. LENTI BOERO <sup>3,4</sup>

<sup>1</sup> *Dipartimento di Scienze dell'Ambiente e del Territorio, Università degli Studi Milano Bicocca, Piazza della Scienza 1, I-20136 Milano, Italy*

<sup>3</sup> *Facoltà di Scienze della Formazione, Università di Urbino, Via Saffi 15, I-60129 Urbino-PS, Italy*

<sup>4</sup> *Laboratorio di Bioacustica e Analisi Comparativa del Comportamento e delle Funzioni Cognitive, Facoltà di Medicina, Università degli Studi di Milano, Via di Rudini 8, I-20142 Milano, Italy*

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It has been recently proposed that music should be regarded as a non-verbal form of communication. In addition, it has also been underscored that some animals can innately master a musical code. In this study we submitted sound frequencies corresponding to musical notes in the Temperate Scale to a young female grey parrot by means of the model/rival approach. The results obtained show that there was no latency in eliciting answers, that the parrot sung in reply a musical repertoire significantly larger than the stimuli played. The note frequencies preferred by the parrot, that she never heard before, ranged from the sixth to the seventh octave and were significantly different from the notes played during the experiment that ranged from the fourth to the fifth octave. All the notes in the parrot's sequences were significantly dependent on the previous one. Therefore, our parrot demonstrated a complex cognitive competence in understanding both the similarities and dissimilarities among the frequencies and was able to master the musical code.

KEY WORDS: grey parrot, animal cognition, music, discrimination, categorization, soundscape.

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<sup>2</sup> Corresponding author (E-mail: luciana.bottoni@unimib.it).

## INTRODUCTION

It is well known that some bird species, including the grey parrot *Psittacus erithacus*, are able to mimic sounds, even human whistles, words and phrases (BERTRAM 1970, TODT 1975). Until recently, it was believed that this kind of mimicry only occurred in captive conditions (KROODSMA & BAYLIS 1982, FORSHAW 1989), but this idea was challenged by a 4 min grey parrot sequence, recorded by CRUICKSHANK et al. (1993) in the tropical forest of Congo, containing several sounds from the repertoire of 10 different species (nine birds and one bat) suggesting that mimicry is a normal adaptive behaviour for the grey parrot and possibly for other birds.

In order to imitate sounds, a grey parrot needs to activate peculiar cognitive competences: first, to isolate the sound to be imitated from the background noise of the acoustic landscape (this is especially true for spontaneous imitation, both from the natural and the human artificial environment, where no local enhancement or attention arousal for the sounds to be imitated is provided); second, to categorize the acoustic stimulus, i.e. to analyse and differentially resolve the different frequencies; third, to encode it into long-term memory as a template for the setting of new motor controls of the syrinx to express the sounds to be imitated (BIZZI & MUSSA-IVALDI 1990); fourth, to monitor the output sound by means of short-term memory in order to match it with the internal template (HINDE 1970).

All these cognitive competences were clearly demonstrated by PATTERSON & PEPPERBERG (1994), with a grey parrot named Alex who was able to reproduce phonetic sounds from the human linguistic environment by using an alternative phonetic articulatory space. The motor control competences were demonstrated by HEATON et al. (1995), who found that in the parrot spp. both left and right syrinx muscles are connected with the left and right motor nuclei and with both sides of the brain.

Beyond these basic motor and cognitive capacities, Alex demonstrated a semantic ability as he was shown to be able to correlate human words with the objects they represent (PEPPERBERG 1981, 1983) and also, together with other parrot spp. (BOTTONI & LENTI BOERO 1999), to master abstract concepts such as equal-different, big-small and numbers (PEPPERBERG 1987).

If a grey parrot is able to use his vocal and cognitive abilities to communicate by means of human-like words, one may wonder whether he may also use the same abilities to communicate nonverbally, i.e. by means of a musical code. It was proposed by GARDNER (1983) that music should be considered as a nonverbal form of communication. BAPTISTA & KEISTER (2000) even proposed a parallel between human music and bird song, in the sense that both imply the use of rhythmic variations, pitch relationships, permutations and combination of notes. In fact, song is the most usual bird communication form. MARLER (2000) draws a parallel between music and animal song: even though they do not have any semantic structure (what he calls lexical syntax or lexicoding, i.e. the recombination of sound sequences in different phrases with new meanings), they both present a phonological syntax, or phonocoding, i.e. the recombination in different sequences of simple sound elements. For this reason music is an interesting stimulus for the verification of whether both the basic cognitive competence of sound discrimination and imitation and the higher competence of categorization and rule understanding can be applied to a non-semantic non-visual stimulus. This is the aim of the present study.

## MATERIALS AND METHODS

Our subject was Teo, a female grey parrot. She was born in captivity in February 1998, was taken out from her nest and hand reared after her 4th week up to her weaning (12 weeks of life). After this period and up to December (10 months of age), she was kept in a single cage and regularly exposed to a human environment. In addition, her cage was kept in proximity to that of an immature, hand reared Red-fronted parrot (*Poicephalus gulielmi*). Therefore, she was very tame and used both to humans and to other birds when we started our musical experiment in December 1998. During her human contacts, to establish a relaxed and friendly relationship, she had also been exposed to human language and therefore learnt to pronounce some human words as well as other sounds such as a hen's call, a canary song, a human laugh and some different whistles. On the other hand Teo had never been exposed to music before the beginning of her training sessions.

*The musical code*

A musical interval is the difference in pitch between two tones, and its quantity is measured by the frequency ratio. Intervals are the basis of any musical system and of the laws of Melody and Harmony (RIGHINI 1970). The most important interval, found in any culture of any historical period, is the octave, in which the frequency ratio is always 2/1. Different subdivisions of this main interval define musical scales: a musical scale is in fact, a series of pitch-ordered tones, which divide the octave in the same number of parts (RIGHINI 1994). The scale used in Western modern music is based on the Equal Temperament, introduced by Andreas Werckmeister at the end of 17th Century (die Musikalische Temperatur, 1691). This system subdivides an octave in 12 equal semitones. Thus, a temperate semitone is defined by a frequency ratio of  $2^{1/12}$  (about 1.05946). In this experiment, we adopted the equal temperate scale, tuned to the standard pitch A (La) 440 Hz.

*Musical training sessions*

To train Teo, we adopted the model/rival technique (TODT 1975, PEPPERBERG 1981). All sessions were performed with a playful approach, suggesting to Teo that something interesting was going to be started. We adopted the basic principles of the musical solfeggio, for example, when a session was started, the principal trainer played either an ascending or a descending scale or just a couple of notes on an electronic keyboard (Korg Wavestation EX Synthesizer). The secondary trainer responded with the opposite sequence played on another synthesizer that is a descending scale in response to an ascending one or viceversa. The same was done with a couple of note, i.e. when the principal trainer played C-D (Do-Re), the secondary trainer played D-C (Re-Do).

To standardize the sessions, the same musical stimuli were regularly presented in all of them. The total stimuli proposed in each session were 14 and consisted in: (a) two musical scales, one pertaining to the fourth and the other to the fifth octave (from 261.6 to 1046.4 Hz) and, (b) series of two contiguous notes, six pertaining to the fourth and six to the fifth octave. In music, octaves are usually named following the correspondent octave on a piano keyboard. However, there are many ways to name them, according to different traditions (Italian, standard American, etc.). In this work we will count the octaves following the number of C's (Do's) on a piano keyboard. Thus, the 'first octave' begins with the first C (Do) (freq = 32.7 Hz) (FROVA 1999). The stimuli were always presented in randomised sequences.

During the same session, once the whole series of the 14 musical stimuli was completed, the roles of principal and secondary trainers were exchanged and the same stimuli were repeated in a new randomised sequence. Therefore, Teo was currently encouraged to take part in the session and the principal trainer reinforced her musical responses by praising and

preening her. Three sessions per week were usually performed and the experiment was continued for a total of 60 sessions, each of them lasting from 5 to 30 min, according to the parrot willingness to cooperate.

#### *Data analysis*

Sounds were recorded by means of a Tascam DA-P1 DAT recorder equipped with a Sennheiser K6 microphone with a directional module Sennheiser ME 67 and with DAT cassettes. Sounds were sampled at 48.000 Hz and the sample size was 16 bit.

Recordings were imported on to a Power Macintosh 7300/200 through a PCI audio card Audiomedia III with the software Sound Designer II (version 2.8.3). On the same computer, the sonograms were produced and analysed by means of the software Canary 1.2.4 (CHARIFF et al. 1995), adopting the following parameters: filter bandwidth 95.16, frame length 2048 points and a size of the FFT transform 2048. Canary allows the measurement of the frequency up to three decimal points. From the sonograms we selected those of Teo's responses that had a musical sound according to at least two different listeners. In order to identify the selected sound as a musical note, in the temporal domain we chose those acoustic signals showing a constant frequency not shorter than 100 msec (FROVA 1999). Then, we had to identify which of Teo's 100 msec signals corresponded to the frequency of an equal temperate scale note. In order to accomplish this task each 100 msec signal was looped and identified by means of a musical tuner Korg DT-3 connected to the computer. The tolerance of the tuner was  $\pm 25$  cents. The cent is a measure based on the logarithmic transformation of the ratio between two musical frequencies. With cents it is possible to separate 12 equal temperate scale notes in intervals of 100 cents and to be accurate in tune measurement. We measured only the fundamental frequency of each note, clearly visible in Fig. 1.

In order to compare different percentage data we used the GLIM 3.77 package designed for fitting generalized linear models. The package interactively calculated the scaled deviances and residual sum of squares for each variate factor, or interactions among them. Scaled deviances asymptotically approach a  $\chi^2$  distribution, which is used in probability testing (BAKER & NELDER 1978, AITKIN et al. 1989). A further advantage of the GLIM 3.77 package is that it is possible to choose the most suitable distribution for data representation, in the

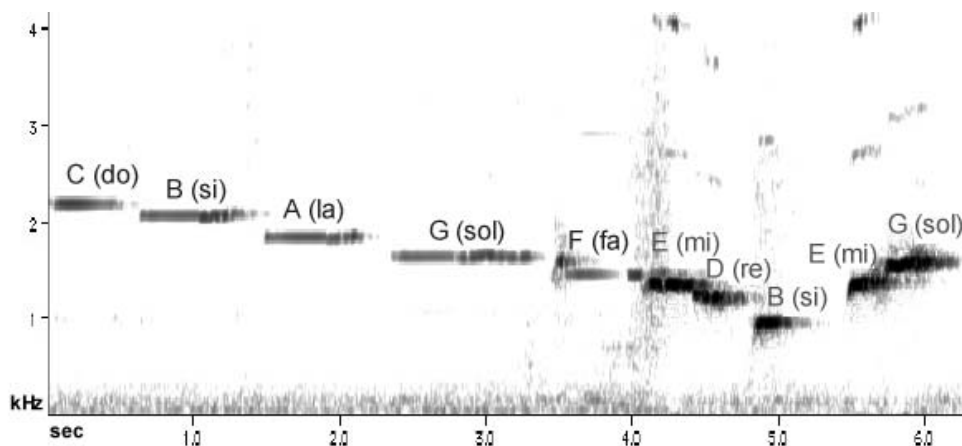


Fig. 1. — A sonogram example showing notes played on a keyboard by the experimenters (the first five) and notes sung by Teo (the latter five).

present case a binomial distribution was chosen. For further details see LENTI BOERO (1995). Quantitative statistics were performed by means of SPSS.

RESULTS

*Experimenter's output*

Physically, the notes are a sub-sample of continuous frequencies, and for this reason in this paper we considered the musical stimuli in their double nature of frequencies and notes.

A total of 81 stimuli consisting of musical sequences of one (n = 7), two (n = 48), three (n = 4), four (n = 10), six (n = 2), seven (n = 9), and eight (n = 1) notes, for a total of 238 notes lying within the fourth and fifth octaves were followed by an answer from Teo. The mean ± SD number per sequence 2.94 ± 1.85. The 74 sequences of two or more notes could be subdivided in 59 ascending melodies, 12 descending melodies, 1 ascending/descending melody, and 2 descending/ascending melodies (see Table 1).

*Teo's answers*

The majority of the parrot's answers (87.8%) overlapped the musical stimulus played by the experimenter. The total number of notes emitted by Teo was 367 (129 notes more than the stimuli), and the mean number of notes per sequence was 4.53 ± 3.09 (range 1-18), a figure significantly different from the mean number of notes of the stimuli (two-tails paired t test: t value = - 4.45, df = 80, P = 0.000). In fact the number of notes emitted by Teo did not correlate with the number of notes played by the experimenter (SPSS, Pearson rho = 0.14, N = 81, P = 0.221). Table 1 shows the melodies of the musical sequences emitted by Teo in response to the experimenter's stimuli. As it can be seen, the answers to ascending melodies stimuli of two or more notes are almost equally subdivided into both ascending (n = 28; 52%) and descending (n = 26; 48%), while in replying to the descending stimuli Teo chose an ascending melody 6 (60%) times, but a descending one only 4 (40%)

Table 1.  
Melodic contours of the musical sequences obtaining answers from Teo.

Stimuli	Answers						Total stimuli
	♪	♪♪ or more	♪♪♪ or more	♪♪ or more	♪♪♪ or more	♪♪ or more	
♪	2 (29%)	1 (14%)	3 (43%)	1 (14%)	—	—	7 (100%)
♪♪ or more	—	14 (24%)	13 (22%)	7 (12%)	19 (32%)	6 (10%)	59 (100%)
♪♪♪ or more	4 (33%)	1 (8%)	3 (25%)	2 (17%)	2 (17%)	—	12 (100%)
♪♪♪ or more	—	—	1 (100%)	—	—	—	1 (100%)
♪♪♪ or more	—	1 (50%)	1 (50%)	—	—	—	2 (100%)

times. In summary, Teo replied with a melody concordant with the one of the experimenter in 32 (43%) of the sequences, and with a different melody 38 (54%) times. These proportions were not significantly different (GLIM  $\chi^2 = 1.0298$ ,  $df = 1$ ,  $P > 0.10$ ).

The frequencies of Teo's output ranged from 261.626 to 3951.067 Hz, they were significantly different from the frequencies played by the experimenter ( $F = 604.761$ ,  $df = 1.603$ ,  $P < 0.000$ ). It is noticeable that Teo uttered the frequencies from 2489.016 to 3951.067 Hz that she had never heard before. About 78.6% of the notes were included in the range from 932.328 to 1975.533 Hz (Fig. 2).

The notes corresponding to the above frequencies are displayed in Fig. 3. They were distributed from the fourth octave ( $n = 12$ , 3.2%) to the seventh ( $n = 47$ , 12.7%), with a strong preference for the sixth octave ( $n = 272$ , 73.5%).

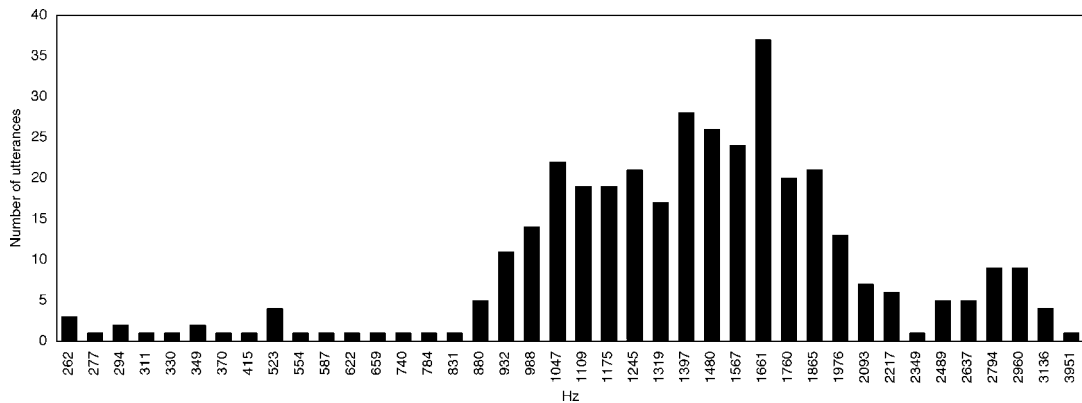


Fig. 2. — Number of utterances per frequency. Frequencies indicated in X axis originate from software analysis output.

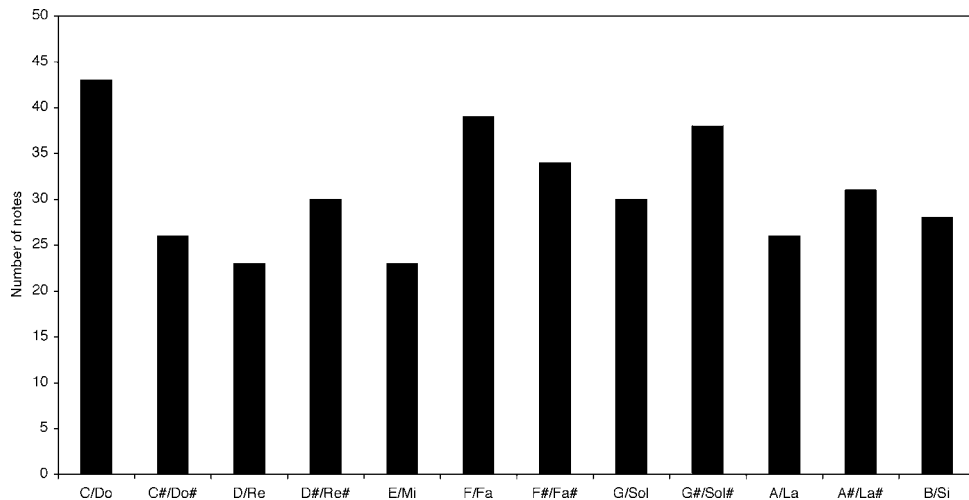


Fig. 3. — Distribution of notes uttered by Teo. Every column groups corresponding notes in all octaves.

Table 2.

Linear regression among the frequencies of Teo's sequences consisting in 2 to 10 notes.

Independent note	Dependent note	Determination coefficient	df	F	Significance value	b
1st	2nd	0.48	73	66.73	0.000	0.73
2nd	3rd	0.33	56	27.00	0.000	0.49
3rd	4th	0.61	40	61.24	0.000	0.82
4th	5th	0.69	33	73.61	0.000	0.93
5th	6th	0.65	21	38.48	0.000	0.78
6th	7th	0.43	13	9.97	0.008	0.75
7th	8th	0.27	8	2.89	0.127	0.38
8th	9th	0.72	5	12.68	0.016	0.90
9th	10th	0.58	4	5.72	0.075	1.12

In order to explore whether Teo transposed not only the frequencies of the single note from the fourth and the fifth octave to the sixth and seventh, but also the relationship among the notes we run consecutive linear regression analysis for each sequence ( $n = 74$ ). The results are displayed in Table 2 where we considered the fundamental frequency of the second note of each sequence as a dependent variable in respect to the first and, as independent in respect to the third, in turn, the third note of a sequence was the independent variable for the fourth. This was repeated for all sequences up to ten notes. The statistical significance is shown in Table 2.

## DISCUSSION

In this study we used a number of melodies to guarantee a variety of simple musical features: notes ranging in the fourth and fifth octaves, two or more notes in ascending and/or descending melodies in correlated sequences. Those stimuli were so suited to the parrot's musical attitudes and so well embedded in her social-affective context that there was no latency in eliciting answers. In fact, we recorded a near complete overlap between stimuli and responses. The stimulus notes were not "parrotly" imitated, but played the role of "triggers" for Teo's original performances, as suggested by our results: (i) a larger number of notes in reply, in comparison to the number of notes in the stimulus played; (ii) a significantly higher frequency of notes ranging largely within the sixth and seventh octaves, that she had never heard before. (iii) Regression analysis showed that each note in Teo's sequences was significantly dependent on the previous one in the same way as stimulus sequences were, showing that the parrot generalized the proposed basic musical rule to a wider range of notes by transposition from the fourth and fifth to the sixth and seventh octaves. Regression analysis shows that there was a tendency to maintain the same ratio between two adjacent frequencies, which is expressed by the slope of regression line ( $b$ ; see Table 2). These findings suggest that the parrot may be predisposed to acquire musical rules.

CORBALLIS (1991) defines as "finite state grammar" a situation in which each word is the "context" for the successive one. In a "musilanguage" hypothesis

(BROWN 2000) we can draw a parallel for the musical phrases of our parrot: indeed the regression showed that each note was a generative context for the successive. In fact, in the transposition to the higher octaves Teo maintained a significant relationship among the frequencies of successive notes in the sequences, although showing a preference for an ascending melody.

It has recently been underscored (GRAY et al. 2001) that animals can innately master a musical code. Analogously as the perception and discrimination of colours allow some species, included humans, to master the complexity of the light wavelengths (SHEPARD 1992), we believe that the discrimination of sound frequencies implies the mastering of the complexity of the soundscape. In our experiment a temperate scale, adopted in Western music, was proposed to a grey parrot, whose cognitive linguistic and semantic competences are well known (PEPPERBERG 1981). Obviously, sound frequencies are continuous, but in the temperate scale notes are defined as a limited number of discrete frequencies. In a proximate view, mastering a musical scale means that our parrot had to use only some specific frequencies from the entire sound range, this implies not only a perceptual competence, but also a categorizing function. BARSALOU (1992) defines categorization as the gateway between perception and cognition. According to PIERCE (1983) all the notes of a diatonic scale can be viewed as located on an ascending spiral in which a single homologous note (i.e. C) is present in each spire (octave) at the same location, each note thus having different frequencies. So we can speculate that Teo heard and categorized the notes played in the fourth and fifth octaves, and mostly replied in the sixth and seventh octaves, showing a complex cognitive competence in understanding both the similarities and dissimilarities among the frequencies. The fact that Teo always answered before the end of the stimulus and with a richer vocalization than that proposed by the experimenter, suggests that she was in some way displaying not only her sound producing competence, but also a “mastering” of the code. This can be considered a kind of duetting between the experimenter and Teo, who showed the close bond with her partner that is necessary for the building a human-parrot interaction (PEPPERBERG 1981).

The possible adaptive significance of Teo’s cognitive competences could be related to the strong pair-bonding typical of this monogamous species that shows a life-long capacity for learning and imitating new sounds in order to enrich the duetting repertoire (CRUICKSHANK et al. 1993).

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