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TEACHING A MUSICAL CODE TO A PARROT: FREQUENCY DISCRIMINATION AND THE CONCEPT OF RHYTHM IN A GREY PARROT (*PSITTACUS ERITHACUS*)

UČENJE GLASBENIH MOTIVOV PRI PAPAGAJU: FREKVENČNO RAZLOČEVANJE IN KONCEPT RITMA PRI SIVEM ŽAKOJU (*PSITTACUS ERITHACUS*)

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ABSTRACT

Teaching a musical code to a parrot: Frequency discrimination and the concept of rhythm in a Grey Parrot (*Psittacus erithacus*)

Music competence and perception should be considered in evaluating human cognitive processes, unfortunately, evolutionary onset of music is still unclear. Although connections between human language and other animal communication patterns remain limited and controversial, humans share musical "language" at least with birds. Recently, many studies seem to point out that in many vertebrate species' song there could be structures comparable to those of human music. African Grey Parrot (*Psittacus erithacus*) is well known for his ability in song and speech learning. In our study we tried to understand if a female African Grey, Theo, were able to learn and properly use some basic elements of the musical language, in particular we choose the intonation and rhythm. We taught first Theo to answer with sequences of "notes" to some simple melodies played with an electric piano, then we recorded every "musical" output sung by Theo. Peak frequency analysis and comparison between parrot's sequences and random generated strings, confirmed the acquisition of the intonation concept and notes amplitude peak showed Theo's tendency to maintain a rhythmic regularity. Furthermore, data analysis stressed the great complexity and innovation in the musical sequences uttered by the bird, that led us to exclude the simple imitation process.

Key worlds: Cognition, music, intonation, temperate scale.

IZVLEČEK

Učenje glasbenih motivov pri papagaju: frekvenčno razločevanje in koncept ritma pri sivem žakoju (*Psittacus erithacus*)

Glasbena sposobnost in njeno zaznavanje se upošteva pri vrednotenju človeških spoznavnih procesov, vendar je evolucijski začetek glasbe še vedno nejasen. Čeprav so povezave s človeško govorico in drugimi živalskimi komunikacijskimi vzorci omejene in kontroverzne, si človeško glasbeno "govorico" delimo vsaj še s ptiči. Izgleda, da v zadnjem času mnoge študije kažejo na to, da je v napevih mnogih vrst vretenčarjev mogoče najti vzorce, ki so primerljiv s človeško glasbo. Afriški sivi žako (*Psittacus erithacus*) je dobro znan po tem, da se lahko uči napevov in človeškega govora. V naši raziskavi smo poskusili ugotoviti, če se samica te vrste, Theo, lahko nauči in uporablja nekaj osnovnih glasbenih elementov, zlasti intonacije in ritma. Najprej smo učili Thea, da je odgovoril z zaporedjem "not" na preproste melodije, ki smo jih zaigrali na električni klavir, nato pa smo snemali vse "glasbene" glasove, ki jih je Theo oddajal. Analiza frekvenčnih vrhov in primerjava zaporedij tonov, ki jih je zapel papagaj, s slučajnimi zaporedji tonov sta potrdili načelno sposobnost intonacije. Analiza amplitudnih vrhov v sekvencah papagajevega petja pa kaže papagajevo nagnenje k ohranjanju enakomernega ritma. Poleg tega je analiza zvočnega oglašanja pokazala na veliko kompleksnost in inovativno sposobnost tega ptiča, ki prekaša preprosto posnemanje predvajanih glasov.

Ključne besede: učenje, glasba, intonacija, temperirana lestvica.

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INTRODUCTION

Music has always been considered an exclusive feature of human beings (MARLER 2000, MARTINELLI 2000), although an increasing number of studies in the intriguing fields of Bioacoustic and Biomusicology seems to suggest the existence of music universals underlain both human music and animal songs (BOTTONI et al. 2003, SCHWARTZ et al. 2003).

Researchers investigate the presence of similarities between human and animal music (BAPTISTA 2000, GRAY et al. 2001, BROSCH et al. 2004) both in terms of use of common rules in string building process and search for cognitive capabilities and informative contents hidden in songs. For example, many songbirds follow what seems to be very similar to our musical scales (ARMSTRONG 1963). Other studies describe peculiar rules and structures of complex songs in mammal species like Humpback Whales (*Megaptera novaeangliae*) (PAYNE 2000a, 2000b). These whales are well known for their moving, melodic songs, uttered mostly by males during winter breeding season, although the meaning of these melodies still remains unclear. According to PAYNE, every song sequence, shows limited basic elements, or notes, assembling phrases: musical themes are composed by phrases combination. In song performing Humpback Whales, open the performance with a theme introduction, then carry on with some variations and close song with the initial theme reprise, showing some similarities with human compositions. PAYNE's studies on seasonal changes in whales community songs (PAYNE 2000b) revealed that whales are somehow conservative in music preferences, but innovations and innovators are welcome at a certain extent: at the beginning of breeding cycle, usually males utter the same melodies of the last year, thus revealing long term memory capacity, but during the breeding season, new melodies can arise, and old phrases and themes can be erased. In birds, the comprehension of basic musical rules and the discrimination of musical pieces was studied in Java Sparrows (*Padda oryzivora*), evidencing that birds show individual preferences for different authors and that classical music was preferred to white noise (WATANABE & NEMOTO 1998). Moreover, the birds could discriminate between piano sonatas performed by different authors, succeeding in oddity-to-sample test and telling apart Bach to Schoenberg (WATANABE & SATO 1999).

Perhaps some of the most interesting subjects for a study about musical abilities in animals are found among parrots: most species, in fact, are famed and able to utter many different forms of vocal mimicry: words, sentences, tunes, whistles, noises, etc.

The aim of this study is to investigate, if an African Grey Parrot (*Psittacus erithacus*) is able to learn and elaborate several elements of the human musical code, as well as to search for cognitive processes in parrot's musical perception and output: in fact, a preliminary work on this topic (BOTTONI et al. 2003) revealed that the subject succeeded in tasks concerning musical strings production, being able to understand and generate fixed frequency ratio sequences, superimposable to samples heard in training sessions, but transposed on an higher octave (BOTTONI et al. 2003). On the basis of previous evidences, we examined the functional use of intonation, i.e. the ability to maintain the accuracy of pitch among the notes of a melody, and the perception and accuracy in rhythm rendering, here intended as the periodic regularity of utterances in a single-string vocalization (Frova 1999).

METHODS

In order to test musical and cognitive capabilities in this species we trained a young female African Grey, Theo, captive born and hand raised from the age of four weeks till weaning (4 months).

Training. The parrot was kept in a standard Grey Parrot cage (90 x 50 x 80 cm) and exposed to human contact and speech, she had free access to pellets, seeds, fresh fruits and water, the cage was cognitively enriched with platforms, small manipulation objects, etc., but we carefully avoided any tool that could emit musical sounds. In the intervals between the experiments, the parrot was allowed out of the cage, for free exploration of the laboratory, and free interaction with the trainer, a fundamental issue in parrot training (Pepperberg 1981). In a previous experiment Theo was exposed to the temperate musical scale played on a keyboard (Bottoni et al. 2003).

To train Theo, we adopted a modified version of the Model/Rival (M/R) method (Todt 1975, Pepperberg 1981). The "correct" response requested was the utterance of a sequence of musical notes, independent on melody, timbre, rhythm or intonation, and it had to be very clear that, in order to get the attention and praise from the trainer the parrot had to produce a sequence of musical notes. Thus the two trainers, had the role of player (P) and listener (L), and alternatively played the musical notes on a Bontempi Electronic mini-keyboard B30 or a Korg Wavestation EX synthetizer. Both keyboards were connected to a couple of preamplified stereo boxes (Karma BS-55). The musical stimuli used were sinusoidal, quadrate waves, with few harmonics, clear timbre, and linear envelopes for the first month (March 2000). In the following months (April 2000-May 2001) we introduced more complex musical stimuli including musical scales, both ascending and descending, children TV series themes, simple melodic musical pieces.

In order to convey the parrot attention to the requested response, we adopted four different settings: 1) both player (P) and listener (L) could be seen by the parrot, the reinforcement was the approaching and praising from the listener; 2) P was in sight of the parrot, while L was out of view, the musical production of P induced L to come in sight and praise P; 3) P was out of sight, while L was in sight, when P played, L went out of sight and loudly praised P in order to be listened by Theo; 4) both P and L were out of sight, after the musical stimulus was heard the praise consisted in loud verbal encouragement, clearly listened by Theo.

In phase 2 we to verify if two cardinal features of human music could be assimilated by our parrot: intonation, defined as "accuracy of pitch control in orderly succession of time units which control sound periodical accentuations" (Righini 1970).

Musical sessions. The experiment lasted 13 months: weekly sessions were kept from March 2000 to April 2001, 44 experimental sessions lasting from 20 to 30-minutes average length were performed generally at the same hour in late morning (10 A.M.).

Immediately before the session started, the microphone was put in the cage, and the recorder switched on. The parrot was generally free to cooperate, but, whenever she showed any sign of distress, the session was suspended for some hours, or postponed to the following day.

Recording techniques. We recorded every sequence played by the experimenters and every utterance produced by Theo on audiocassette D.A.T. Sony lasting 64 and 90 min, by means of a D.A.T. Tascam DA-P1 recorder, equipped with a directional microphone Sennheiser K6. Acquired data were processed with an Apple Power Macintosh 7300/200 200 MHz and 128 MB RAM, with PCI sound card Digidesign Audio Media 3 and sound acquisition software Sound Designer II (v. 2.82). Sonograms and spectrograms of Theo's musical sequences were performed and measured with sound analysis software Canary 1.2.4.

Data analysis was achieved with SPSS 10.0 pc software.

DATA ANALYSIS

We tried to verify if two cardinal features of human music could be assimilated by our parrot: Intonation, defined as "accuracy of pitch control in sound string production" (Mürbe et al. 2004).

Rhythm, here intended as "orderly succession of time units which control sound periodical accentuations" (Righini 1970).

In order to understand the amount of imitated strings in parrot's production, two independent judges, were first asked to listen to the original musical themes *ad libitum*. Then, they listened the songs sung by Theo, and, for each song, they were asked if: a) the song does not match any of the themes previously heard (that is a novel creation of Theo), b) the song matches, at least in part, some of the themes, c) the song completely matches some of the themes. Judges' answers were classified as: a) novel creation, b) partial imitation, c) total imitation of the melodies.

Intonation. The analysis of intonation was run on spectrograms, by means of fundamental frequency peak measurement, which allowed us to identify notes and tell notes apart from other non-musical features as whistles from the natural repertoire of the bird: as in previous works (Bottoni et al. 2003), we considered as musical notes all utterances with a stable frequency lasting longer than 100 ms, according with Frova (1999). Notes were then identified with the aid of an electronic tuner and frequency peak was measured for each note of every sequence. In order to assess Theo's accuracy in frequency maintenance, we compared parrot intervals, here intended as frequency ratios, with intervals drawn out from given musical stimuli. Two of the major problems arisen were 1) the variability of tuning in Theo's answers, that is the difference among musical stimulus administered with keyboards tuned on A/La 440 Hz, and parrot string frequency range, which was generally higher than the one played, and 2) a proper reference lack in evaluating musical string frequency ratios.

To obtain a reference to assess the degree of intonation of each parrot string we realized a Fortran analysis program which compares frequencies extracted from a musical sample with frequencies from a tempered scale auto-generated, starting from a given basic frequency, changeable at will: this program first produce a scale, starting from the given frequency, then compares it with the frequencies in a sample. As a starting point we selected the note A/La 440 Hz, because the frequency range uttered by Theo was always over 440 Hz. The starting frequency was incremented to one cent at a time, for a total of 100 different basic frequencies, in order to include an entire semitone (an octave interval=1200 cents).

For any basic frequency, the program builds a temperate scale (adding $2^{/12}$ to the previous frequency value) and every scale is tested against the musical strings from Theo. The program calculates the difference (in cents) between a note uttered by Theo and the two notes of higher and lower frequency including it. For each run, the program calculates the mean distance (in cents) of the considered musical string from the musical scale generated. For every sequence of runs, the program isolates the least mean distance (in cents), among the mean distances calculated. Thus it is possible: 1) to obtain a reference value for all the notes in a motive, 2) verify if Theo adopted the considered scale, 3) isolate out of tune notes.

In order to solve problem 2) and to test the tendency of the program to transform an out of tune sequence into an intonated one, we needed a method to judge the mean of minimal deviance in case of random frequencies. A second program, based on the same algorithm was used, whose input consisted in frequencies randomly generated. At the start, the program first requires a given number of notes per sequence to be sung, in order to compare random generated sequences with parrot ones. The program then calculates the mean, the standard deviance and produces a new series of random frequencies for every sequence. In this way we could calculate the mean and standard deviation of a random sample of notes.

Rhythm analysis was led on peak time, measured directly on waveforms. Peak time was defined as maximum amplitude time in a pulse. In order to analyze a sequence, according to periodicity and rhythm, we have to select motives with -at least- three sound pulses (see Fig. 1): in that way we were able to measure distances on time axis on the waveform and evaluate periodicity. In the same time we recorded and measured time intervals of handclaps sequences produced by a music trained human subject, in order to compare data between parrot and human rhythmic production. To verify the accuracy of the rhythmic production, we calculated the time interval between two pulses, we then averaged the time values for every sequence, then divided each value in a sequence by the average of the entire sequence.

RESULTS

Theo's utterances consisted were 369, they included notes lasting from 0.3 to 2.2 sec (mean 0.7), and ranging from 656 to 3762 Hz. Frequency range in parrot sequences varies from a 656 Hz minimum to a 3752 Hz maximum with a frequency of 1300 Hz being the mean value.

Twenty one utterances (5.44%) only consisted in clicks, 264 (67.62%) only consisted in notes, and 105 (26.94%) included both notes and periodical elements (clicks). Descriptive analysis of strings showed a preferential use of 3-5 notes in performing duets and answering to musical stimuli, although longer sequences composed by 6-10 notes were not uncommon.

The judges listened 369 Theo's samples and agreed in 100% concordance tests that 306 (83%) were completely new themes never heard before. Only 63 (17%) of Theo's musical output were concordantly judged as similar to a previously heard melody.

Intonation analysis was run on 369 sequences, divided in groups according to number of notes per string. For each group, mean and standard deviance was compared with the mean and standard deviance of the sequence of notes randomly generated by means of Z test for two means. 272 (73.71%) of the strings were intonated, and 97 (26.29%) were out of tune (see Fig. 2).

Rhythm. A total of 113 strings with at least three rhythmical features were chosen and analysed. As shown in Fig. 3 the distributions for both Theo's and human sample were normal, and both curves were strictly grouped around the value of 1, that is the periodicity proposed in musical stimuli. However, variance differences between Theo's and experimenter's curves were significant suggesting that the parrot's performance was somehow lesser than the human's.

DISCUSSION

The relationships between animals' cognitive and musical competences have been addressed from different points of view. The emission of natural quasi-musical sounds, having aesthetic meaning for humans, was addressed for many species of birds and mammals, and their roles in sexual selection and territorial behavior have been debated (Reid et al. 2004).

The African Grey is a long-lived species typical of forested habitats, well known for highly developed general cognitive abilities (Pepperberg 2001). Evidences from field experiments (Cruickshank et al. 1993) seem to stress that these parrots imitate biological and physical sounds from the environment in the wild and mostly use the biological ones in social interactions (Pepperberg 2001). As in many species of birds (Cruickshank et al. 1993) duetting is a tool for pair bonding in the African Grey, and this is the biological background on which our experiment was designed.

In a previous study we demonstrated that the musical notes and simple ascending and descending scales played from a keyboard were "triggers" for Theo's original performances, and that she employed higher frequency of notes never heard before (Bottoni et al. 2003). The object of the present study were not the simple notes of "solfeggio", but "chunks" of notes assembled in simple melodies, that is more structured musical stimuli in order to investigate the pitch and rhythmic competences of our parrot. A relevant finding was that Theo imitates our musical stimuli in a least percentage of cases, in fact judges stressed that the bird started a sequence with one of the learnt motives, then shifted to a new brand close, experimenting the insertion of a new sequence of notes creating new melodies never heard before, noticeably, those melodies were most frequently on higher octaves that the melodies played by the experimenter.

Physically, sound frequencies are continuous entities, and the musical notes of temperate scale in human music are sub-samples of those entities, chosen on the base of a compromise allowing the best possible consonance between all the possible combination of notes within or across octaves, defined as the frequency intervals having the best consonance (FROVA 1999, SCHWARTZ et al. 2003). Through history several musical scales were created and adopted (FROVA 1999). Thus, by no means the notes of the temperate scale are "natural", and the intervals between the frequency of the notes must be appraised, in order to be repeated in new melodies. Our results indicate that 73.71% of the strings were intonated, and only 26.29% were out of tune, moreover, the strings were emitted at higher octaves, never heard before, thus showing that Theo was able to traspose the relationship between frequency intervals perceived and processed to frequency intervals never heard before: a generalization of the previously demonstrated ability of note transposition (BOTTONI et al. 2003). Because the temperate scale is a human artifact it seems as the parrot' brain worked as a "sound analyzer" able to take apart "admitted" and "not-admitted" frequency intervals proposed by the experimenter and used it in preferred octave in order to interact with him. Because of the tropical origin of the species it is conceivable that the musical competences exhibited are shaped by the acoustic environment of the forest. In a rainforest, sounds might come both as noise, or musical periodic waves. Both types of sounds may have a periodic pattern of presentation (LARGE & PALMER 2002). Sounds and noises are multiple overlapping acoustic events that must be acoustically isolated from the soundscape, and related to their origin in order to survive. In a similar way the visual channel shows analogous performance: the basic property of vision is to isolate the objects boundaries in the surrounding world by means of edge detection (WILSON 1975). The acoustic channel is characterized by an high fading while the visual channel shows a low fading (WILSON 1975), as a matter of fact the sound has a short permanence in the environment. Thus, the independent characteristic of melodic routes, representing *what kind* of sound happens, and the rhythmic routes, representing *when* sound happens, might be necessary to categorize and isolate a sound from the surrounding. The high fading might also explain the existence of both short and long-term memory in music processing in humans (SAFFRAN et al. 2000), and the fact that serial pattern recognition is a typical bird trait (PEPPERBERG 2001).

LARGE & PALMER (2002) define rhythm as the whole feeling of movement in time and in a cognitive model they propose that a small set of oscillators operates at periods and phase-lock to external musical events. The rhythmic intervals recorded from Theo and from musical trained experimenter, had values strictly grouped around 1. However, the parrot's curve shows a little more dispersion around modal value in comparison with musical trained experimenter: this could be due to the comparison between the parrot and a expert human, or maybe to a different internal oscillator in the bird. Future research will solve this problem.

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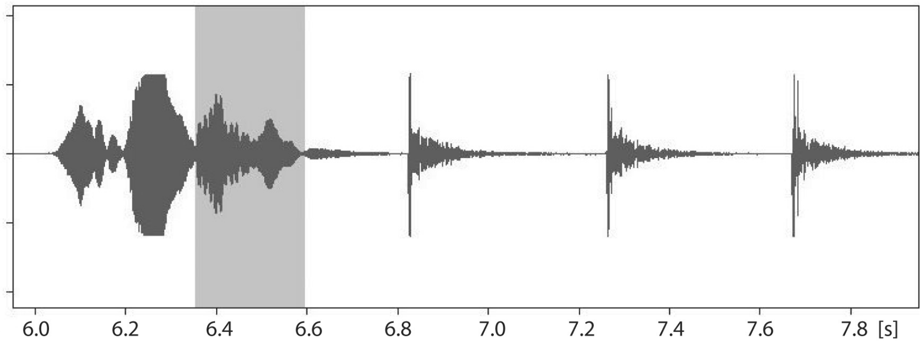


Figure 1: Sonogram screenshot, depicting a parrot musical sequence with clear periodical elements: three *clicks* following the last note of a sequence (highlighted). Notice the accuracy in click timing.

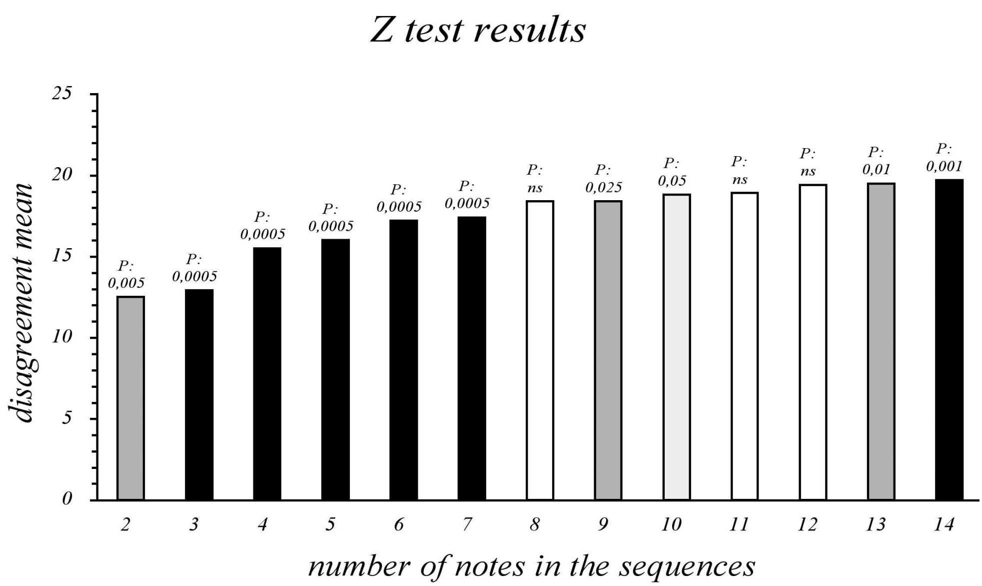
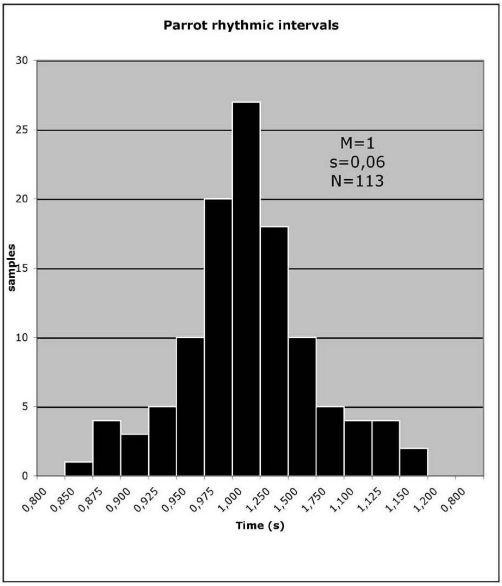


Figure 2: Z test result histogram. Different shades of the bars show significance. Black bars: high significance value. Dark grey bars: very significant value. Light grey bars: significant value. White bars: non significant value.



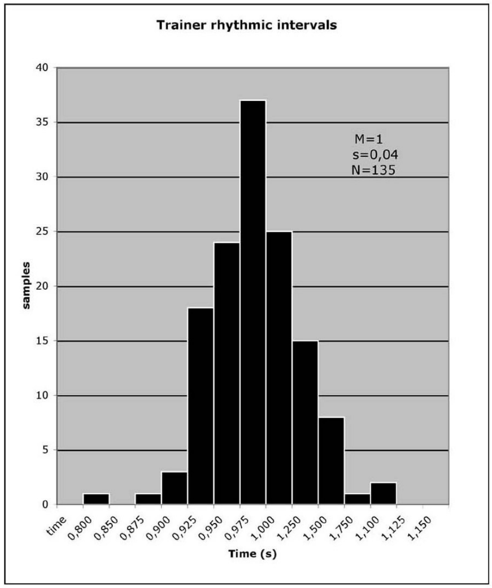


Figure 3: Histogram comparison between rhythmic timing accuracy of human trainer and parrot. Both samples are strictly grouped around the value 1.