Brain maturation changes characterized by Algorithmic Complexity (Lempel and Ziv Complexity).

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EXPERIMENTAL DATA

Literature on the use of chicken electroencephalogram (EEG) is not extensive. Research efforts have largely concerned the use of the EEG either as an indicator of the general integrity of the nervous system or as a measure of specific brain states, such as sleep cycles and other EEG rhythm defined states.

In a previous work scalp-applied recording electrodes were used to monitor changes in basal EEG patterns in chickens during post hatch development. Frequency spectra produced by Fast Fourier Transform show biphasic morphology in all chickens with one peal at about 6 HZ and another at 26Hz. Changes in the lower frequency band show progressive development and provide a possible index of brain development. Both amplitude and dominant frequency of the spectra decrease between weeks 3 and 8 post hatch, reaching adult levels between weeks 5 and 7. The results suggest that modifications of basal EEG reflect the widespread functional changes in neuronal circuits occurring in chicken during the “synapse maturation” period, between 3 and 8 weeks' post hatch.

In animals and also in human evolutive changes are correlated with the presence of different rhythms. The time series in this work come from twenty four chickens (*Gallus domesticus*) studied during six weeks. Four electrodes take the EEG signals from four different areas of the chicken brain: left and right frontal and left and right posterior areas of the scalp with an additional reference electrode placed at the back of the head [1]. One bird with the electrodes is shown in Fig. 1 and typical signals are shown in Fig.2.

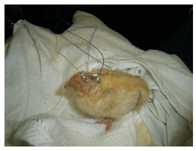
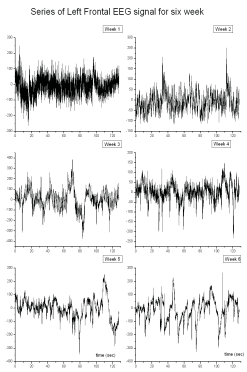


Fig 1: bird with four electrodes (LF, RF, LP and RP)

Fig 2: Typical chicken EEG (bird 1, electrode (LF)



PREPROCESSING

A preprocessing is required in order to eliminate undesired frequencies produced by a repetitive motion typical of these birds. This preprocessing is not straightforward (it can not be done with band pass filters) and was the object of a previous paper [2].

ZIPPING COMPLEXITY

The Algorithmic Complexity has shown its ability to distinguish evolutionary characteristics in many fields. For a string of characters it is defined as the length in bits of the smallest program that produces as output the string. The problem with this definition is that it is impossible, even in principle, to find such a program. Nevertheless, the zippers or file compressors are algorithms conceived to do that job at least approximately. The Lempel and Ziv algorithm (LZ77) is used for most zippers and it is one of the best known file compressors.

$c_{ijk} = l_{ijk}^{Z} / l_{ijk}^{U} \quad (i=1,\ldots,24;\quad j=1,\ldots,6 \quad and \quad k=1,\ldots,4)$ $\qquad l_{ijk}^{U(Z)}$ = unzipped (zipped) string length (bytes) for chicken i, week j, electrode k

SURROGATES

Experimental data are obtained by a sampling process. The effect of sampling rate on the algorithmic complexity and the feasibility of the proposed method was demonstrated by Li, Kuo and Jaw. This drawback is solved using surrogates: an ensemble of random nondeterministic data sets with the same mean, variance and power spectrum as the experimental time series. There are several methods to calculate surrogate data sets with the conditions stated above. Here we use the algorithm by Henry, Novell and Camacho [3].

Essentially the method consists on:

1) evaluate the time series discrete Fourier transform Z
2) Add a random phase to obtain Z'
3) Construct the inverse Fourier transform f Z'. This is a surrogate time series. Each series has $c_{ijk}^{s}\ (s=1,\ldots 100)$

We used a hundred of surrogates for the analysis of chicken EEG presented in table **1.** Zipping Complexity is finally

$$C_{ijk} = \frac{c_{ijk}}{\left\langle c_{ijk}^{s} \right\rangle_{s}} \quad (i=1,\ldots,24;\quad j=1,\ldots,6 \quad and \quad k=1,\ldots,4)$$

Detrented Fluctuation Analysis (DFA): Description of the method

The procedure consists of five steps. Let us suppose that x_k is a series of length N, and this series is of a

1. Determine the profile

$$Y(i) \qquad {}_{k\ \ 1}^{\ \ i} [x_k \qquad \langle x \rangle]$$

2. Divide the profile $Y(i)$ into N_s nonoverlaping segments of equal length s.

$$N_s = \text{int}\left(N/s\right)$$

3. Calculate the local trend for the N_s segments by least square fit of the series. Then determine the variance:

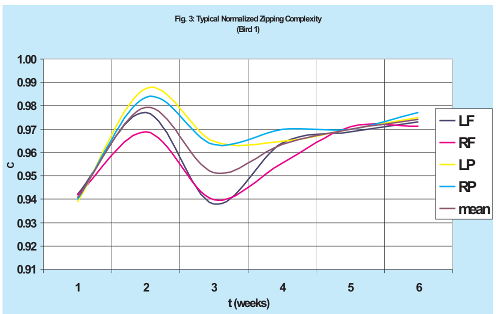
$$F^2(\ \ ,s) \quad \frac{1}{s} \ {}_{i\ \ 1}^{\ \ s} \{Y[(\quad 1)s \quad i] \quad y\ \ (i)\}^2$$

4. Average over all segments to obtain the DFA

$$DFA(s) = \sqrt{F^2(n,s)}$$

5. Determine the scale behavior of the fluctuation functions by analyzing log-log plots DFA(s) versus s . If the series x_i are long-range and power-law correlated

$$DFA(s) \sim s^H$$



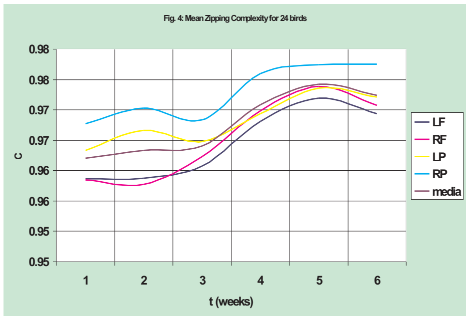


Table 1:
Typical behavior of DFA and Zipping Complexity (ZIP) as funcions of time. Values for birds 1 and 2 are reported.

Week	DFA		ZIP	
	Bird 1	Bird 2	Bird 1	Bird 2
1	0,1815	0,1984	0.94	0.95
2	0,2560	0,2300	0.98	0.97
3	0,2742	0,2213	0.95	0.97
4	0,1950	0,2280	0.96	0.96
5	0,2273	0,2602	0.97	0.96
6	0,2296	0,2451	0.97	0.97

Conclusions

- Both DFA and Zipping Complexity act as indicators of bain evolution in chicken
- For a given chicken there is a typical oscillatory behavior
- Mean complexity of birds increases with time during weeks 3 to 5. This period is reported as the Synapse Maturation period in previous works.
- A similar behavior appears in the FFT mean amplitud in 3Hz to 10Hz window

References

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