High frequency dendrodendritic potentials and their meaning for computing operations in the cerebral cortex*

Isabel Barahona da Fonseca[1], J. Barahona da Fonseca[2] and J. Simões da Fonseca[3]

[1]FACULTY OF PSYCHOLOGY OF LISBON.
Fax: 351-1-793 34 08
ALAMEDA DA UNIVERSIDADE. 1600 LISBOA. PORTUGAL.

[2]FCT/UNL. DEPARTMENT OF ELECTRICAL ENGINEERING
Phone: 351-1-294 44 64. EXT 1007. Fax: 351-1-2957786.
QUINTA DA TORRE. 2825 MONTE DA CAPARICA. PORTUGAL

[3]FACULTY OF MEDICINE OF LISBON.
Fax: 351-1-796 40 59
AV PROF EGAS MONIZ. 1600 LISBOA. PORTUGAL.

1 - The incontroversial achievement which the Hodgkin - Huxley model of the neuron represents leaves unanswered many questions concerning the role that synaptic and dendritic activity play in brain cortex functioning (Hodgkin and Huxley, 1952). A possible attribution of a computational role to dendrodendritic trees which does not directly involve the somato-axonal integrative model of Hodgkin and Huxley was raised after studies of Graubard and Calvin.

In a series of theoretical works our group did explore dendritic and subthreshold synaptic activity showing that they have a computational power equivalent to analog computation in neural networks under adequate time constraints (J. Simões da Fonseca 1996, I. Barahona da Fonseca et al., 1995). The experimental results which we report in this work show that dendrodendritic computation plays a relevant computational role concerning cognitive/affective psychological events.

Namely, using as indicators periodic waveforms extracted from EEG records obtained during different psychological states it was possible to adequately separate them only on that bases.

* This work was sponsored by a grant from Bial Foundation. Porto. Portugal and by JNICT PBIC/TIT/2527/95.

TABLE I

Classification results of Multivariate Discriminant Analysis performed over power spectrum components of periodic waveforms identified in EEG samples recorded during fantasy production (Left Fronto Temporal Leads). For each condition it is indicated the percent of cases adequately classified.

	Anxiety	*Sadness*	*Anger*	*Mistrust*
Joy	Joy: 73% Anxiety: 96%	Joy: 88% Sadness: 83%	Joy: 88.5% Anger: 91.7%	Joy: 61% Mistrust: 42%
Anxiety		Anxiety: 96% Sadness: 95%	Anxiety: 96% Anger: 95%	Anxiety: 84% Mistrust: 37%
Sadness			Sadness: 62.5% Anger: 75%	Sadness: 95% Mistrust: 92%
Anger				Anger: 41% Mistrust: 70.8%

Table I shows the adequacy of signals recorded in Left Fronto-Temporal leads to separate joy, sadness, anxiety, anger, fear and mistrust. It remains, nevertheless, to be further clarified which is the role that dendrodendritic trees play in the generation of EEG signals.

2 - The interpretations we have proposed for our data imply that EEG signals are relevant for information processing performed in the brain.

Computation performed bellow Action Potential threshold provides a frame of reference for analog computation performed by synaptic and dendritic activity. To test this hypothesis , an alternative to the choice of a predominantly dendrodendritic neural structure adequate for the recording of that activity without interference of Action Potentials would be to register nervous signals well above the possible limits of frequency range of repetitive firing of soma and axons which have 1.2 KHz as upper bond.

We tried to obtain data concerning our hypothesis studding the auditory system. It is well known that oscillation frequency of Basilar Membrane in the Cochlea analogically represents the frequency of auditory stimuli tonotopically distributed along the length of the membrane as it was demonstrated by von Békésy.

At the level of the auditory cortex it is also observed a tonotopic representation as it was shown by Tunturi. Nevertheless, the correspondence between the auditory frequency map and the spatial distribution of loci for each frequency in the cortex leads to a situation in which there is no activity markers which at the neuronal level may contribute to understand how the representation of frequency is effectively made. In the analog computation paradigm for dendrodendritic trees, the problem of finding a sufficient variety of state to represent the correlates of stimuli of high frequency would not exist - namely a dendrodendritic closed circuit with a perimeter of 500 microns, would oscillate at 8 KHz in case the velocity of propagation of signals would be of the order of 4 m/s.

To test these ideas we used a biological amplifiers with a bandwidth of 20KHz and also a record sampling frequency of 20KHz.

Subjects were submitted to sinusoidal auditory stimuli of single frequencies respectively 60 Hz, 100 Hz, 250 Hz, 500Hz, 1KHz, 2KHz, 3KHz, 5KHz, 10KHz.

The stimulation was made steadily and the recording was performed during 1 second. In a sample of 25 subjects, it was made the comparisons between the FFT components calculated for each stimulus frequency and the state of rest without auditory stimulation.

It was observed a significant difference for the frequency range under testing in the FFT evaluations.

Although alternative theoretical interpretations for dendrodendritic encoding for auditory stimuli can be found in models of parallel multiple axonal channels, these proposals rise the difficulty of conceiving a theory in which signals in one channel remains strictly phase locked to signals in the remaining parallel channels. Representation through not analog coding would also be a possible solution for the problem - but if our data are confirmed the analog model seems to have a greater likelihood of representing the effective cortical encoding of auditory stimuli. Simultaneously, this interpretation would favor the consideration of dendrodendritic activity as most relevant for information processing.

REFERENCES

BARAHONA DA FONSECA L, BARAHONA DA FONSECA J, SIMÕES DA FONSECA J (1995): Dendritic computation in the brain in J. Mira, F. Sandoval (Eds) *From Natural to Artificial Computation* International Workshop on Artificial Neural Networks. Springer 268-275.

GRAUBARD C, CALVIN WH (1979): Presynaptic dendrites: Implications of spikeless synaptic transmission and dendritic geometry. *Neurosciences. Forth Study Program.* MIT Press, 317-331

SEGEV I, RINZEL J, SHEPHERD GM (Eds) (1995): *The theoretical foundation of dendritic function.* Selected Papers off Wilfrid Hall. MIT Press.

SIMÕES DA FONSECA J (1996): Representation of psychic events in neural networks in R. Moreno-Diaz and J. Mira y Mira (Eds) *Brain Processes, Theories and Models.* An International Conference in the Honor of WS McCulloch 25 Years after His Death. MIT Press, 173-183.

von BÉKÉSI G (1960): Experiments in hearing. E. G. Weber (ed.) New York: McGraw-Hill.