INFLUENCE OF HUBS IN THE STRUCTURE OF A NEURONAL NETWORK DURING AN EPILEPTIC SEIZURE

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Anomalies in the connectome are present in patients with neurological disorders, such as schizophrenia, children with autism, Alzheimer's disease, epilepsy.

We investigate the effect of the network topology in an emergent property of the brain dynamics: the synchronization.

Synchronization occurs in healthy people, but it is mainly found in the Brain activity of people with epilepsy .

An epileptic seizure is defined as a transient occurrence of signs and/or symptoms due to abnormal excessive or synchronous neuronal activity in the brain (hypersynchronism).

Generalized seizures are believed to instantaneously involve almost the entire brain.

Focal seizures appear to originate from a circumscribed region of the brain.

Epileptic network comprises anatomically and functional connectivity between different parts of the brain. The presence of hubs is a well documented pattern appearing during seizures.
Has the network topology a causal effect on the synchronization?

It is not clear today whether the seizure travels along a determined structure of a time scale much longer than that between the onset and the offset of a seizure, or it is the structure per se responsible for the synchronization which produces the seizure. How is the interrelation Of structure with the dynamics of propagation and the ending of the seizure?

Moreover, as these epileptic networks show a time dependent topology, with two clear states, ictal and non-ictal activity, we analyze the influence of ictal into post non-ictal activity.

Model

Here we present a model where we modify the structure and study the effect in the synchronization of the system, understanding the ictal periods as those of high synchronization.

Modification of the topology of the network in two ways:

a)Increasing the connectivity in a random way

b)Increasing it in a controlled way, augmenting the number of hubs

Izhikevich model

$$\frac{dv}{dt} = 0.04v^2 + 5v + 140 - u + I$$
$$\frac{du}{dt} = a(bv - u),$$

$v \rightarrow c$

$u \rightarrow u + d$

v: membrane potential

u: membrane recovery rate

Mode of work:
Excitatory-inhibitory ratio is fixed to 4:1
Total number of nodes: 1000
Start with 30% initialized

1 -- More connections are added in random nodes to simulate the presence of hubs. They are gradually added governed by two parameters:
a) HR, the hub ratio, percentage of nodes which will receive more connections and will become hubs.

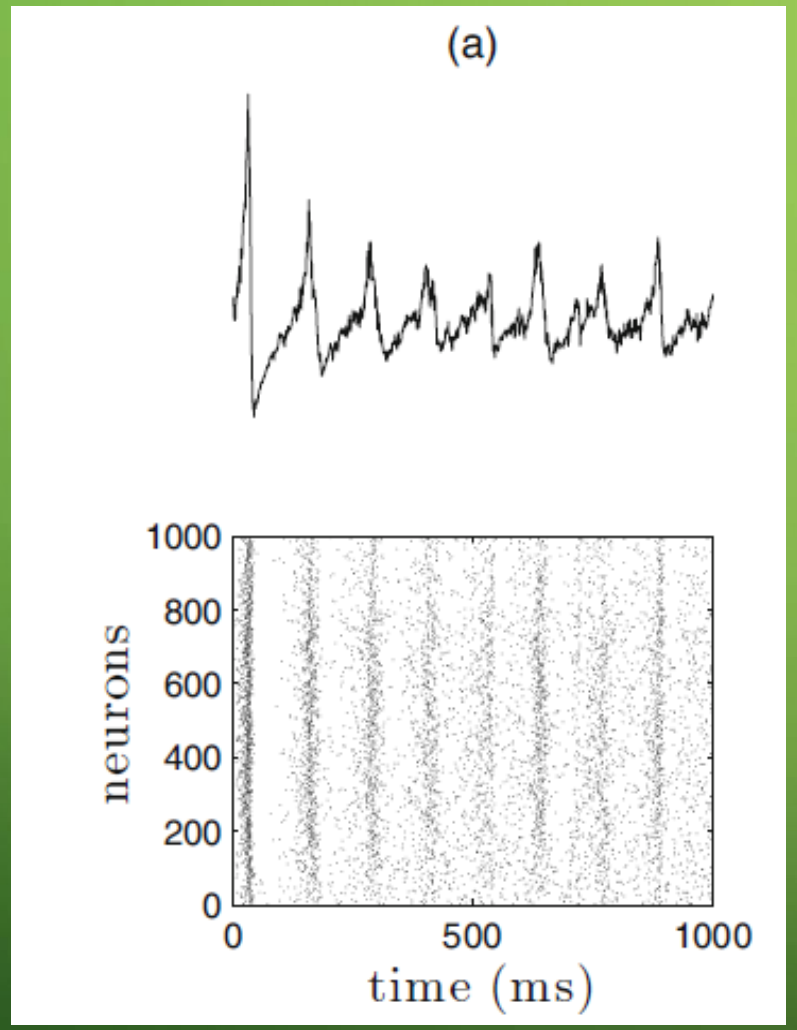
b) The percentage of connections added per node which all simulations is fixed at 70%.

Ex.: HR=0.1 means that 10% of the total number of nodes will be linked to 70% of other nodes

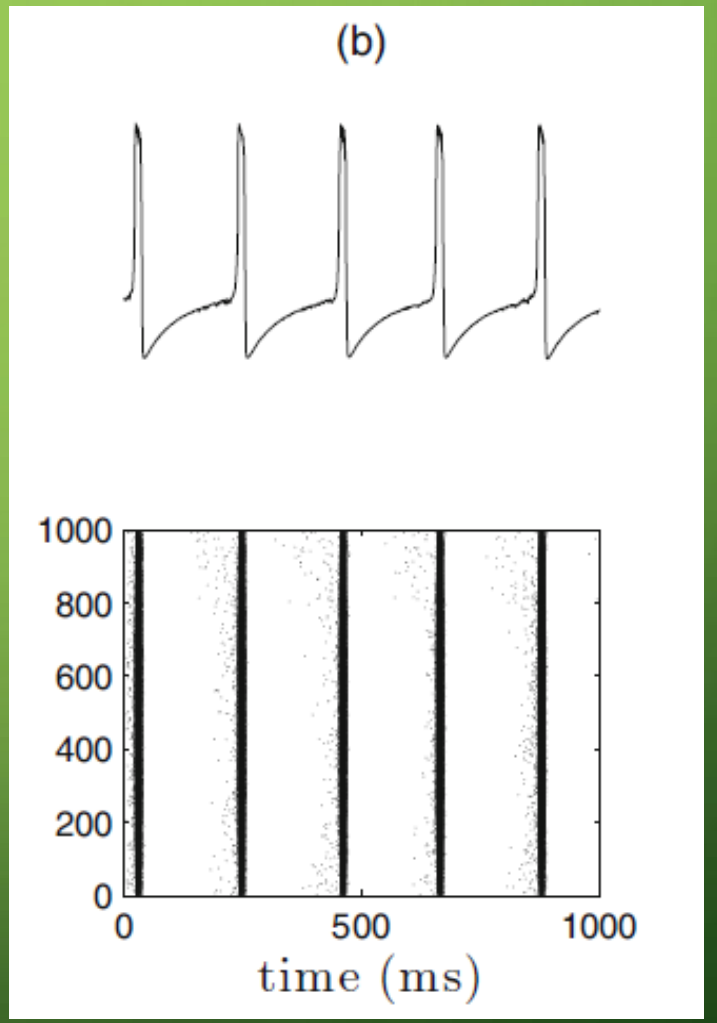
2 - - to compare the effect the same amount of connections were added in a random way

We investigate the effects on the firing spikes.

Local Field Potential (upper graphs) and Spiking Distance (lower graphs).



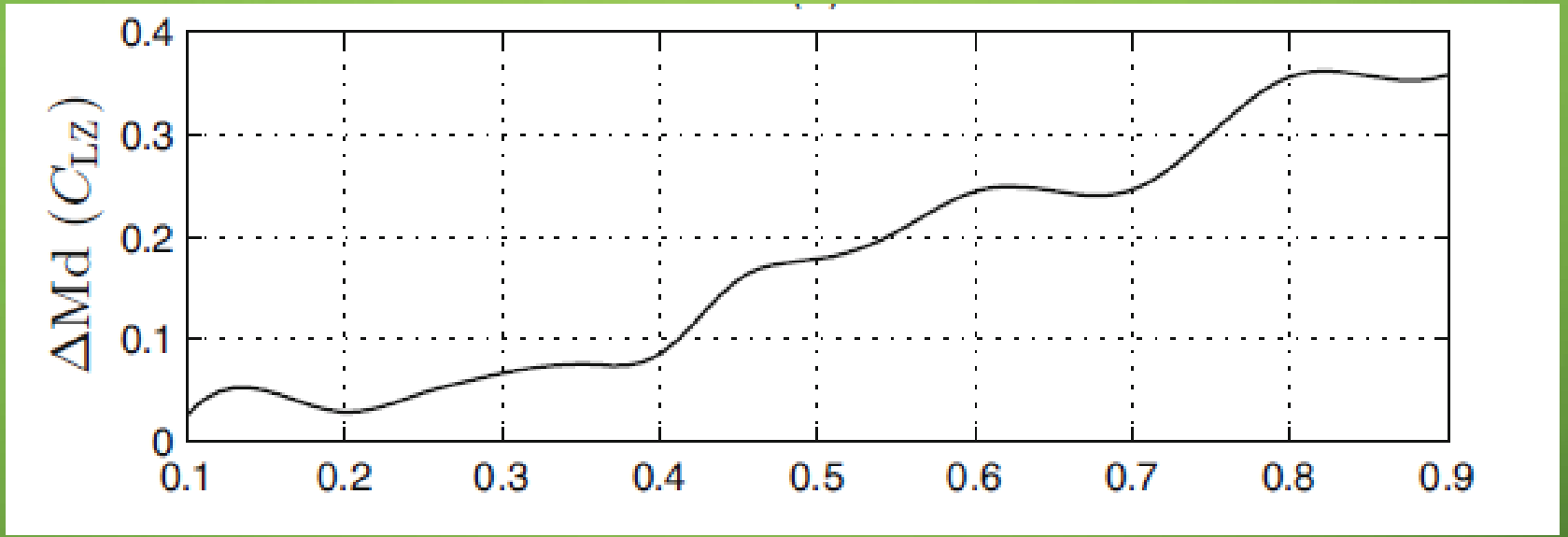
HR = 0.3



HR = 0.7

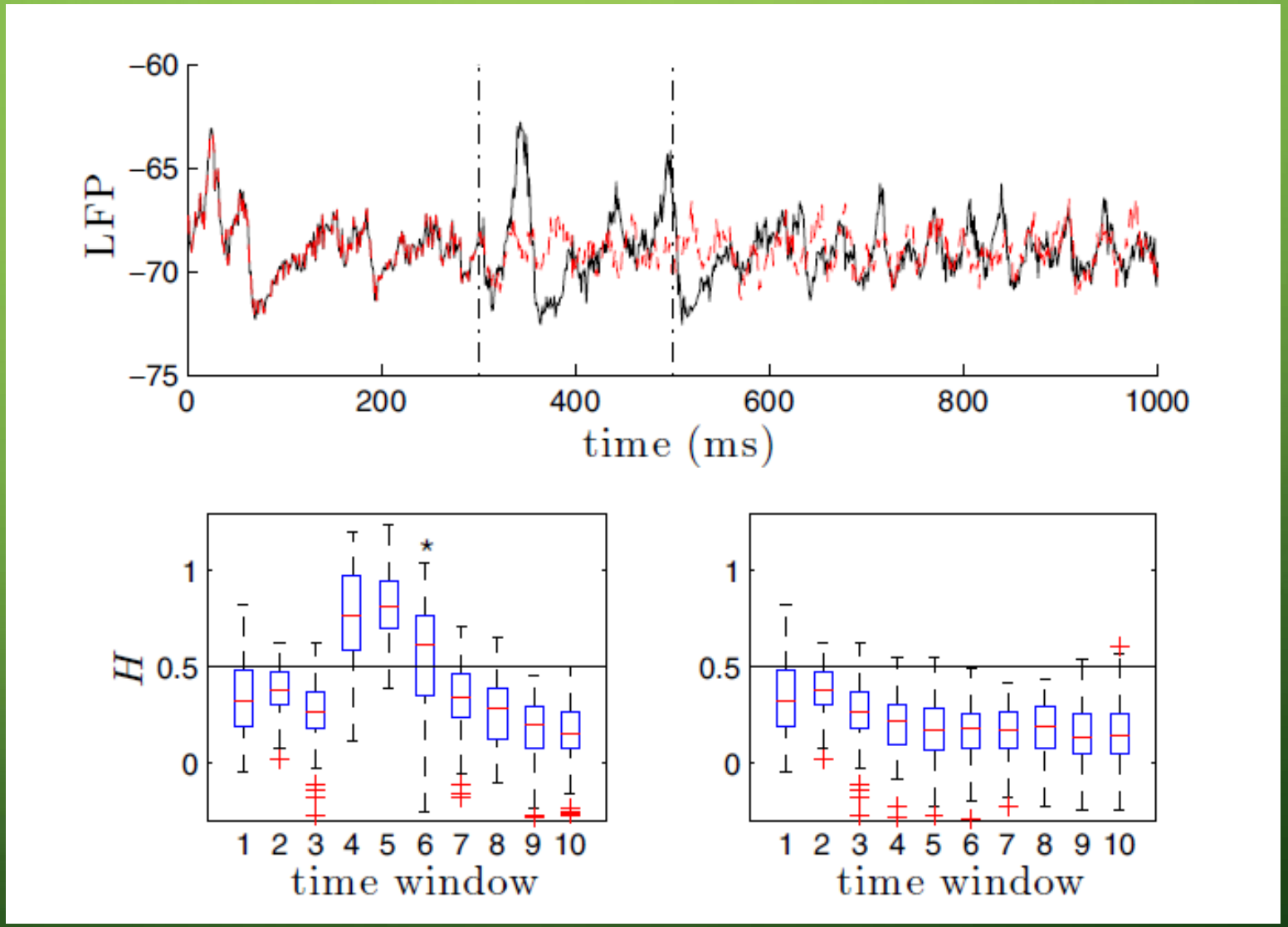
Spike distance measure for networks with Random and Non-random connections

hubs ratio	SD_{R}	SD_{NR}	gain
0.1	0.267	0.267	0
0.2	0.266	0.263	0.011
0.3	0.264	0.230	0.128
0.4	0.259	0.105	0.594
0.5	0.253	0.048	0.810
0.6	0.239	0.033	0.861
0.7	0.210	0.029	0.861
0.8	0.143	0.028	0.804
0.9	0.064	0.027	0.578



Difference of complexity between random and Non-random connections

Influence of ictal topology (seizure) over the post-ictal behavior



Results

a) The spike activity of a single neuron is more regular by increasing the number of hubs

b) The complexity of the signal decreases with the number of hubs and for some short time after the seizures

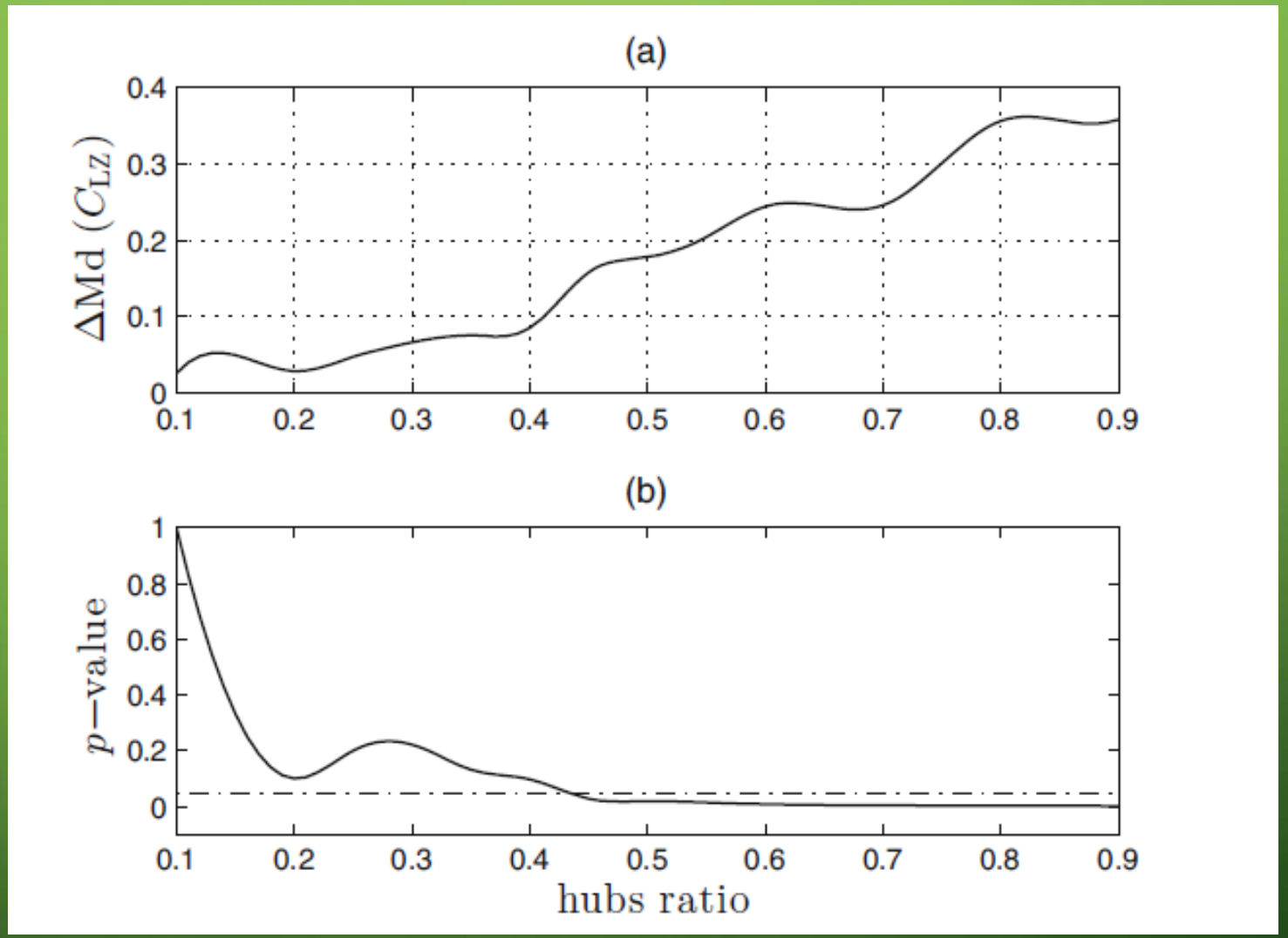
c) The post ictal signal retains some of the properties of the crisis

Conclusions

Using the Izhikevich model of a neuron, we studied the influence that the structure (random and non random hubs) has in the synchronization of a network.

We identify the high synchronization state with the ictal state of the brain well known in epilepsy and study the how the presence of hubs affects the post-ictal answer in the Local Field Potential.

Thanks!


(a)
0.4
0.3
0.2
0.1
0
ΔMd (C_{LZ})
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
(b)
1
0.8
0.6
0.4
0.2
0
p—value
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
hubs ratio