Rapid feature selective neuronal synchronization through correlated latency shifting

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Scope

The role of ***spontaneous*** brain activity in **early visual processes**

The study of coherent fluctuations in response among neuron-pairs in the ***cat primary visual cortex***

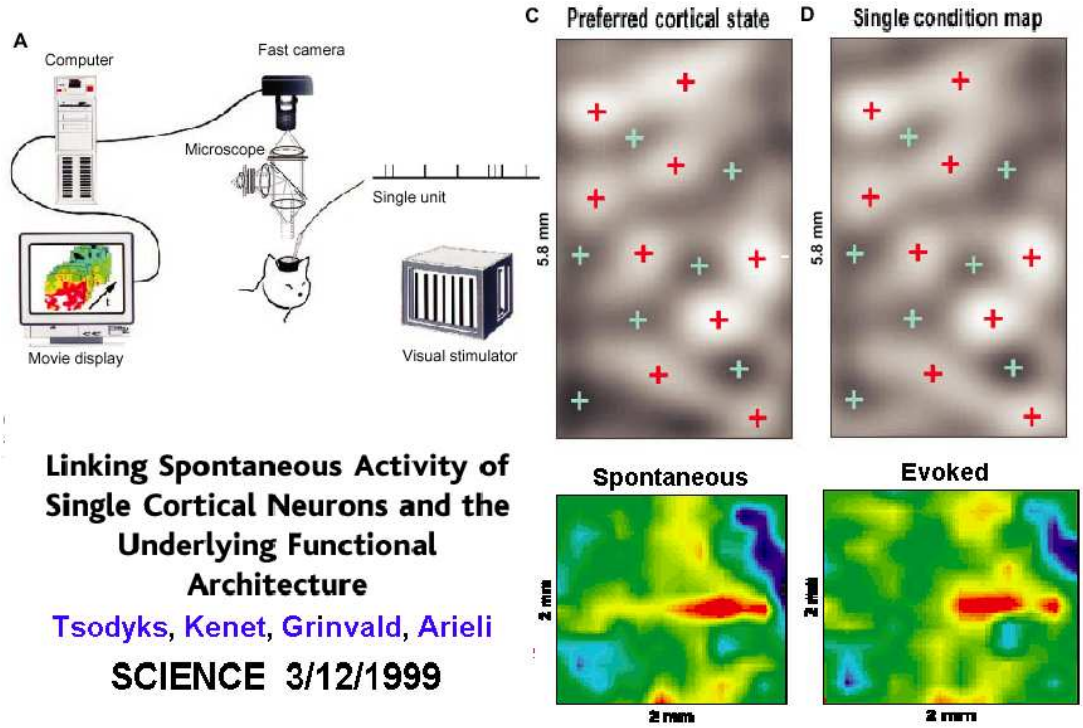
The linkage between this correlated fluctuation in the response and the preceding ***Local Field Potentials***

The functional role of the LFPs-oscillations in the neuronal synchronization.

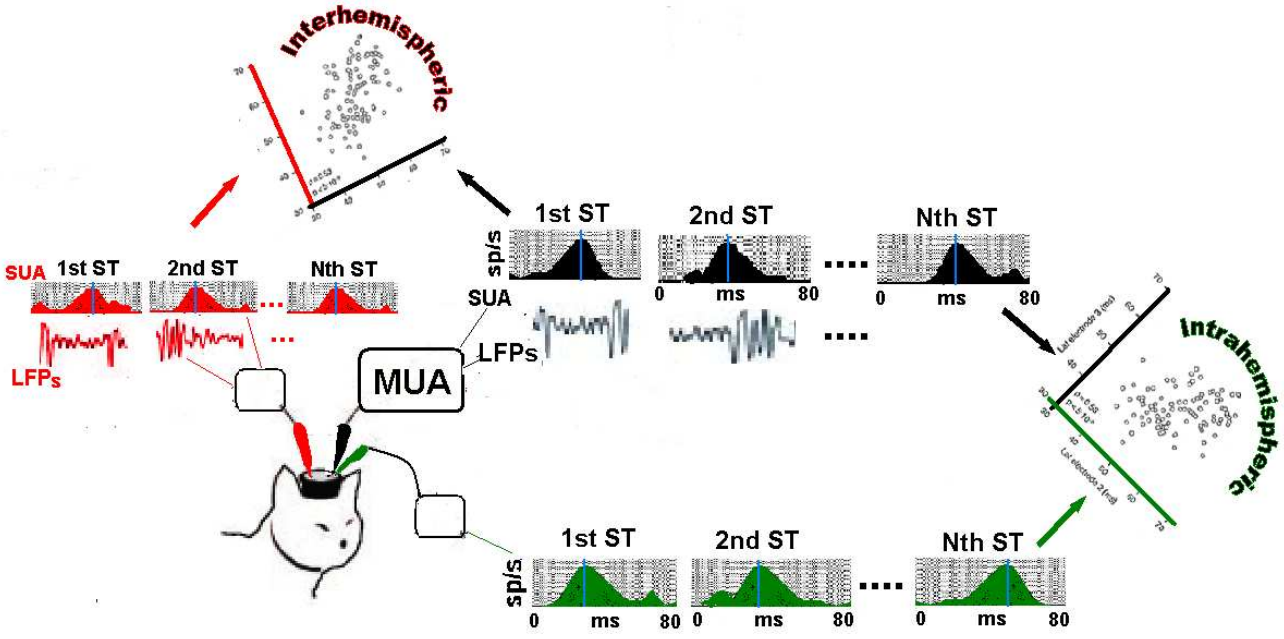
OUTLINE / METHODOLOGICAL APPROACH

In a ***voltage-sensitive dye imaging*** and ***single-cell recording*** study**,** using spike-triggered averaging it was shown that the images exhibited a columnar pattern very similar to the condition orientation map (stim-triggered averaging).

Spontaneous fluctuations in excitability are correlated
within and across columns with similar orientation preference.



Using ***multielectrode recordings***, they are studying the effect of spontaneous fluctuations on the **Single Unit**-response **latencies/amplitudes**



MATERIALS & METHODS

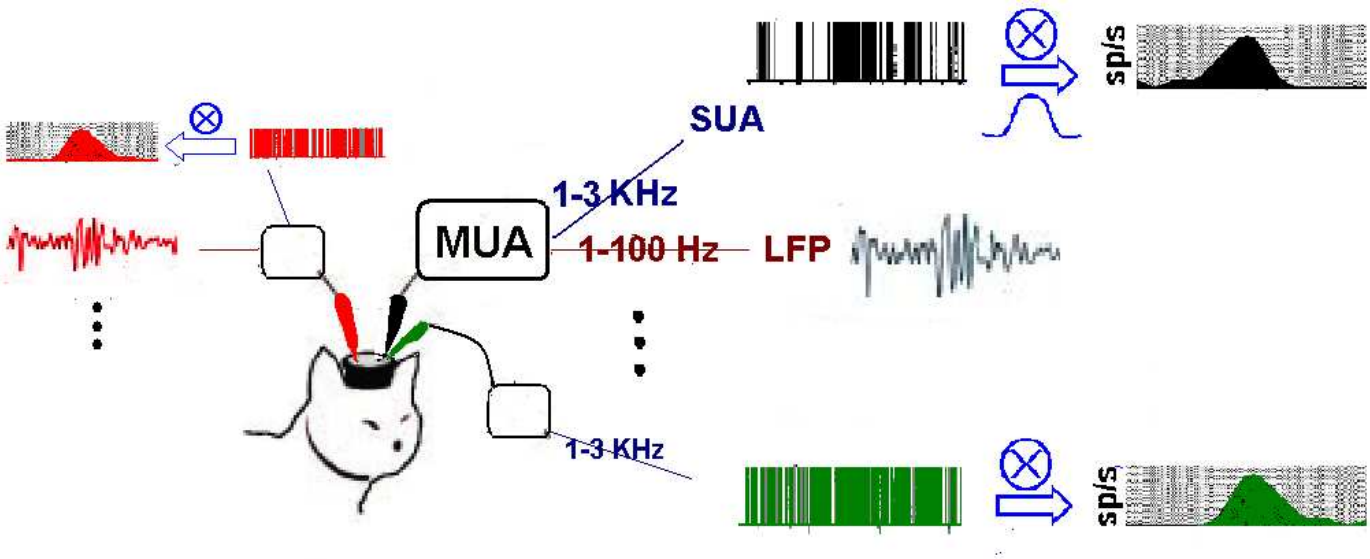
DATA COLLECTION

Multi-neuron activity and LFPs were recorded with 2-8 electrodes
-from 299 recording sites (66 penetrations) close to the representation of the area centralis from area 17 of 5 anesthetizes & paralyzed cats
-from 92 rec. sites in V4 of 1 awake fixating macaque monkey

RFs of the recorded neurons were estimated (light bars) and the tuning / preferred orientation was assessed using *vector averaging*
RFs were considered to be overlapping if overlap was above 5%.

-Neurons at each rec. site were stimulated with stationary flashed bars to evoke maximal responses.
An array of stimuli was presented: 100-300 rep, for 2 s, ISI 15s.

Data analysis



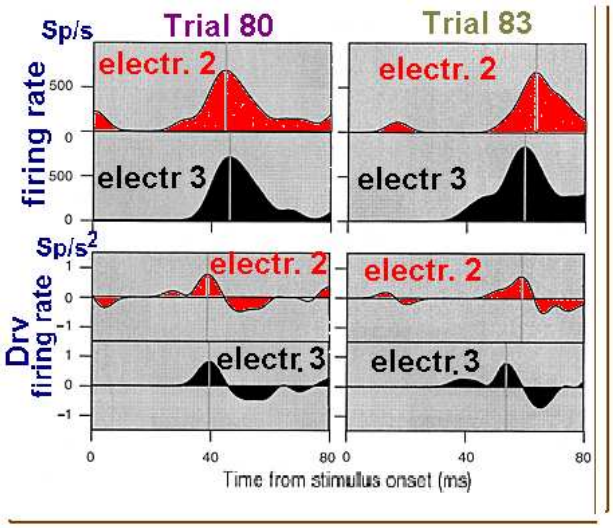
The **Latency** of a response: the time between the stimulus onset and the peak of the spike density (not all the responses provided latency measurements)

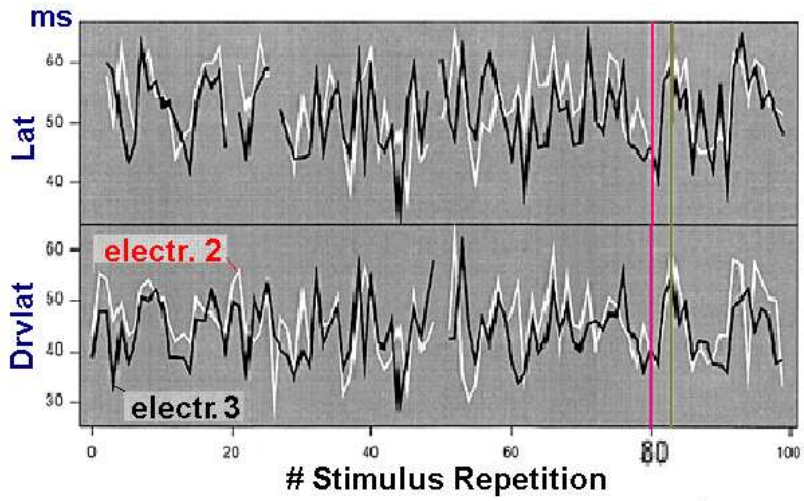
Correlation analysis was based on the *non-parametric* ***Spearman rank correlation coefficient***

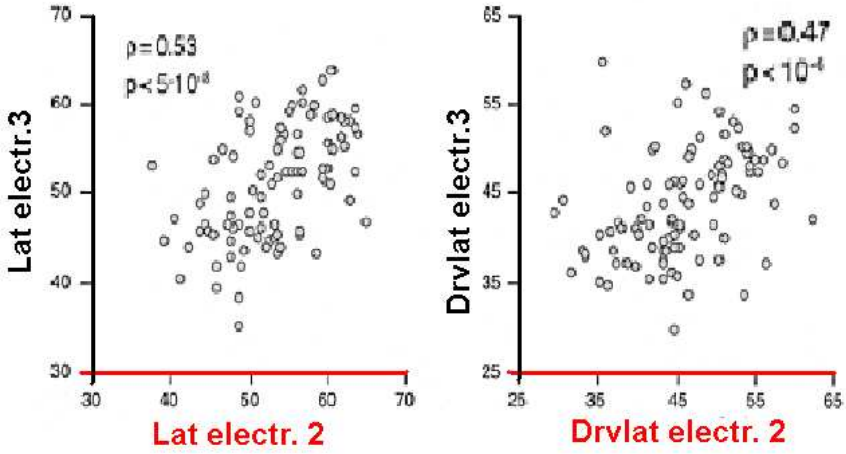
The **sorting** is used as a means to isolate typical cases of a predictor in order to explore its role on the responses.

RESULTS

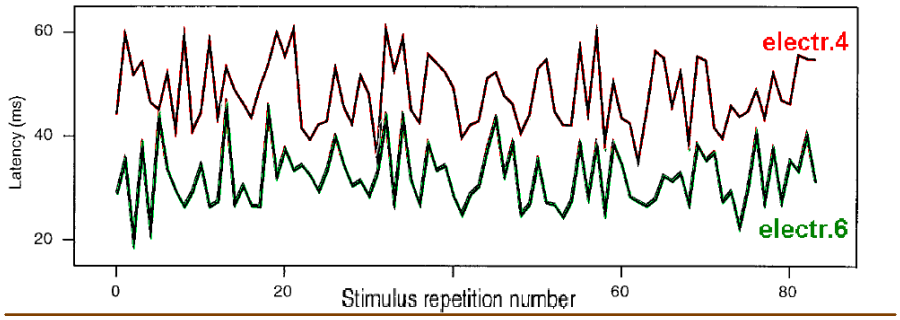
I. Covariation of simultaneously recorded responses.

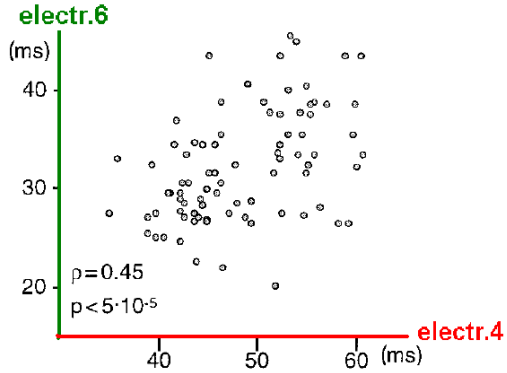






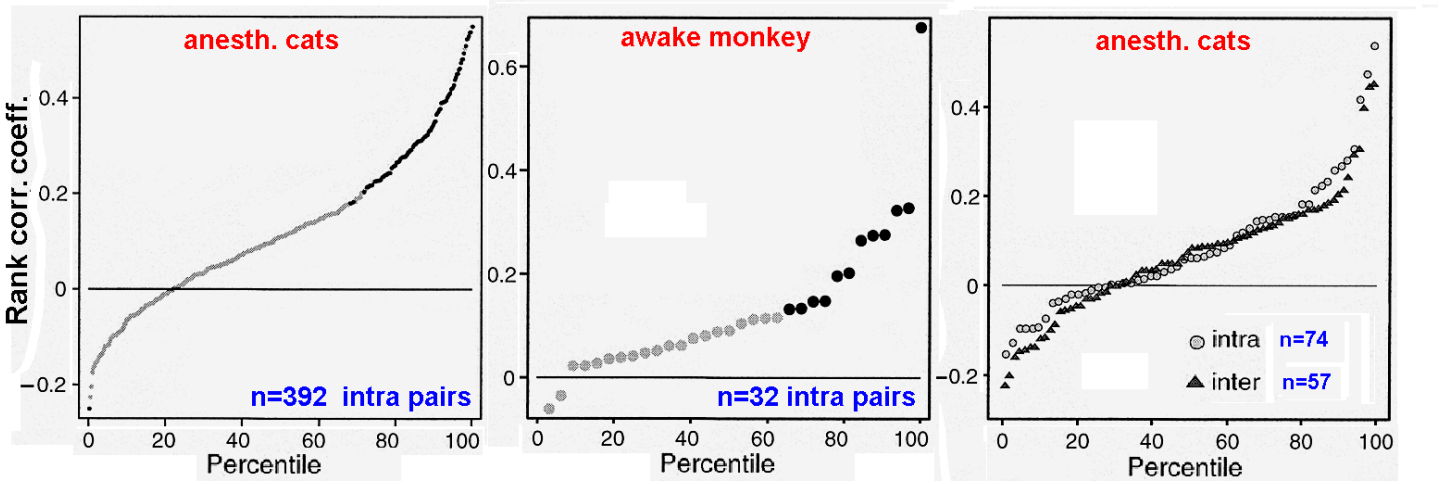
Latency covariations occurred on a trial-to-trial basis, but stimuli were identical across trials. They cannot be attributed to shared thalamic input because they existed even for responses from different hemispheres





Of 392 pairs, 98 (25%) showed significant correlation ($p<0.05$); $r_{ave}=0.34$.

Latency-correlations were as strong for interhemispheric as for intrahemispheric pairs



These Latency covariations appeared also in data recorded from area **V4** of an awake fixating monkey; therefore,
they are not a result of highly synchronized brain rhythms (e.g. sleep/anesthesia).

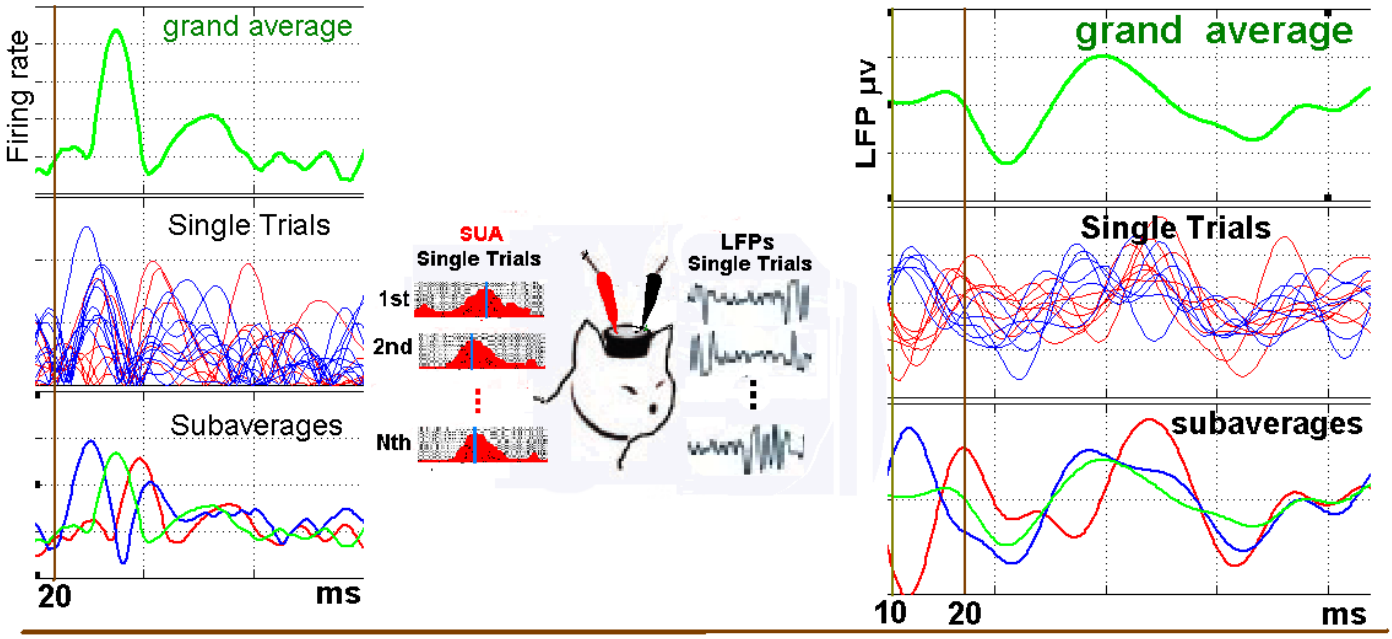
II. The phase of LFPs-trajectory predicts neuronal response latency.

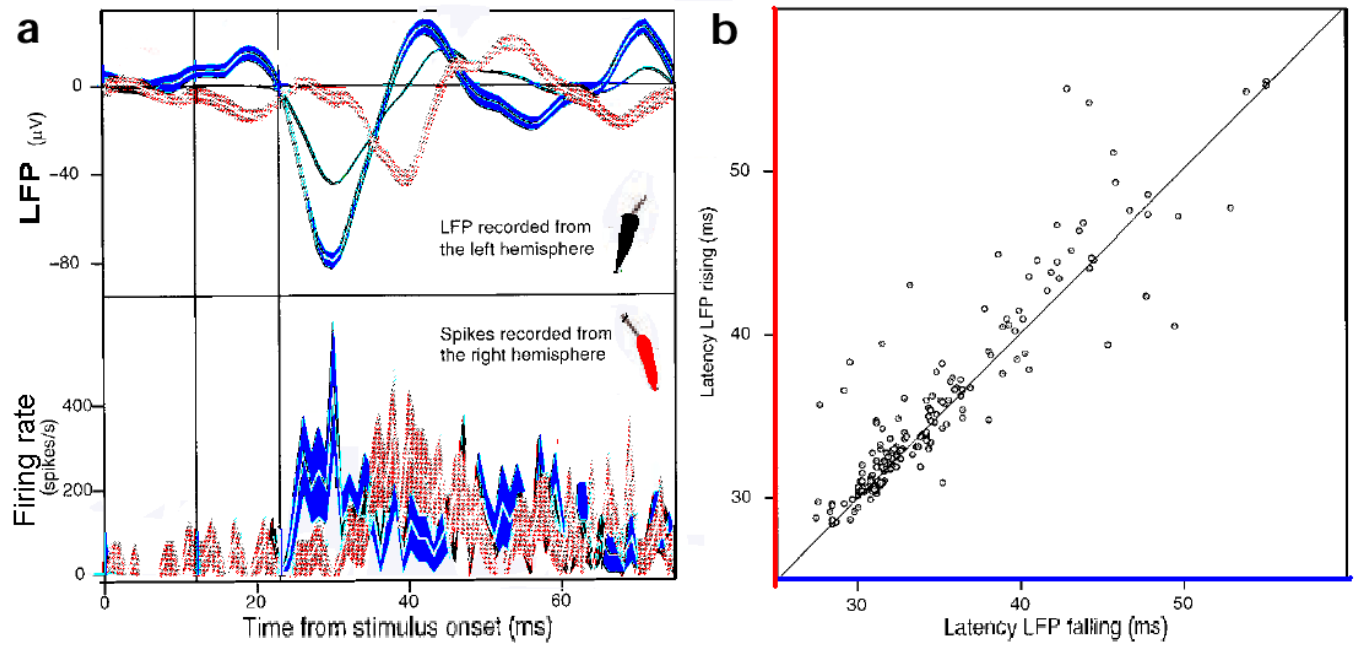
Subthreshold membrane-potential fluctuations that are synchronous in local cluster of cells influence the spike timing.
LFPs reflect average transmembrane currents of neurons around the tip.

To investigate the impact of LFPs fluctuations on the response latencies, different trajectories of LFPs recorded from one hemisphere, are compared regarding the single-neuron's response timing in the other hemisphere.

Sorting responses according to LFPs preceding response onset revealed that Negative LFPs predicts short latencies :
i.e negative LPFs correspond to intracellular depolarization

Prediction was possible as early as 16 ms after stimulus onset, excluding the possibility that the trajectories had been influenced by responses to the stimulus





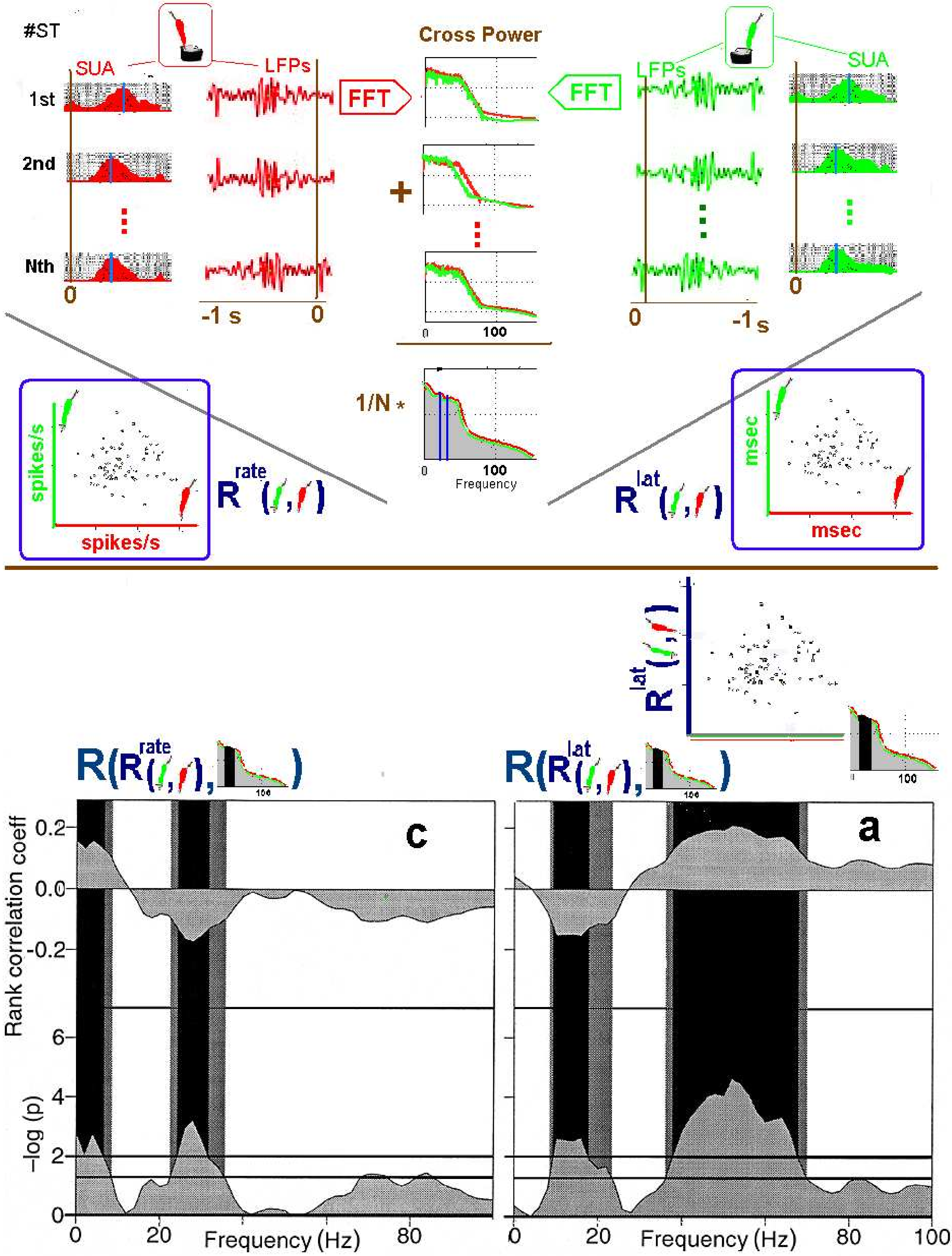
The limitation of predictability to intervals as short as 20 ms, suggests that these excitability fluctuations occurred at a fast time scale, in the frequency range of gamma oscillations.

III. The role of gamma-band oscillations in latency covariations.

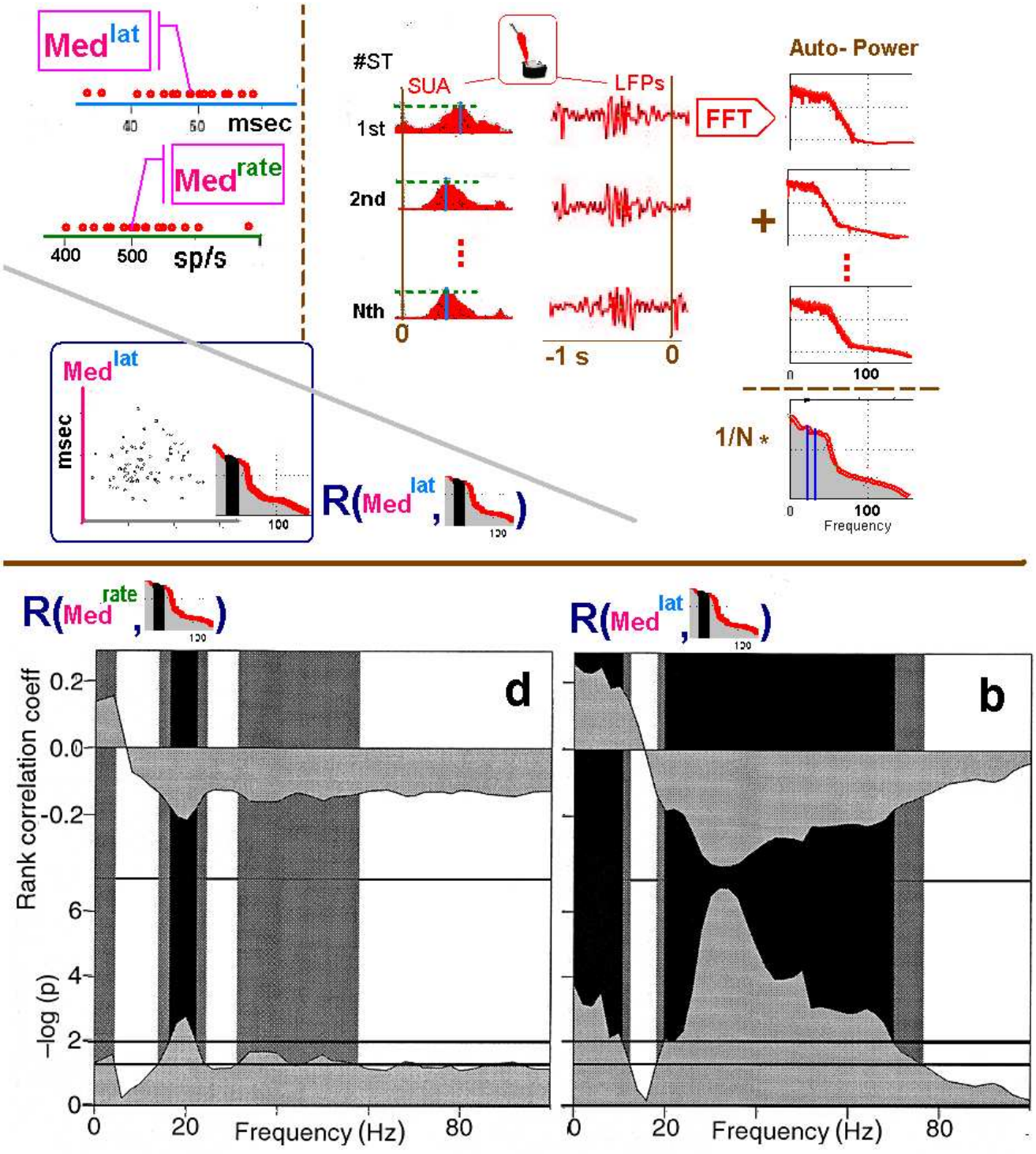
The study of the average LFPs ***cross-power spectrum:*** 1sec prestimulus period and the corresponding pairwise SU-responses covariations showed that

a. latency covariations are due to rapid than slow fluctuations of the membrane potential.

b. <u>weak</u> amplitude covariations are only due to slow fluctuations.


#ST
SUA
LFPs
1st
2nd
Nth
0
-1 s
FFT
Cross Power
100
1/N *
Frequency
spikes/s
msec
R rate
R lat
Rank correlation coeff
0.2
0.0
-0.2
6
4
2
0
−log (p)
c
a
Frequency (Hz)
20
80
100

To examine the effect of oscillations on absolute latencies/amplitudes, they studied the ***auto-power spectrum*** (1s prestimulus) of ongoing LFPs and the corresponding *median* values for all 212 rec. sites.

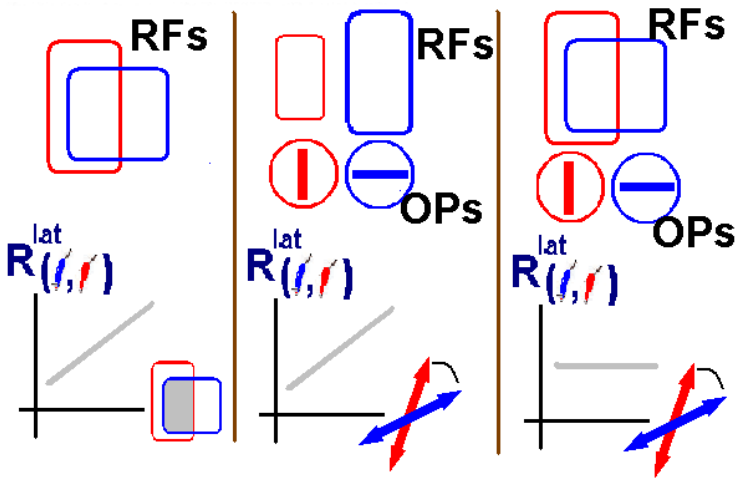


Response latencies are shorter when LFP oscillations are in high frequency range. This Shortening of latencies is not due to increased global excitability, during phases of high gamma oscill., since the discharge rates are not increased (fig.d).

During ↑γ **activity ⇒ neuronal responses are shorter & neurons exhibit rapid coherent fluctuations in the timing of their firing.**

IV. Coherent latency fluctuations exhibit columnar selectivity

Topological study
of spontaneous
excitability fluctuations:



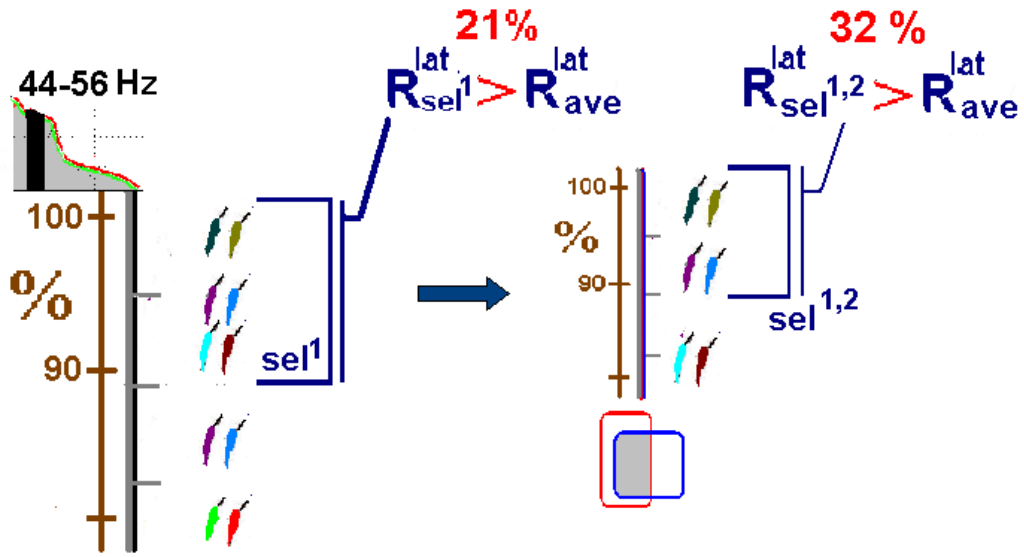
For pairs with overlapping RFs, Latency Covariation was analogous to RF-overlap
The Lat.Cov. was analogous to Orientation-Preference similarity, for non-overlapping pairs of orientation-selective neurons; but not for overlapping ones

The coherence of spontaneous fluctuations exhibits topological specificity and is probably due to intracortical interactions, since its pattern matches the topology of tangential intra-areal and of callosal conections.

V. Correlation Strength & Perceptual Binding

↑ prest. LFP-γ activity & ↑ RF-overlap are the strongest predictors for Lat. Cov.

To further investigate their impact, the **Extreme-case selection strategy** is adopted



VI. Fast vs Slow Oscillations / Latency vs Amplitude Covariations

A dissociation between latency and amplitude covariations was noticable.

Slow LFPs are weekly correlated with amplitude covariations. These covariations are correlated with RFs overlap, but uncorrelated with *orientation preferences.* They exhibit much less topological selectivity and are of a more global nature.

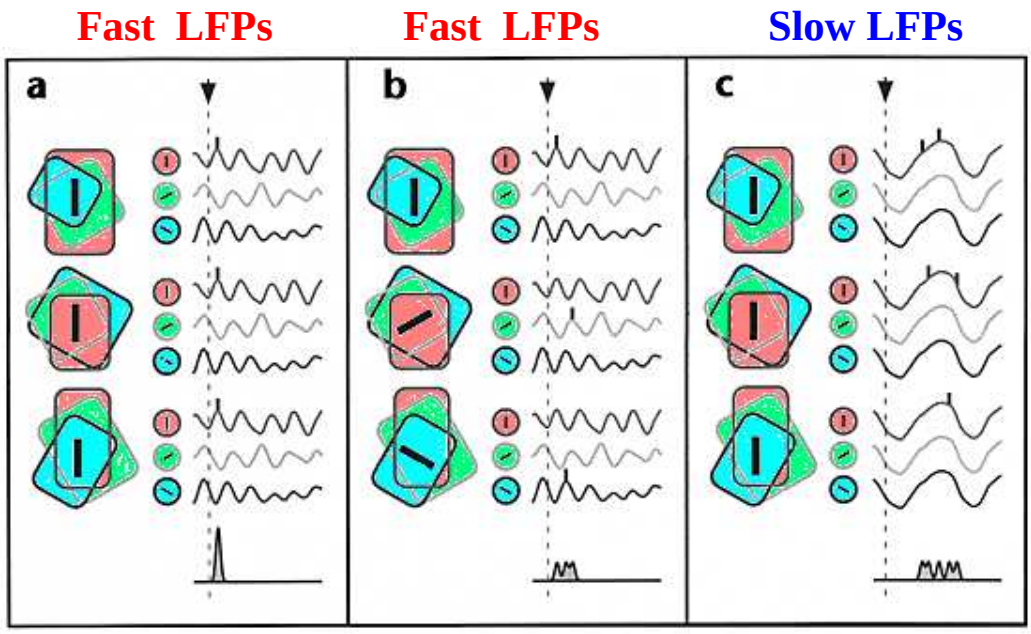
Fast prest. LFPs predict strong latency covariations,
but have no influence on amplitude covariations.

The latency data are in accordance with optical recordings (Arieli) :
"neurons have bigger probability of generating a spontaneous spike when neurons of the shame orientation Preference in other columns are simultaneously active".

Moreover, column-specific covariations of excitability are confined to states of high gamma power.

Enhanced coherence of responses is achieved by adjusting the timing on a fast time scale

than by modulating response amplitudes



Conclusions

- "spontaneous activity & the resulting variability of responses are not noise, but signatures of a dynamic coding process in which temporal relationships among discharge patterns are meaningful and contain information"

- "suppression of response fluctuations by ***averaging*** is inappropriate experimental strategy in search of neuronal codes"

- "Modulating the temporal coherence of responses could be used for rapid response selection and grouping.

Spontaneous activity, in high frequency range, could support such modulation strategy and can be controlled in a top-down process : attention/expectancy".

Discussion

- Type of stimulation
- Condition of cats
- Long term modulation
- Robust / Non-Parametric Statistics