Laminar profile of state-dependent visually evoked responses in primate visual cortex

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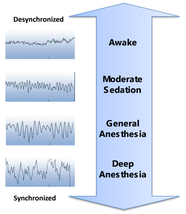
326.04/G25(G27)

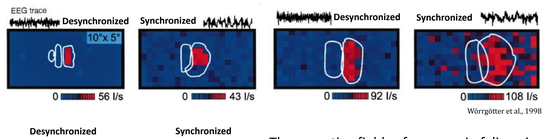
Introduction

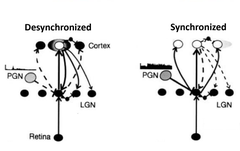


Behavioral arousal is reflected in a continuum of cortical activity profiles that vary between high frequency-dominated **desynchronized** activity and low frequency-dominated **synchronized** activity.

Accordingly, one can **quantify cortical arousal** by determining the relationship between high vs. low frequency components of neural activity (such as with the clinically relevant bispectral index scale (BIS)[1]).

Does the state of arousal affect sensory processing in primary visual cortex?





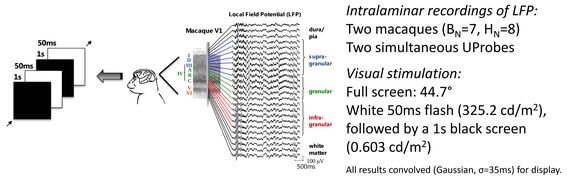
The receptive fields of neurons in feline visual cortex are generally wider during states of reduced arousal.

One model suggest that the shrinkage of receptive fields in the desynchronized state is due to lateral cortical connections and corticothalamic feedback[2].

What are the mechanisms by which arousal modulates cortical responses?

To answer this question, we determined visual responses within the *feedback* and *feedforward* layers of V1.

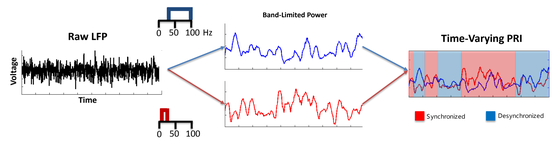
Methods



Intralaminar recordings of LFP:
Two macaques (B_N=7, H_N=8)
Two simultaneous UProbes

Visual stimulation:
Full screen: 44.7°
White 50ms flash (325.2 cd/m²), followed by a 1s black screen (0.603 cd/m²)

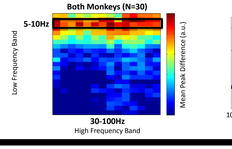
All results convolved (Gaussian, σ=35ms) for display.

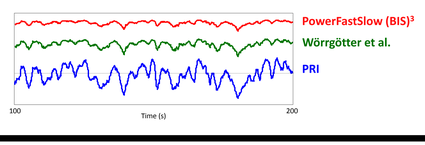


We devised a novel index for quantifying cortical arousal that allows for classification. LFP is filtered into to low (5-10Hz) and high (30-100Hz) frequency components. Each band is rectified, convolved and normalized. Then a power ratio index is computed as:

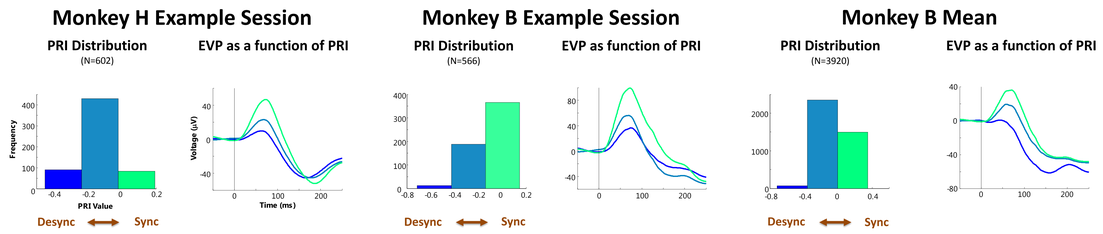
$$\text{Power Ratio Index (PRI)} = \frac{Power_{lf} - Power_{hf}}{Power_{lf} + Power_{hf}}$$

Desynchronized: PRI < 0
Synchronized: PRI > 0



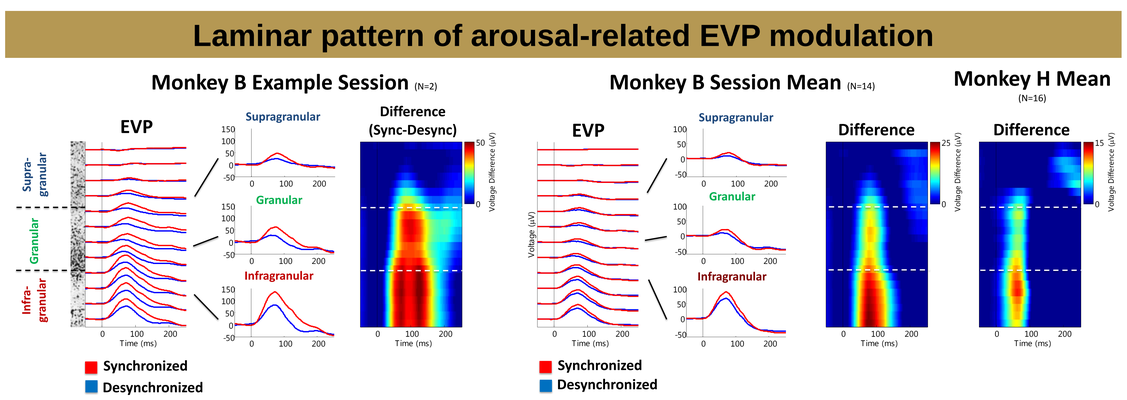


EVP magnitude in early visual cortex decreases with heightened arousal



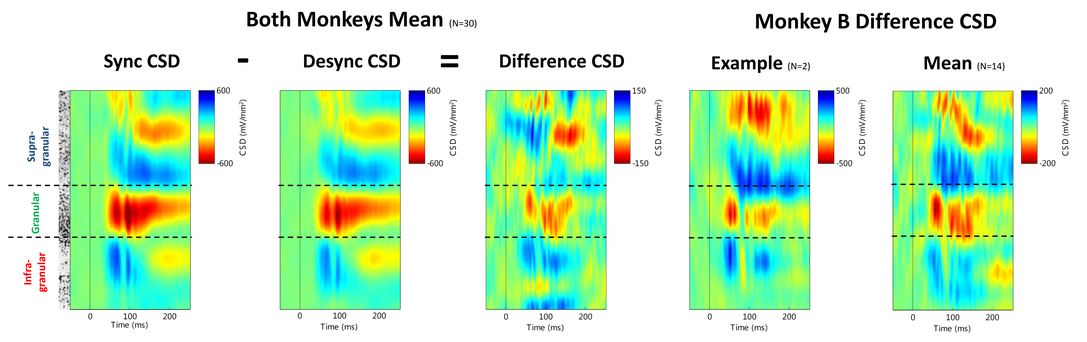
EVP magnitude <u>increases</u> as cortical activity becomes more synchronized.

Laminar pattern of arousal-related EVP modulation



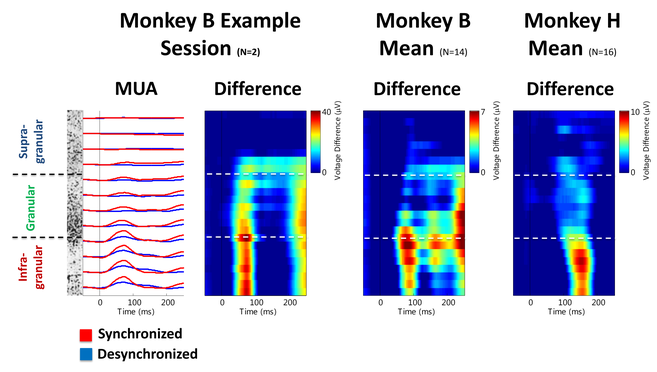
State dependent EVP modulation is most pronounced within the <u>granular and infragranular layers</u> of V1.

CSD modulation with cortical arousal



The initial current sink in the granular layers as well as subsequent sinks in the extragranular layers are of greater magnitude when cortical activity is in a low-frequency dominated (synchronized) activity state.

State dependent spiking activity

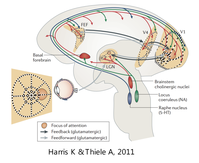


State dependent modulation of spiking responses <u>increases</u> with cortical depth.

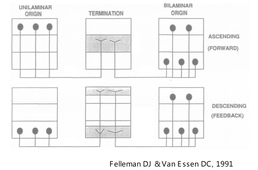
Summary

Cortical arousal is promoted and maintained by a widespread system that involves the reticular formation, aminergic nuclei, non-specific nuclei of the thalamus, the hypothalamus and the basal forebrain[5].

The transition between desynchronized to synchronized states of cortical activity has been shown to affect visual processing as early as primary visual cortex[2,6]. However, if and how it affects the laminar microcircuitry is an open question[7].



Harris K & Thiele A, 2011



Felleman DJ & Van Essen DC, 1991

Our results suggest the following:

- Increased cortical arousal correlates with *decreased* visual responses in primary visual cortex.
- This state-dependent modulation of neural responses is most prominent in the deep (infragranular) layers
- The initial thalamocortical input is already affected by the state of cortical arousal

References

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Acknowledgements

The project described was supported by the Whitehall Foundation, Alfred P. Sloan Foundation, Award numbers P30-EY-08126 and P30-HD-015052 from the NIH, NSF Graduate Research Fellowship DGE-0909667, Fine Science Tools, the Vanderbilt Vision Research Center, the Vanderbilt Brain Institute, and the Vanderbilt Center for Integrative & Cognitive Neuroscience