The relationship between awake and anesthetized neural responses in the primary visual cortex of the rat

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Introduction

In our previous work, we have shown that external visual stimulation influences the pattern of neural activity in the primary visual cortex of the awake behaving ferret only modestly (Fiser et al., Nature 2004). This raises the possibility that spontaneous activity plays a more significant role in sensory coding than previously believed. One potential example of such a role is promoting more efficient information transfer in the cortex. We investigated this alternative by testing a new hypothesis proposed recently by Rajan, Abbott & Sompolinsky (unpublished).

According to their hypothesis, the particular combination of recurrent connections and level of spontaneous activity in the cortex keeps the network in an operating domain where sensory information is propagated in a highly efficient way. Specifically, they propose that the interaction of such recurrent networks propagated in a highly efficient way. Specifically, they propose that the interaction of such recurrent networks in the optimal regime should lead to better propagation of intermediate frequencies of a periodic signal. In the present study, we provide support for this proposal by measuring signal and noise levels of cortical activity under periodic visual stimulation and dark (spontaneous) conditions in waking and anesthetized rats, which represent the cortical network operating in the optimal and suboptimal domains, respectively.

Methods

- 29 single and multi-units (23 of which were clearly visually-driven) were obtained from the primary visual cortex (V1) of three adult Long-Evans rats.
- We used chronically implanted, 16-channel electrode arrays fitted to an adjustable microdrive.
- Visual stimuli included complete darkness (spontaneous condition), plus periodic 1 Hz, 2 Hz, 4 Hz, and 8 Hz whole-screen white-black flashing.
- Two repetitions of recordings were made for all five stimulus conditions, plus each for four levels of isoflurane anesthesia and an awake condition, where rats were headfixed and passively viewing.
- Anesthetized recordings were performed at four different concentration of isoflurane, ranging from deep to very lightly anesthetized (2.0% to 0.6%).

Results

1. Firing rates and LFP power spectral densities generally decrease with increased isoflurane.

2. Autocorrelation functions show how a cell’s firing is distributed over time, including how much of it is evoked by a periodic stimulus such as flashing light.

3. Signal increases with higher concentrations of anesthesia.

4. Noise also increases with higher concentrations of anesthesia, but to an even greater extent.

5. Across cells and conditions, noise is reduced when the stimulus is on. In addition, noise is a non-monotonic function of stimulus frequency.

Conclusions

- The decreased S/N ratio with increased anesthesia suggests that the primary visual cortex in awake animals is tuned for efficient information transmission.
- The increased S/N ratio for the periodic visual stimuli (relative to the spontaneous case) is due more to a reduction in noise than to an increase in the signal component. In addition, there is a preferred intermediate frequency range, where noise is lowest. Both of these observations support the idea that efficient information transmission in the brain is accomplished by entrainment of the dynamic network as suggested by Rajan et al.
- These data suggest that spontaneous activity in the waking brain is not an epiphenomenon but rather an essential part of cortical processing.