EFFECTS OF ANESTHESIA ON NEURAL ACTIVITY IN THE PRIMARY VISUAL CORTEX OF THE RAT

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Introduction

In 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. We proposed that instead of massive changes in firing rates, cortical neural coding might be modulated by spontaneous activity. We suggested that spontaneous activity is not noise but changes in firing rates, cortical neural coding might be better described as internal dynamics of cell-assemblies modulated by sensory input. We also suggested that spontaneous activity is not noise but that it represents the internal state of the neural circuitry. In the present study, we provide further evidence that spontaneous activity, which can be manipulated by the volatile anesthetic isoflurane, modulates visual processing.

Methods

Recordings of LFP and multiunit activity were obtained in two adult Long-Evans rats (with data from one presented here). We used chronically implanted, 16-channel electrode arrays consisting of a single bundle of 12.5-µm-diameter nichrome/formvar wire electrodes fitted to an adjustable microdrive. Recordings were made in six stimulus conditions under four levels of isoflurane anesthesia. Recordings from the same cells across conditions and levels of isoflurane are compared here. Anesthesia ranged from deep to light (1.6% to 0.6%), and visual stimuli included complete darkness, 1 Hz, 2 Hz, 4 Hz, or 8 Hz whole-screen white-black flashing, and a natural scene movie.

Results

1. Firing rates across levels of anesthesia are not monotonically ordered.

2. Power spectral densities generally decrease with increased isoflurane, and may be affected by the frequency of stimuli.


4. Autocorrelations show visually evoked activity.

5. However, the degree to which units are visually evoked changes with isoflurane concentration and with changes in the stimuli.

6. Autocorrelation changes in two general ways across stimulus conditions.

   - One type of unit generally decreases with increased frequency.

   - Another type of unit peaks at intermediate frequencies.

7. Coherence decreases with decreased isoflurane, particularly in higher frequency bands.

Conclusions

- Firing becomes more and more sparse with increased concentrations of isoflurane, and stimulus frequency may affect LFP power differently depending on the level of spontaneous activity.

- Autocorrelations generally decrease with increased isoflurane, indicating a dependence of these visual responses on network properties.

- Most cells have a preferred frequency range: low or intermediate. In addition, the preferred frequency may change with isoflurane, which would suggest a complex relationship between state-dependent spontaneous activity and incoming stimuli.

- Previous studies have shown increased coherence in LFPs during slow wave sleep and ketamine/xylazine anesthesia (Destexhe et al., J. Neuroscience, 1999; Contreras and Steriade, J. Neuroscience, 1995). Our results show clear increases in local coherence between units and LFPs with increased isoflurane, suggesting that isoflurane does dampen cortical activity in similar ways as natural states such as sleep and other anesthetics such as ketamine/xylazine.