Natural scene movie responses are more precise in synchronized than desynchronized cat V1

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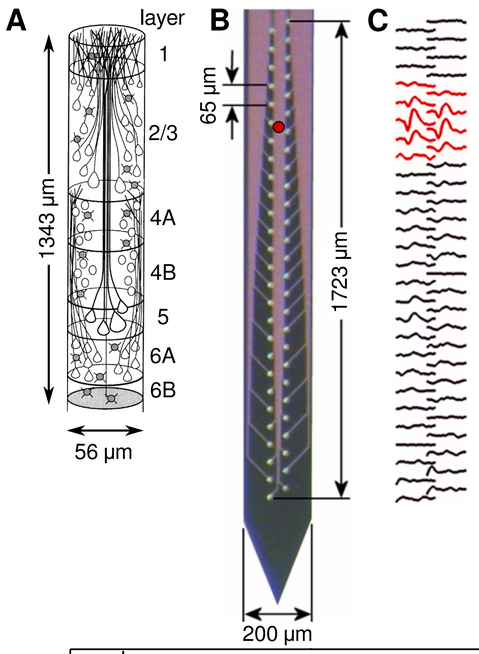
Introduction: How might the ongoing cortical state affect responses to naturalistic sensory stimuli? We recorded spiking responses simultaneously from dozens of single units across most layers of isoflurane-anesthetized cat V1 using high-density silicon polytrodes[1] (**Figure 1**). As a more naturalistic alternative to visual stimulation with white noise movies or drifting bars & gratings, we presented short natural scene movie clips hundreds of times each. Spiking responses were divided up according to cortical state (synchronized & desynchronized)[2], determined by the relative energy in low and high frequency components of the deep layer local field potential (LFP) (**Figure 2**). Cortical state switched spontaneously (**Figure 3**). Responses to natural scene movie clips had short, temporally precise, sparse, and reliable events (**Figure 4**). Precision was as fine as 20 ms, calculated from the full width half max (FWHM) of peaks in the trial-averaged responses. Response events were more precise, sparse, and reliable in the synchronized than desynchronized state (**Figures 4 & 5**), conflicting with existing results in rodent sensory cortex[3-6].

Figure 1: High density 54-channel silicon polytrodes recorded both high-pass spike waveforms (**C**) and low-pass LFP. Single unit spikes were detected and sorted from the high-pass data using a divide & conquer method[7].



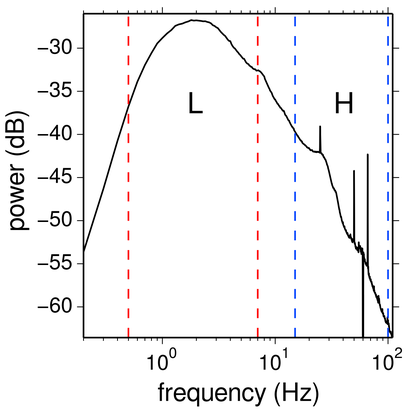


Figure 2: LFP power spectral density (PSD) averaged over all recordings. Low (L) and high (H) frequency ranges are shown. Synchrony index (SI) was defined as the power ratio SI = L/(L+H), and ranged from 0 to 1. SI was calculated for each 30 s time bin.

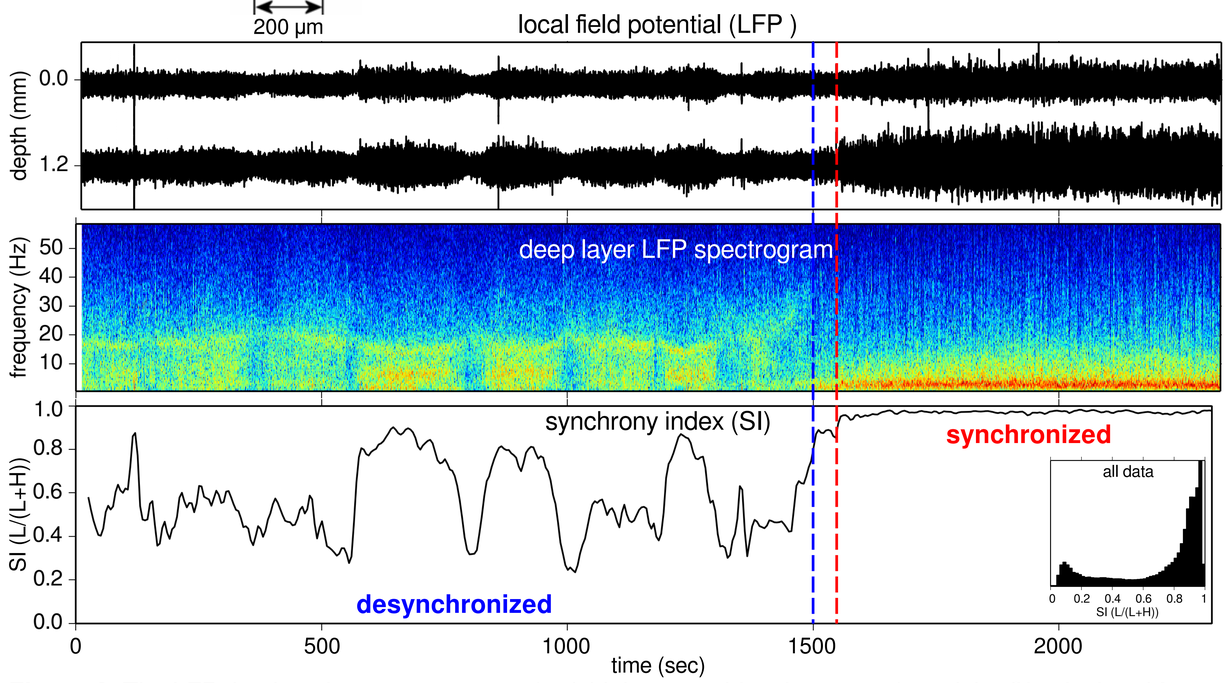


Figure 3: The LFP, its deep layer spectrogram (red: high power, blue: low power), and the SI calculated from the spectrogram, for a 39 min recording with 400 repeats of a 5 s natural scene movie clip. The LFP in the synchronized state had higher amplitude than in the desynchronized state (demarcated by vertical dashed lines). A wider range of frequencies and greater variability in the spectrogram are visible in the desynchronized state, while a 1/f type of distribution and UP/DOWN phases (vertical lines in the spectrogram) are visible in the synchronized state. **Inset**: SI distribution for all 137 hours of recorded data.

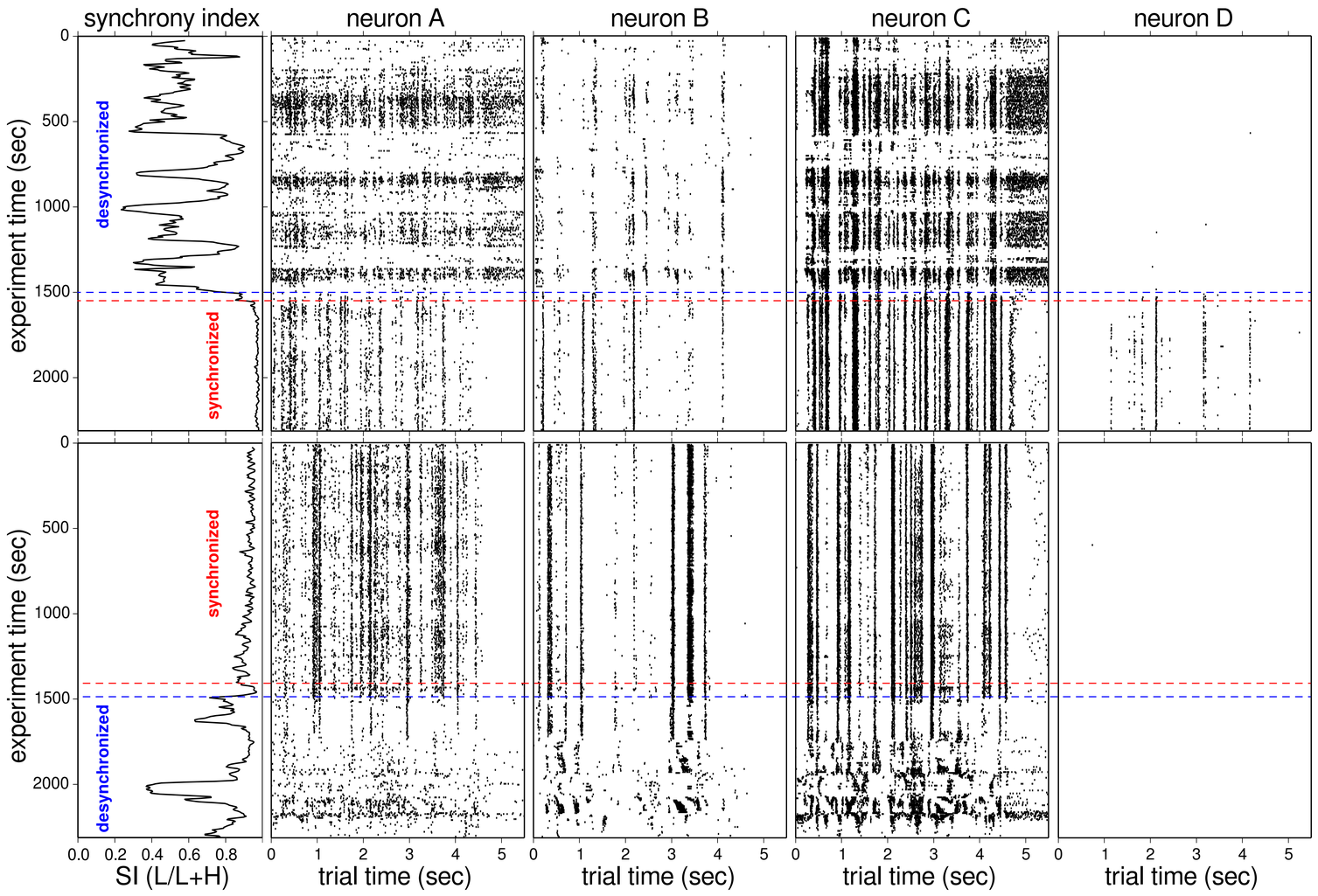


Figure 4: Responses of four example neurons to two different repeated movie clips (**top & bottom** panels, top panel corresponds to **Figure 3**). Cortical state spontaneously switched from desynchronized to synchronized, and then back. Responses were visibly more precise within a trial (horizontally) and more reliable across trials (vertically) in the synchronized state. Some cells were responsive only to specific movies, and some only during the synchronized state (**right**). No cells were responsive during only the desynchonized state.

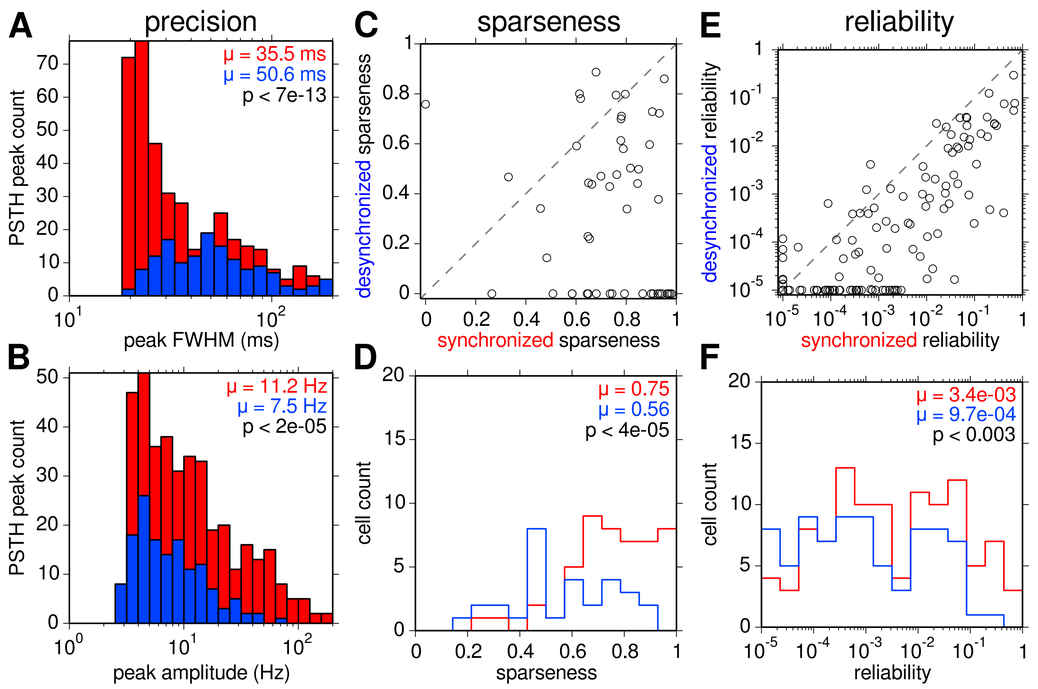


Figure 5: Response events were detected in the trial-averaged responses (PSTHs), and were narrower (**A**) and taller (**B**) in the synchronized (**red**) than desynchronized (**blue**) state. PSTH sparseness[8] (**C-D**) and response reliability (**E-F**) were also higher in the synchronized state. Each point in **C & E** represents a neuron in a consecutive pair of states. Reliability was taken as the mean correlation between all pairs of trials for each cell during each movie and cortical state[3]. Means and p-values (Mann-Whitney U test) are shown.

Discussion: These results are surprising because the synchronized state under anesthesia is thought to correspond to quiescent periods in awake animals, and the desynchronized state to alert attending periods[2]. Neural responses are stronger for attended than unattended stimuli[9]. Our results therefore complicate the analogy between cortical states in anesthetized & awake animals. One possible reason for this conflicting[3-6] result may be the greater columnar organization of stimulus features in cat V1 than in rodent V1. Travelling waves of activation[10,11] (UP phases) in the synchronized state may interact differently with incoming stimuli in the two species. This explanation predicts a similar result in anesthetized ferret and primate V1.

Funding: CIHR and NSERC.

References:

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