Introduction

The response properties of cortex are not static. Identical stimuli may generate very different cortical responses, a phenomenon often thought to be due to an interaction with ongoing activity (Arieli 1996; Kisley 1999). Here we investigate how the vibrissa evoked population spiking (multi unit activity or MUA) response of alpha chloralose anesthetized rat barrel cortex depends upon the prestimulus magnitude and phase of ongoing local field potential (LFP) oscillations. We correlate the magnitude and phase of the LFP oscillation immediately prior to vibrissa deflection with the size of the evoked MUA response in all cortical layers. The implications for contrast sensitive properties as a function of Up and Down states are discussed (Shu 2003; Petersen 2003; Sachdev 2004).

Methods

Surgical Procedures

Three Sprague-Dawley rats weighing 200-350g were anesthetized with 1.5% halothane in oxygen for surgery. A tracheostomy was performed and cannulae were inserted in the femoral artery and vein for monitoring of blood pressure, blood gas and alpha chloralose administration. After surgery halothane was discontinued and alpha chloralose anesthesia was maintained with 10mg/kg intravenous bolus of alpha chloralose followed by continuous infusion at 40 mg/kg*hr*1. Following tracheostomy animals were mechanically ventilated with a mixture of air and oxygen. The animal was fixed in a stereotaxic frame, the skull over the barrel cortex was thinned and a well of dental acrylic was built around the edge of the thinned skull. A craniotomy and durotomy were performed over the barrel cortex. The well was filled with a buffered saline containing 135 mM NaCl, 5 mM KCl, 5 mM Hepes, 1.8 mM CaCl2, 1 mM MgCl2. (Simons 1989; Armstrong-James 1992; Moore 1998).

Cortical Laminar Electrodes

A linear micro-array with 23 contacts spaced 100 micrometers apart (laminar electrode) was slowly inserted into the barrel cortex perpendicular to the cortical lamina and the principle whisker identified as that which produced the largest evoked response. The recorded extracellular field potential was amplified and filtered into a low pass (0.1-500 Hz) and a high pass (500-5000 Hz) component recorded at 20KHz (the MUA) which was rectified by taking its absolute value (Ulbert 2001; Devor 2003).

Vibrissa Stimulation Protocol

The principle whisker was deflected repeatedly by a computer controlled piezoelectric stimulator. The stimulator, positioned 3mm from the base of a whisker, deflected the whisker upwards and allowed a free return to the resting position (Devor 2003). The stimulus protocol employed 27 different stimulus amplitudes spaced linearly with a maximum interstimulus interval of 1200 mm (699 degrees/s). 1050 stimulus presentations (40 of each amplitude) and 600 nulls (no stimulus) were used. The inter-stimulus interval was 1 second and the vibrissa deflections and nulls were randomized. This stimulus protocol was repeated 2-4 times in each rat.

Results

MUA Response to Vibrissa Deflection is Highly Variable

• The MUA response of rat barrel cortex to identical stimuli is highly variable.
• This variability is, at least in part, generated by spontaneous cortical oscillations.
• Phase can be used to rigorously describe the LFP oscillations, even though they are highly non-sinusoidal.
• The MUA response is a strong function of both the magnitude and phase of the LFP immediately prior to vibrissa deflection.

Conclusions

• Considering only the LFP magnitude implies the response is largest in the Down state.
• Phase plots show the response is not a monotonous function of LFP magnitude, in fact it depends strongly on the LFP’s recent history. This suggests the response properties of barrel cortex are rather than a strict partitioning into Up and Down states would include.

References