Auditory responses and stimulus-specific adaptation are largely preserved across NREM and REM sleep in rat primary auditory cortex.

Yuval Nir [1], Vladyslav V. Vyazovskiy [1,2], Chiara Cirelli [1], Matthew I. Banks [3], and Giulio Tononi [1]

[1] Department of Psychiatry, University of Wisconsin, Madison, WI, 53719, USA

[2] Department of Biochemistry and Physiology, University of Surrey, Guildford, Surrey, GU2 7TE, UK

[3] Department of Anesthesiology, University of Wisconsin, Madison, WI 53706, USA

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Abstract

Sleep entails a disconnection from the external environment, but to what extent signal propagation along ascending sensory pathways is preserved across vigilance states remains unclear. It has been suggested that the thalamus may not relay effectively sensory inputs to the cortex in sleep, but recent evidence challenges this view.

In this study, neuronal and LFP responses to sounds in rat primary auditory cortex were compared between wakefulness and sleep. Adult WKY rats were implanted with microwire arrays (~50 kΩ) in right A1 (n=6). After a week of recovery, sleep stabilization, and habituation to stimulation, acoustic stimuli were presented (free-field) in a sound-proof, acoustically-calibrated environment as rats spontaneously switched between vigilance states. In the first experiment, 24 sounds were presented pseudo-randomly with inter-stimulus intervals (ISIs) of 1250±250ms at 3 intensities (30,55,80 dB SPL). Stimuli included short (100ms) and long (600ms) tones, clicks and click-trains (duration = 500ms), more complex stimuli including environmental sounds and rat vocalizations (duration = 250-1000ms), as well as FM sweeps (0.5-2kHz, duration = 100ms) and 'chirp AM' tones [10kHz, f_{mod} = 20-200Hz, duration = 600 ms). In a second 'oddball' experiment, low (8kHz) and high frequency (45kHz) tones were presented frequently (90%) or rarely (10%) in a mixed and counter-balanced manner (ISIs = 750±100ms, 55 dB SPL). Local field potentials (LFPs), and single unit activity (SUA) were recorded continuously along with epidural EEG, EMG and video, and spike sorting was performed offline. Vigilance states were scored in 4s epochs on the basis of EEG, EMG, and behavior.

We recorded from a total of 520 units in A1 and quantitatively compared SUA across vigilance states. Trials categorized as wake, NREM or REM sleep showed robust differences in baseline LFP power spectra and neuronal discharges (e.g. firing rate in NREM was 80.5% of that in wakefulness, $p < 10^{-43}$). On average, both the selectivity and the magnitude of evoked SUA were comparable across wakefulness, NREM and REM sleep (differences < 8.1% between all states), and this was confirmed separately for onset, offset, and sustained responses. In the oddball paradigm, robust stimulus-specific adaptation (SSA) was observed following the onset of repetitive tones. SSA was similar in magnitude across vigilance states, suggesting that basic deviance detection persists in sleep. These results support the notion that responses to external stimuli are preserved in primary sensory cortices across sleep. A functional disconnection may prevent activity to effectively drive high-order cortical regions.

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