Letter

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Sparse optical microstimulation in barrel cortex drives learned behaviour in freely moving mice

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Electrical microstimulation can establish causal links between the activity of groups of neurons and perceptual and cognitive functions[1, 2, 3, 4, 5, 6]. However, the number and identities of neurons microstimulated, as well as the number of action potentials evoked, are difficult to ascertain[7, 8]. To address these issues we introduced the light-gated algal channel channelrhodopsin-2 (ChR2)[9] specifically into a small fraction of layer 2/3 neurons of the mouse primary somatosensory cortex. ChR2 photostimulation *in vivo* reliably generated stimulus-locked action potentials[10, 11, 12, 13] at frequencies up to 50 Hz. Here we show that naive mice readily learned to detect brief trains of action potentials (five light pulses, 1 ms, 20 Hz). After training, mice could detect a photostimulus firing a single action potential in approximately 300 neurons. Even fewer neurons (approximately 60) were required for longer stimuli (five action potentials, 250 ms). Our results show that perceptual decisions and learning can be driven by extremely brief epochs of cortical activity in a sparse subset of supragranular cortical pyramidal neurons.

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Behavioural report of single neuron stimulation in somatosensory cortex

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Understanding how neural activity in sensory cortices relates to perception is a central theme of neuroscience. Action potentials of sensory cortical neurons can be strongly correlated to properties of sensory stimuli[1] and reflect the subjective judgements of an individual about stimuli[2]. Microstimulation experiments have established a direct link from sensory activity to behaviour[3, 4], suggesting that small neuronal populations can influence sensory decisions[5]. However, microstimulation does not allow identification and quantification of the stimulated cellular elements[6]. The sensory impact of individual cortical neurons therefore remains unknown. Here we show that stimulation of single neurons in somatosensory cortex affects behavioural responses in a detection task. We trained rats to respond to microstimulation of barrel cortex at low current intensities. We then initiated short trains of action potentials in single neurons by juxtacellular stimulation. Animals responded significantly more often in single-cell stimulation trials than in catch trials without stimulation. Stimulation effects varied greatly between cells, and on average in 5% of trials a response was induced. Whereas stimulation of putative excitatory neurons led to weak biases towards responding, stimulation of putative inhibitory neurons led to more variable and stronger sensory effects. Reaction times for single-cell stimulation were long and variable. Our results demonstrate that single neuron activity can cause a change in the animal's detection behaviour, suggesting a much sparser cortical code for sensations than previously anticipated.