

Representation of Vibrissal Self-Movement in the VPM Thalamic Nucleus

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Rodents use their vibrissae (whiskers) to sense the external world. By rhythmically sweeping their vibrissae back and forth in a behavior known as “whisking”, the vibrissae contact objects near the face. This behavior allows the animal to form perceptions about its immediate surroundings. Thus, rodents must keep track of their own vibrissal movements as well as those created by contact with external objects. It has been shown previously that vibrissal self-movement information is encoded at the periphery (Fee et al, 1997), and recent work from our laboratory suggests that neurons in primary somatosensory cortex encode object position in terms of the phase in the whisk cycle at which contact occurs. Furthermore, there appears to be a class of neurons that show a dramatic, non-linear increase in firing rate when contact occurs at the neuron’s preferred phase (Curtis and Kleinfeld, 2009). These cells may therefore provide a substrate for the animal’s ability to determine the position of an object with a single vibrissa (Mehta et al, 2007). It is presently unknown how this computational property observed in cortex is implemented in the nervous system. Answering this question requires knowledge of how the self-movement and touch signals are represented in the thalamic nuclei that provide inputs to cortex. As a first step, experiments involving electrically induced “fictive” whisking in anesthetized animals have suggested several classes of cells in the ventral posterior nucleus (VPM) and the posterior medial nucleus (PoM) of the thalamus. One class of cells in the dorsal medial portion of VPM is hypothesized to be responsive to both whisking and touch (Yu et al, 2006), but critical experiments with awake animals that are naturally whisking are needed to determine the role of these cells (as well as other classes of VPM and PoM cells) in the perception of self-movement.

To answer this question, we recorded the single unit activity of neurons in VPM in awake, head-fixed rats as they whisked in air, and we applied brief puffs of air to stimulate the vibrissae externally. We report a class of cells that respond with short (<10 ms) latencies to external air-puff stimulation, characteristic of cells in VPM in the anesthetized animal. A subset of these cells tends to fire preferentially at particular phases of the whisk cycle. We have observed the three following qualitative response types: “unimodal” cells which peak at one phase in the whisk cycle; “bimodal” cells which respond at two different phases of the whisk cycle; and cells that appear to be inhibited at a single phase of the whisk cycle. These results confirm that the hypothesized whisking/touch neurons in VPM (from electrical whisking experiments in anesthetized animals) do in fact respond to both internally and externally generated vibrissae movements in the awake, actively whisking rat. These cells may therefore play a role in the animal’s ability to determine the position of an object that makes contact with the vibrissae. However, whether these cells encode movement in absolute (position) or relative (phase) coordinates, as well as the nature of potential interactions between internally and externally generated stimuli, remain to be determined and are critically important for determining how the confluence of whisking and touch signals in cortex arises.

References

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