This Week in The Journal

Representation of Odor Value in Olfactory Tubercle

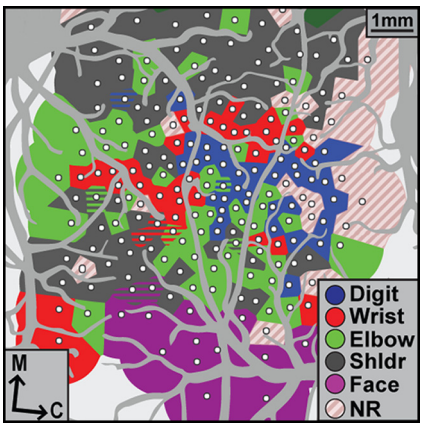
Daniel J. Millman and Venkatesh N. Murthy

(see pages 4335–4347)

Odor provides important information about the proximity of rewards, such as food and mates, and dangers, such as poisons and predators. Although some odors are innately attractive or aversive, the valence of others is learned. Learning the significance of odors involves the olfactory tubercle, a brain structure that receives direct inputs from the olfactory bulb and cortex, as well as from reward-related areas, such as the ventral tegmental area and nucleus accumbens. Indeed, many neurons in the olfactory tubercle exhibit higher firing rates in response to odors that predict reward than those that predict the absence of reward (Gadziola et al., 2015, J Neurosci 35:4515). Another brain region that might be involved in olfactory associative learning is the piriform cortex. This region has been shown to encode odor identity, which might be important in assessing value.

To investigate reward encoding in the posterior piriform cortex (pPC) and olfactory tubercle, Millman and Murthy recorded single units in these areas as mice sniffed odors that predicted the presence or absence of water reward. Consistent with previous work, spiking in pPC neurons was sparse across odor presentations, suggesting that the responses were selective for odor identity. But there was no evidence that pPC neurons encoded odor valence. In contrast, most olfactory tubercle neurons showed markedly different responses based on odor valence. These differences emerged within 300 ms of the first sniff. Furthermore, classifiers trained on olfactory tubercle population responses to a subset of odors could decode the valence of other odors. When mice were presented with novel odors, they quickly learned to discriminate rewarded and unrewarded odors. As they did so, the responses of neurons in the olfactory tubercle changed. Importantly, classifiers trained to decode the valence of previously learned odors were initially unable to determine the valence of novel odors, but decoding performance improved to >90% as the session progressed, paralleling improvements in mouse behavior.

These results show that neurons in the olfactory tubercle respond to odor valence with short latency after perception of a previously learned odor, and they quickly acquire valence-related responses to novel odors. Future work should determine which of the many subtypes of olfactory tubercle neurons exhibit odor valence selectivity, how this selectivity is acquired, and how it drives appropriate behavioral responses.



Patches of M1 controlling movement of different forelimb joints (determined by intracortical microstimulation at white dots) are intermingled in M1. Stimulation in striped tiles evoked dual movements. Major blood vessels are shown in gray. Nonresponsive (NR) sites failed to evoke movements. See Card and Gharbawie for details.

Intrinsic Connectivity of M1

Nicholas S. Card and Omar A. Gharbawie

(see pages 4348–4362)

Primary motor cortex (M1) is organized broadly somatotopically, with adjacent regions controlling movements of legs, arms, and head. Within these domains, however, somatotopy breaks down. For example, within the forelimb region, the movement of particular joints is evoked by stimulation of nonadjacent patches intermingled with patches that control other joints. How these patches work together to control movements is unclear, but axonal projections between patches are almost certainly involved. Indeed, M1 neurons receive more inputs from within M1 than from other cortical areas. Yet, little is known about this intrinsic connectivity. To remedy this, Card and Gharbawie used intracortical microstimulation to activate small groups of neurons in the arm and hand regions of primate M1, and identified regions functionally connected to these neurons using intrinsic signal optical imaging. This technique allowed examination of a relatively large area (~10 × 10 mm) of M1 at a finer resolution (~13 μm/pixel) than is achievable with fMRI.

Stimulation at sites within the forelimb region led to short-latency activation within a patch surrounding the stimulation site, followed by activation at several discrete patches at sites up to 7 mm away. Notably, most of the surface area covered by these activated patches was within the forelimb region, with limited activation within the hand zone and face area. Comparison of activation maps evoked by stimulation at different sites within the arm zone suggested that patches are reciprocally connected. Stimulation in the hand zone also activated a relatively large patch of cortex at the stimulation site, plus smaller patches at noncontiguous sites. Stimulation within the hand zone activated a smaller total area than stimulation in the arm zone, and the bulk of this activation was within the hand zone, although considerable activation extended into the arm zone.

These data suggest that neurons in M1 have dense local connectivity, forming patches that are reciprocally connected with discrete patches controlling movement of the same limb. Future work should compare activation patterns evoked by microstimulation with patterns evoked during behavior, to determine whether different subsets of the interconnected patches are activated during different movements.

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