NEUROPHYSIOLOGY

Identifying posture cells in the brain

The parietal cortex represents body posture and other factors in spatial awareness

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For an animal to successfully feed, mate, and avoid danger, its brain must integrate incoming information from many sensory modalities, combine the information with previously stored knowledge about the world, and then send appropriate output commands to the muscles. The information in this process is highly spatial in nature, but it is not anchored to any one coordinate reference frame. For example, sensory data from a fingertip tells the animal about a point in space, but exactly which point in space depends on the position of the finger relative to the wrist and arm it is attached to, as well as on the actual location of the animal in the world. Similarly, for the information on the retina, the point depends on depth of field, position of the eye within the socket, position of the head relative to the body, and location of the animal in the world. In order to integrate this highly spatial information, the brain needs to transform between coordinate systems. On page XXX of this issue, Mimica *et al.* (*1*) demonstrate how the posterior parietal cortex in the brains of rats represents different aspects of the animal's posture, that is, the relative position of different parts of its body, implying that these posture cells could be one of the building blocks for coordinate transformation in the brain.

The parietal cortex has reciprocal connections to frontal motor areas as well as to almost all sensory areas in the mammalian brain (see the figure). It is thus expected to play a role in multiple cognitive functions such as multisensory integration, movement planning, working memory, and spatial navigation. Recordings from the parietal cortex of head-fixed monkeys revealed cells sensitive to light at specific positions on the retina, with responses further modulated by the position of the eyes, position of the head, and even by limb-position (*2-5*). These experiments also revealed cells related to quick eye movement, grasping, and reaching. Such complex responses hinted that within the parietal cortex some form of spatial transformation might occur between the various reference frames of the receptors (for example, eyes) and effectors (for example, hands) (*6*).

Building on this, Mimica *et al.* recorded single neurons from the posterior parietal cortex (PPC) and frontal motor cortex (M2) of freely moving rats while tracking reflective markers attached to various parts of the rodent's body. The authors found that slightly more than half of the populations in PPC and M2 were tuned to postural features (including head, neck and back positions), with some of the cells responding to the conjunctive postures of multiple body parts. The authors also demonstrated that they could reliably decode the activity of the neuron population in these regions so as to predict postures. A posture signal of this kind would be a key component of the transformation between reference frames because it would enable, for example, conversion from a head-centered coordinate frame to a body-centered coordinate frame.

Previously, PPC cells in rodents were shown to specifically encode simple locomotion behaviors, such as left and right turns and forward runs (7); and a more complex series of locomotion behaviors, for example, running straight followed by a right turn (*8*). Responses of these cells could be highly dependent on the given task, such as leftward movement in a maze versus in an open field (*9*) or they could be related to working memory, for example, remembering which of two paths to choose when approaching a T junction in order to reach a reward (*10*). However, it is possible that in all of these cases the animal was simply exhibiting very different postures at different points in the activity being undertaken, for example, turning its head to the right prior to making a right turn, or turning in a very different manner during the hairpin tasks compared to the open field task. Indeed, Mimica *et al*. disambiguated locomotion from posture and found posture to be far more correlated with PPC cellular activity, thus providing a more consistent and simpler explanation for

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the phenomenon of encoding complex locomotion behaviors.

However, even if posture is central to the PPC, there are many details left to uncover. Can it be driven by passive posture change, or is it dependent on actively updating posture only? And what happens when the animal is static: does the PPC behave the same as when the animal is constantly shifting posture? Does the PPC represent current posture only, or does it also or instead handle the planning and execution of future postures? Mimica *et al*. present evidence that activity in PPC neurons precedes that in M2 neurons. These regions are then coupled to the superior colliculus, which contains cells tuned to, and likely driving, the rotational movement of the head in 3-dimensional space (*11*). This suggests PPC-M2 network activity could be the driving force for the downstream postural changes. If that is the case, how do the postural signals in the PPC and M2 become translated into rotation signals in the superior colliculus? Where does the transformation happen and what is the nature of feedback between the different regions?

Further, can the posture cells support other complex cognitive functions in the PPC, such as spatial memory and navigation? To perform such functions, there must be a transformation from body-centric (egocentric) to world-centric (allocentric) coordinates, such that information is expressed in a manner invariant to the animal's location, and anchored to the external environment. Allocentric signals have been reliably observed in the hippocampus, which is connected to the PPC via the retrosplenial cortex. And indeed, cells in the PPC have been found to encode not just egocentric body movements (left or right turns), but also a direction signal expressed in both egocentric and allocentric reference frames (*12*). Thus, the transformation between egocentric and allocentric reference frames presumably happens in either the PPC or retrosplenial cortex (*13, 14*). But how? And what role do PPC posture cells play in the process? Future experiments will be needed to reconcile the newly found posture cells in the PPC-M2 network by Mimica *et al.* with previous work on the PPC in rodents and primates, so as to establish how these cells support the complex cognitive functions of the PPC.

REFERENCES

1. B. Mimica *et al*., Science **362**, xxx (2018).
2. R. A. Andersen *et al.*, *Science* **230,** 456 (1985).
3. R. A. Andersen *et al*., *Annu. Rev. Neurosci.* **20**, 303 (1997).
4. R. A. Andersen, *Philos Trans R Soc Lond B Biol Sci*. **352**, 1421 (1997).
5. P. R. Brotchie *et al*., *Nature* **375**, 232 (1995).
6. Y. E. Cohen, R. A. Andersen, *Nat. Rev. Neurosci*. **3**, 553 (2002).
7. B. L. McNaughton *et al*., *Cereb Cortex* 4, 27 (1994).
8. D. A. Nitz, *Neuron* **49**, 747 (2006).
9. J. R. Whitlock *et al*., *Neuron* **73,** 789 (2012).
10. C. D. Harvey *et al*., *Nature* **484,** 62 (2012).
11. J. J. Wilson *et al.*, *Curr. Biol*. **28**, 1744(2018).
12. A. A. Wilber *et al*., *J. Neurosci.* **34**, 5431 (2014).
13. A. Bicanski, N. Burgess, *Elife*, 7, e33752 (2018).
14. L. H. Snyder *et al*., *Nature* **394**, 887 (1998).

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Posture cells in the PPC-M2 network

Posture cells have been discovered in the PPC-M2 network. PPC neurons in rodents have reciprocal connections to various cortical areas, including visual, auditory, primary somatosensory, and prefrontal cortices, as well as the secondary motor and retrosplenial cortices, thus supporting a series of cognitive functions.