

Homeland Defense Begins in Precentral Cortex. Focus on “Sensorimotor Integration in the Precentral Gyrus: Polysensory Neurons and Defensive Movements”

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The reaction of a major league baseball player to a high velocity pitch differs from that of an average individual in a way that transcends mere skill. If most of us are put in the flight path of a 90 mi/h baseball, our response will look qualitatively unlike that of an experienced professional. Rather than produce a well-timed and well-placed swing of a baseball bat, we would more than likely close our eyes, grimace, drop the bat, and bring our arms to the defense of our face, all in short order. The nervous systems of both invertebrate and vertebrate organisms have adapted specialized circuits specifically for the avoidance of looming and possibly injurious stimuli. Recent studies of the representation of movements in macaque precentral cortex suggest the existence of a separate neural circuit for the control of defensive, versus nondefensive, movements (Graziano et al. 2002a).

Although much progress has been made in understanding the cortical control of movement, at present there is significant confusion concerning the functional divisions within the precentral gyrus. Can areas within it be divided up only according to the particular motor effector controlled (i.e., arm, hand) or the region of workspace (Graziano et al. 2002b)? Are the anatomically defined areas differentially involved in motor preparation and execution and the production of motor sequences or the type of sensory guidance (Tanji 2001; Wise et al. 1997)? Perhaps key to progress in understanding the organization of precentral cortex would be some clue as to how natural skeleto-motor behavior in monkeys might itself be divided up. Are there particularly obvious subclasses of primate motor behavior? In visual cortex, much work has been devoted to identifying the particular specialization of cortical areas in representing the kind of stimulus dimensions naturally encountered by the animal, e.g., color and movement. As a result, the past few decades have seen an explosion of knowledge on the organization of macaque visual cortex (Felleman and Van Essen 1991). That there is a class of movements specialized for defensive behavior suggests a strategic basis from which one can explore the functional organization of precentral cortex.

In this issue, Cooke and Graziano (p. 1648–1660) study the neural mechanisms of defensive behaviors in a region of precentral cortex previously found to contain neurons using visual, tactile, and auditory cues to signal the presence of stimuli within extrapersonal space (Graziano and Gross 1998). Building on the confluence of evidence of extrapersonal space representations within this zone of cortex [the polysensory zone (PZ)] and the observation that electrical microstimulation of this area evokes

flinch-like movements, Cooke and Graziano pursue the role of this area in transforming a particular type of sensory input (threatening) into a particular type of motor output (defensive). First, the authors compare an oculomotor component of naturally evoked defensive responses with one evoked by microstimulation of PZ. Remarkably, the metrics of the two look virtually identical. In both cases, the oculomotor component consists of a nonsaccadic, centering movement of the eyes. Second, the authors studied the activity of PZ neurons during air-puff-evoked defensive movements. These neurons, in addition to being driven by the puff of air on their tactile receptive fields, responded with a variable magnitude that reliably correlates with the magnitude of the monkey's flinch.

Cooke and Graziano, faced with the difficulty of 1) interpreting the defensive-looking behaviors evoked by microstimulation and 2) evaluating the causal role of PZ neurons in controlling natural defensive movements, adopted a combined single-unit and microstimulation approach. Both approaches, used alone, have noteworthy limitations. Correlating the rate or pattern of single neuron responses at different stages of a sensorimotor pathway with a particular behavior is the most frequently used approach, but it inevitably begs the question of whether the neural activity actually causes the behavior. Electrical microstimulation of neural tissue to evoke behavioral responses can seemingly reveal the causal role of particular neural circuits, but it suffers from the presumed nonphysiological signals it imposes on neurons, thus calling into question the relevance of the evoked phenomena. The authors recognize that, ultimately, an adequate account of the neural control of movement will depend on a coherence of results from both of these approaches. Thus far, both kinds of evidence suggest a role of PZ neurons in transforming polysensory evidence of threatening stimuli into defensive movements.

REFERENCES

- Cooke DF and Graziano MSA.** Sensorimotor integration in the precentral gyrus: polysensory neurons and defensive movements. *J Neurophysiol* 91: 1648–1660, 2004.
- Felleman DJ and Van Essen DC.** Distributed hierarchical processing in the primate cerebral cortex. *Cereb Cortex* 1: 1–47, 1991.
- Graziano MS and Gross CG.** Spatial maps for the control of movement. *Curr Opin Neurobiol.* 8: 195–201, 1998.
- Graziano MS, Taylor CS, and Moore T.** Complex movements evoked by microstimulation of precentral cortex. *Neuron* 34: 841–851, 2002a.
- Graziano MS, Taylor CS, Moore T, and Cooke DF.** The cortical control of movement revisited. *Neuron* 36: 349–362, 2002b.
- Tanji J.** Sequential organization of multiple movements: involvement of cortical motor areas. *Ann Rev Neurosci* 24: 631–651, 2001.
- Wise SP, Boussaoud D, Johnson PB, and Caminiti R.** Premotor and parietal cortex: corticocortical connectivity and combinatorial computations. *Annu Rev Neurosci* 20: 25–42, 1997.

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