Contrasting Interpretations of the Nonuniform Distribution of Preferred Directions Within Primary Motor Cortex

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TO THE EDITOR: A recent paper by Georgopoulos and colleagues (Naselaris et al. 2006) revisits the influential and controversial issue of population coding within primary motor cortex (M1). Although researchers uniformly recognize that neural activity in M1 often covaries with the direction of limb movement, it is unclear whether these “preferred directions” reflect a high-level representation of hand motion (e.g., Georgopoulos et al. 1986; Graziano et al. 2002; Schwartz and Moran 1999), a low-level representation of the musculoskeletal apparatus (e.g., Mussa-Ivaldi 1988; Scott 1997; Sergio and Kalaska 1998; Todorov 2000), or a mixture of both (e.g., Crutcher and Alexander 1990; Hatsopoulos et al. 2006; Kakei et al. 1999).

Georgopoulos and colleagues contribute to this effort with three observations on neural tuning during three-dimensional (3D) reaching: 1) the most common “preferred directions” are forward/up and backward/down hand movements, 2) the alignment between hand motion and the combined activity of the neural population varies with reaching direction, and 3) the magnitude of this population signal also varies with reaching direction. The authors interpret these findings as an augmented representation or “hyperacuity” of particular spatial directions within the framework of high-level planning. They further hypothesize that forward/backward reaching movements are more frequent and thus engage practice-dependent plasticity mechanisms.

An alternative interpretation is that the biased distribution of preferred hand directions is evidence against the hand-based theory and evidence for a low-level representation. In fact, this conclusion was reached several years earlier based on the same three global patterns of M1 activity (Scott et al. 2001), a similarity and contrast overlooked by Georgopoulos and colleagues. Whereas the recent study used a 3D paradigm, Scott and colleagues studied reaching movements that involved just flexion and extension of the shoulder and elbow. The strength of this planar paradigm is the ability to compare neural activity to measured mechanical variables such as joint motion and joint torque. Thereby, they demonstrate that the neural bias is lawfully related to nonuniformities in the limb’s complex mechanics and likely reflects the impact of muscle shortening on muscle force; a similar nonuniformity of preferred directions has since been confirmed in arm muscles (Kurtzer et al. 2006).

It should be noted that Georgopoulos and colleagues were unlikely to reach this conclusion relating neural activity to low-level representations due to the limitation of their paradigm, i.e., only 3D hand motion is recorded, whereas the arm’s seven degrees of freedom can contribute to its motion. This difference in paradigms helps explain how the two groups arrive at substantially different conclusions from the same results. The reader is left to decide between these dramatically different interpretations of the same basic result.

REFERENCES


