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Presentation Abstract

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Abstract: Most theories of motor cortex have assumed that neural activity represents movement parameters. This view derives from an analogous approach to primary visual cortex, where neural activity represents patterns of light. Yet it remains unclear how well that analogy holds. Single-neuron responses are remarkably complex, and marked disagreement persists regarding which movement parameters are represented. A better analogy might be with other motor systems, where a common principle is the production of rhythmic, oscillatory neural activity. We developed methods appropriate for analyzing the population response during rhythmic movement. We first confirmed - using data from the walking monkey and swimming leech - that our methods successfully isolate the expected population structure: rotations of the neural state at a frequency matching that of behavior, captured in a two-dimensional neural state space.
We then examined neural activity recorded from motor and premotor cortex of monkeys performing variants of a delayed reach task. We analyzed the population response for 8 datasets, involving a total of 615 isolations. We found that neural responses in motor cortex of reaching monkeys contain a brief but strong oscillatory component, even though the reaches were not themselves rhythmic. At the level of the population, we observed rotations of the neural state at ~2.5 Hz that persisted for ~1-1.5 cycles. These brief rotations were consistent in direction and angular velocity across conditions, and rotation phase and amplitude followed naturally from the preparatory state. A variety of controls demonstrate that these

features are not expected of traditional models or of arbitrary multiphasic responses. More broadly, the presence of brief but strong quasi-oscillatory features is quite unexpected for non-rhythmic reaches. A possible explanation is provided by the patterns of EMG, which were both multiphasic and easily fit by a basis employing oscillations.

These results demonstrate a remarkable degree of simple structure in the population response. That simple underlying structure explains many of the otherwise confusing features of individual-neuron responses. Those features include the lack of correlation between preparatory and movement-period tuning, and the frequent reversals of preferred direction during movement. Indeed, the basic multiphasic nature of cortical responses is expected given the underlying rotations of the neural state. Furthermore, the population response has a simple dynamical interpretation: preparatory activity provides the initial state of a dynamical system, a large component of which is approximately harmonic.

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