The activity of motor cortex neurons during reaches is temporally complex and exceedingly heterogeneous.

Is neural activity in the motor cortices translated fairly directly into muscle activity, or does it embody a representation of kinematic parameters such as hand velocity? Prior work has addressed this question by varying posture, load or initial hand position. We chose a similar approach, but varied reach speed. Two monkeys were trained to reach to radially arranged targets while keeping within speed windows instructed by target color. Fast reaches (red targets) were near the limit of the monkeys abilities (~70-150 cm/s peak speed depending on distance; ~100-200 ms duration). Moderate reaches (green targets) were ~2/3 as fast (~40-105 cm/s; ~150-300 ms duration). For both reach speeds, EMG activity recorded from the major muscles of the arm/shoulder differed considerably from the profile of hand velocity. Hand velocity was single-peaked, roughly bell-shaped, and scaled in the expected manner for fast vs. moderate reaches. EMG patterns were more complex, often multi-peaked, and did not simply scale for fast vs. moderate reaches. We asked whether the temporal patterns of neural activity, recorded from motor and dorsal premotor cortex, more closely resembled those of hand velocity or of the muscles. We found that the response patterns of individual neurons were strikingly complex, often containing multiple activity peaks during the reach. The number, amplitude and phase of these peaks varied with reach direction, distance and speed, often in rather idiosyncratic ways. In particular, patterns of neural activity for the two reach speeds were rarely scaled versions of one another. Thus, neural responses were inconsistent with a code dominated by hand velocity signals. On the other hand, the response patterns of individual neurons typically did not match the activity of any recorded muscle. It may be that the responses of many neurons combine to produce the response of a given muscle. Alternately, there may be no straightforward relationship between the activity of most motor cortex neurons and either kinematics or muscle activity. Indeed, there are theoretical reasons to suspect this. For a recurrent network trained to generate temporal patterns of activity, the hidden units will not in general have a straightforward relationship with the output pattern. Attempting to describe the activity of such units in terms of their ‘representation’ would be largely futile. We suggest that the same may be true of motor cortex.

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