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CONTRIBUTION OF MOTOR PREPARATION AND EXECUTION NOISE TO GOAL−IRRELEVANT MOVEMENT VARIABILITY

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Variability is intrinsic to motor performance, but its cause is not well understood. Van Beers et al. (2004) and others have proposed that movement variability is due primarily to online noise. An interesting feature of motor variability is that it is often much larger in goal−irrelevant dimensions than in goal−relevant ones. Todorov and Jordan (2002) have proposed that this asymmetry is an effect of online noise on a control strategy that reduces variability only in goal−relevant dimensions. We asked if it could explain goal−irrelevant variability for ballistic movements, which seem too fast for online control to play a role. We trained a macaque to make fast movements to radially arranged targets (12 cm rad). Endpoint variance was small (0.84 cm^2) yet variability in peak reach speed was large (102 cm^2/s^2). We then attempted to match Todorov's model's behavior to that observed by varying the magnitude of its online noise. When the model's endpoint variance matched the monkey's, variance in peak speed was about 50 times smaller than observed. This result was robust with respect to the model's free parameters as well as to the model of the dynamics of the arm. These data argue that, for fast movements, online noise cannot account for variability in peak speed given the observed endpoint accuracy. To test if peak speed variability might result from variability in motor preparation, we recorded from 77 neurons in PMd of two monkeys during the delay period of a delayed reach task. After measuring each neuron's sensitivity to reach speed, we compared peak speed to delay period firing rate on each trial. Significant correlations were often seen for single neurons, and the effect was clear for the population (regression, $p<0.01$). Thus, both modeling and physiology argue that, for fast movements, goal−irrelevant variability is due appreciably to variability in motor preparation.

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