The decay of motor adaptation reveals an asymmetry in the stability of motion state-dependent learning

Abstract: The mammalian brain generates motor commands to initiate movement, and through interactions with our environment this motor output is adapted in order to reduce the error between the planned and actual movement. One readily learned motor adaptation involves the predictive compensation in response to changes in the physical dynamics of the environment. These dynamics are time-varying physical perturbations that are a function of the motion state, such as limb movement velocity. Analysis of the adaptive responses suggests that this high-dimensional motor output can be represented as simple combinations of position and velocity signals linearly modified with stiffness and viscosity gains. Here, we were interested in the stability of this short-term learning when the movement perturbations are based on different combinations of limb position or velocity. In the initial experiments, subjects made reaching arm movements and we tested the ability to adapt to different perturbations that subsequently resulted in biased amounts of the respective motion-based learning (velocity and position) before the decay period. Based on these results we modified a simple neural network model of motor adaptation to make predictions of the decay patterns following adaptation to different, untested movement dynamics. Finally, we trained additional subjects on the motion-state perturbations used in the simulation and confirmed the predictions of the model. We show that (1) there is a significant separation between the observed gain-space trajectories for the learning and decay of adaptation for the perturbations tested and (2) for combined motion-state perturbations, the gain associated to changes in limb position decayed at a faster rate than the velocity-dependent gain, even when the position-dependent gain at the end of training was significantly greater. Collectively, these results suggest that (1) the decay of motor adaptation is not merely the reversal of the learning process, but at least a partially distinct process likely involving separate mechanisms and (2) the state-dependent adaptation associated with movement velocity is relatively more stable than that based on position. These results may have implications for the effective design of rehabilitation paradigms and the selection of motion-based signals for prosthetic control.