Learning of Visuomotor Adaptation: Insights from Experiments and Simulations

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Repetitive prism adaptation leads to dual-adaptation, where switching between adapted and normal state is instantaneous. Up to now, it was unclear whether this learning is triggered by the number of movements during each phase of adaptation or instead by the number of phase changes from adaptation to readaptation and back. Here, we varied these two factors using a virtual environment, simulating prism adaptation. Ten groups of subjects (5 subjects/group), each defined by a particular displacement and number of movements per phase, conducted 1200 movements. The initial pointing errors of each phase decay exponentially with the number of movements for all groups due to learning. We also observe a faster learning rate per phase change for longer adaptation and readaptation phases. These results clearly indicate that learning rate of visuomotor adaptation is defined primarily by the number of interactions with the environment in the adapted and normal states and that the number of phase changes only plays a marginal role on the learning rate of direct effects.

An additional aspect of dual-adaptation is the speed of adaptation and readaptation in the individual phases. In the current literature some authors found a change in adaptation and readaptation rates during repetitive adaptation, whereas others found constant rates. Overall, we find an increase in adaptation and readaptation rates after repetitive adaptation, but this trend cannot be found in each individual group.

We are motivated to study adaptation and dual-adaptation processes as reinforcement learning-like problems, where the subject receives a global feedback signal (the reinforcement/punishment/error signal) after each trial. With this global signal the subject is able to change, individually, inner parameters like synaptic weights, in order to look for and find an optimal behavior.

To understand the dynamics of dual-adaptation found in the empirical data, we investigate a feed forward network subjected to a reinforcement learning scheme, which is based on stochastic fluctuations of the synaptic weights. We simulated the learning of two different situations and observed that the total duration of the stimulus presentation plays the main role for the learning. We find also that the speed of learning per phase change depends on the length of phases, thus linking the model to our experimental observations. In summary, learning rate is a function of the number of movements irrespective of how often phase is changed.