Titles:

A two-process model explains use-dependent locomotor learning

To vary or not to vary: two computational models of use-dependent locomotor learning

Variability of training does not change aftereffects in use-dependent locomotor learning

Model names:

The two-process model (referring to strategic and use-dependent components)

Bayesian model

Abstract

Use-dependent learning biases future movements in the direction of prior movements. Previously, we observed a dose-response relationship with regard to the stepping asymmetry participants practiced during training and the persistent aftereffects they demonstrated when instructed to walk symmetrically. We also showed an association between amount of practice, in terms of time, and the strength of the aftereffect. Studies of upper extremity reaching suggest that the variability of the environment may be another key factor in determining the magnitude of use-dependent learning. From a Bayesian perspective, the more consistent the environment, the stronger the bias, as the posterior probability gets weighted towards a more certain prior. We therefore asked the question of how environmental stability affects use-dependent learning in locomotion, as humans frequently have walk in a variety of different settings requiring changes in gait parameters. First, we compared two computational models that make dissociable predictions regarding the effects of variability during learning on the use-dependent process. One is a two-process model in which strategic corrections drive the changes in behavior during training. In parallel, a low-level use-dependent bias develops based on the large explicitly-driven stepping asymmetries. The other model is a Bayesian model of use-dependent biases which predicts the location of the future step asymmetry targets based on the averaging of the prior distribution of targets and a likelihood of all possible target locations. In a series of simulations, we show that the two-process model predicts similar aftereffects regardless of variability in target distribution while the Bayesian model predicts a smaller aftereffect with greater amounts of variability in the target distribution. We obtained the most likely parameter values for each model by fitting each model to bootstrapped samples of previously collected data. We then compared the models to empirical data. Subjects walked on a split belt treadmill with the belts tied while watching visual feedback of their step length. During the learning phase, changes in step asymmetry were induced by changes in the visual step length targets. The target locations were sampled from a normal distribution with a mean of 22% step asymmetry and a standard deviation of 0%, 5%, and a uniform distribution between 5% and 40%. Surprisingly, we found the size of the aftereffects were not different between groups despite the large variability of target distributions. These data support the two-process model in which the use-dependent process increases based on prior asymmetries regardless of the variability of targets, not the Bayesian model which estimates the next target position based on the location and size of the prior and likelihood. These results provide a clearer picture of the properties of use-dependent learning in locomotion and gives clinicians important parameters of gait training through use-dependent processes.