

Impact of reinforcement on action selection, initiation and execution during motor skill learning

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The ability to learn motor skills is a fundamental feature of human behavior, which relies both on sensory and on reinforcement feedbacks (*i.e.*, reward and punishment, Galea et al. 2015, Nat Neurosci). How such reinforcements lead to improved performance during motor skill learning remains an open question. In fact, skill learning can result from improvements at several levels of control, including action selection, initiation or execution. Here, we tested the impact of reinforcement on these different levels during motor skill learning.

After 2 short practice blocks, subjects performed 10 blocks (360 trials in total) of a modified version of a force-tracking task (Steel et al., 2016, Sci Rep). Each trial started with a cursor appearing at the bottom of the screen and subjects were asked to squeeze a pinch-grip sensor to bring the cursor at the center of a fixed target and maintain it there for the rest of the trial. To reach the target, subjects had to exert a force ($\text{Target}_{\text{Force}}$) corresponding to 10 % of the individual maximal voluntary contraction. On most trials, the cursor disappeared shortly after the beginning of the trial. Hence, subjects had to learn to approximate the $\text{Target}_{\text{Force}}$ in the absence of visual cursor. A trial was classified as successful if the mean of the difference between the actual force and the $\text{Target}_{\text{Force}}$ was under an individualized threshold. At the end of each trial, subjects received a reinforcement feedback based on their performance (*i.e.*, Success or Failure). In this task, success depended on force control at the level of action selection (*i.e.*, $\text{Force}_{\text{Set}}$; the closer the mean of the selected force was to $\text{Target}_{\text{Force}}$, the higher the chances of success), at the level of initiation (*i.e.*, the faster the onset [$\text{Force}_{\text{Start}}$] and the steeper the rate [$\text{Force}_{\text{Rate}}$] of force production, the better) and execution (*i.e.*, $\text{Force}_{\text{Exe}}$; the lower the force variability during the tonic phase, the better). Moreover, we analyzed the evolution of the different force variables

at the three levels of control, as well as the impact of reinforcement (*i.e.*, Success or Failure) on performance in the next trial across training.

As expected, the proportion of successful trials increased over training, indicating that subjects learned the motor skill. Moreover, we found that skill learning occurred at the level of action initiation (earlier Force_{Start} and steeper Force_{Rate}) and execution (reduced Force_{Exe}) but not at the level of action selection (no change in Force_{Sel}). Interestingly, subjects improved at all levels of control in trials following a Failure, while they exhibited the opposite pattern following a Success. However, importantly, this effect of reinforcement changed over the course of learning. In fact, the beneficial effect of Failure increased across training while the detrimental effect of Success decreased. It remains to be determined whether these effects would vary with a reinforcement involving an actual monetary loss or gain.