The dorsolateral striatum constrains the execution of motor habits through continuous integration of contextual and kinematic information.

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The striatum is required for the acquisition of procedural memories but its contribution to motor control once learning has occurred is unclear. Here we created a task in which rats learned a difficult motor sequence characterized by fine-tuned changes in running speed adjusted to spatial and temporal constraints. Specifically, we customized a motorized treadmill and trained rats to obtain rewards according to a spatiotemporal rule. Once the treadmill was turned on, animals could stop it and receive a drop of sucrose by entering a “stop area” located at the front of the treadmill (**Fig. 1a**). In addition to this spatial rule, a temporal constraint was added : stopping of the treadmill was only effective if animals waited at least 7 s (goal time) before entering the stop area (correct trials, **Fig. 1b**). If animals entered the stop area before the goal time, an error sound was played and they were forced to run for 20 s (incorrect non-rewarded trials, **Fig. 1b**). Initially, rats generated strong forward accelerations as soon as the treadmill was turned on and entered the stop area before the goal time, resulting in a majority of incorrect trials (upper panels, **Fig. 1c**). After an extensive training (1-3 months of daily sessions), rats finally executed a stereotyped sequence that could be divided in 3 overlapping phases : 1) passive displacement from the front to the rear portion of the treadmill, 2) stable running around the rear portion of the treadmill and 3) acceleration across the treadmill to enter the stop area (bottom panels, **Fig. 1c;)** Tetrode recordings of spiking activity in the dorsolateral striatum (DLS) of well-trained revealed continuous integrative representations of running speed, position and time (**Fig 2**). These representations were weak in naive rats hand-guided to perform the same sequence and developed slowly after learning. Finally, DLS inactivation in well-trained animals preserved the structure of the sequence while increasing its trial-by-trial variability and impaired the animals capacity to make corrections after incorrect trial. We conclude that after learning the DLS continuously integrates task-relevant information to constrain the execution of motor habits. This finding provides a new framework to understand the contribution of the basal ganglia to motor learning and control.

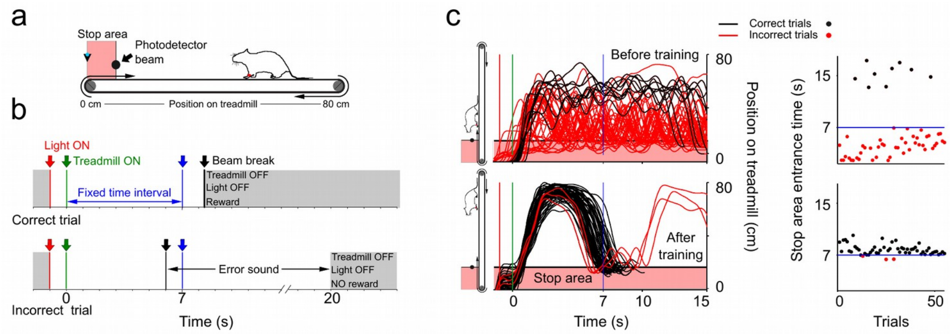

Figure1. A fixed interval estimation task adapted to treadmill locomotion favors the learning of a stereotyped running sequence. a, Behavioral apparatus. **b**, Task description. **c**, Running trajectories (left) and entrance times in the stop area (right), for two sessions, before (top) and after (bottom) learning.

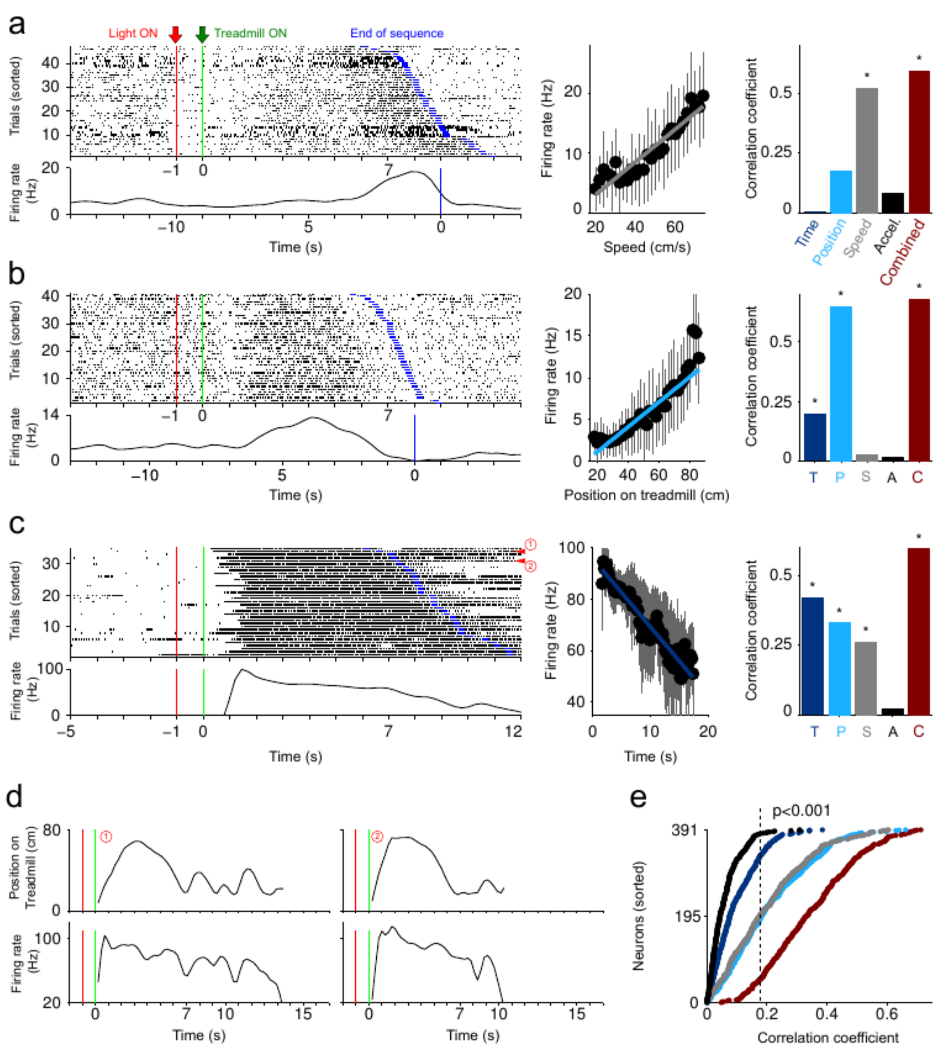

Figure 2. Linear and integrative representation of running speed, animal's position and time after learning. a-e, Three illustrative units whose firing rate is primarily correlated with running speed (), with position on the treadmill (**d**), or with a combination of time, position and speed (**c**). Left panels show spike rasters (top) and average perievent histograms (bottom), aligned to the end of the motor sequence (a-c) or treadmill start (d,e). Middle scatter plots show average firing rate versus best correlated task variable (error bars indicate standard deviation). Right panels show partial and multiple correlation coefficients between firing rate and task variables (stars indicate p < 0.001, Pearson partial correlation coefficient). **d**, Two illustrative trials taken from the unit shown in e, with trajectories (top) and instantaneous firing rates (bottom). **e,** Partial and multiple correlation coefficients between firing rate and task variables, sorted for all the recorded units (3 rats, same color code than a-c). Pearson partial correlation coefficients with p value < 0.001 are on the right side of the dashed line.