How can motor skills be mastered in the presence of noise, remembered without rehearsal, despite perpetual synaptic drift?

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Two profound aphorisms about motor skill learning, one vintage and one newly-minted, are as follows: Once learned, one never forgets how to ride a bike. To be excellent at anything requires roughly 10,000 hours of practice.

While sayings do not constitute science and these aphorisms may not always be strictly true, they do tap into something fundamental about biological sensorimotor control. A fine motor skill learned to a high level of proficiency tends not be forgotten, even if unrehearsed for decade; further, an inordinate amount of practice is required to achieve such a level of performance. Any theory of motor learning must be able to reproduce these findings.

But what are the neural constraints that should guide such a theory? We argue that, for maximal probative power, each of these attributes of motor skill learning ought to be considered in the face of uniquely neurobiological constraints that act most directly in opposition to their attainment. In the case of the durability of motor memories, we ask the following question: how can a motor memory endure for decades unrehearsed when the entire set of synapses that embody that memory will have undergone thousands of cycles of wholesale exchange? In the case of the need for extended practice, we ask the following question: given that sensorimotor circuits exhibit high levels of thermal noise at both the neural and muscular levels, how is it possible to use extended practice to overcome this impediment and achieve expert performance? By definition, thermal noise levels cannot be diminished, so at best the circuits can re-organize their structure to somehow minimize the effects of these noise sources on the learned task.

Here we present a theory that provides an explanation of both of these phenomena. The theory relies on the use of massively redundant circuits with extremely high learning rates to overcome the obstacles imposed by multiple indigenous noise sources. Finally, this theory of hyperplastic and noisy neural networks shows how the durability of a motor skill and the initial need for extended practice are actually related! In geometric terms, the extended practice allows the network to assume a solution configuration for the skill in weight space that it is orthogonalized from – i.e., becomes non-interfering with -- all other skills.