Plasticity within the cortico-striatal and cortico-cerebellar systems during motor learning

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Operationally defined, motor skill learning refers to the process by which movements, either produced alone or in a sequence, come to be performed effortlessly through repeated practice (Willingham, 1998). Doyon and colleagues (2002, 2003) have recently proposed that during the acquisition process of a skill, representational changes within the cortico-striatal and cortico-cerebellar systems depend not only on the stage of learning, but on whether subjects are required to learn a new sequence of movements or to adapt to environmental perturbations as well. We proposed that in the fast (early) learning phase, both motor sequence and motor adaptation tasks recruit similar cerebral structures: the striatum, cerebellum, motor cortical regions (e.g., premotor cortex, SMA, pre-SMA, anterior cingulate), as well as prefrontal and parietal areas. During this phase, dynamic interactions between these structures are thought to be critical for establishing the motor routines necessary to learn the skilled motor behavior. When a task is well learned, however, such that there has been some consolidation of the skill, the subject has achieved asymptotic performance and its performance has become automatic, the neural representation of a new motor skill is then believed to be distributed in a network of structures that involves the cortico-cerebellar or the cortico-striatal circuit depending on the type of motor learning acquired. At this stage, Doyon and Ungerleider (2002) suggested that for motor adaptation, the striatum is no longer necessary for the retention and execution of the acquired skill; regions representing the skill are now involving the cerebellum and related cortical regions. By contrast, a reverse pattern of plasticity is thought to occur in motor sequence learning, such that with extended practice, the cerebellum is no longer essential, and the long-lasting retention of the skill is now believed to involve representational changes in the striatum and associated motor cortical regions.

In this presentation, I will discuss a series of experiments using brain imaging techniques that support Doyon and Ungerleider's model. More specifically, with fMRI and motor sequence learning paradigms, I will present evidence in accord with the idea that the cortico-striatal system plays a critical role in the early acquisition phase and long-term maintenance of this skilled behavior. Furthermore, using a motor adaptation task and new functional connectivity data analyses, I will describe the results of studies that are in agreement with the notion that the cortico-cerebellar system is involved not only in the early but in the maintenance of a motor adaptation skill.