Losing control

Brain vs spinal cord

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Neurologic examination after focal motor injury tends to focus on weakness rather than control. One reason for this may be the implicit assumption that weakness precludes control. Most neurologists, however, are familiar with the common bedside finding in patients with hemiparesis after stroke: they can squeeze your hand with surprising force but cannot make individuated finger movements. This dissociation is also seen when comparing the effect of a unilateral hemispheric stroke on motor performance in the ipsilateral arm; strength is unaffected but skilled movements are impaired.[1] The separation between control of movement and of isometric force has a long tradition in the design of robot arms[2] and psychophysical evidence suggests that these 2 types of control may be partitioned in the brain.[3]

In this issue of *Neurology*®, van Hedel et al.[4] shed further anatomic light on the strength/skill dissociation by comparing leg motor deficits in patients with incomplete spinal cord injury (iSCI) and patients with unilateral hemispheric stroke. The main hypothesis was that these 2 patient groups would show differential skill levels despite comparable degrees of weakness. The hypothesis was based on the idea that in iSCI, all descending pathways from the brain to the spinal cord segments below the lesion are affected in the same proportion and thus control should be relatively preserved within a given weakness envelope. In contrast, after stroke, cortical areas as well as descending pathways are affected, and it is the former that leads to the loss of skill. Skill can be impaired bilaterally because bilateral cortical areas are needed for skilled use of either limb. The authors predicted, therefore, that the patients with iSCI would have weakness but relatively preserved skill, whereas in cortical stroke patients, weakness and decreased skill would be present, the latter bilaterally.

The investigators measured patients' maximum ankle dorsiflexion (DF) and plantarflexion (PF) torques, and evaluated their performance of a tracking task, whereby they had to match a visual displayed force level by applying ankle DF or PF torques with their foot strapped into a custom-built device. The task was adjusted to the level of muscle weakness for individual patients so that skill level would not be confounded by lack of strength. Performance on the task was measured by calculating the root mean square error (RMSE) between the target and response trajectories. The patients with iSCI had decreased strength in their dominant leg compared to healthy controls, but their performance errors in the torque-tracking task started at similar levels, improved at a comparable rate, and reached a similar level as controls. The cortical stroke patients had similar levels of weakness of their affected leg compared to the iSCI patients, but their initial performance on the skill task even with their unaffected side was significantly worse. Notably, however, their learning rate was not worse than the iSCI group.

Thus this study confirmed the investigators' predictions of dissociation between strength and skill and lends further support to the distinction between the effects of damage to cortical areas vs descending pathways. This study also raises the important problem of how to evaluate motor learning in neurologic patients. Although neurorehabilitation is based on the assumption that patients can still learn,[5] relatively few studies have examined the effect of brain or spinal injury on motor learning itself.[6-8] It is a formidable challenge to compare learning capacity between groups with different initial levels of performance. If learning curves are compared, as was done in this study, the result can go in opposite directions depending on whether additive or multiplicative measures are used to assess learning. For example, if a patient starts at a hypothetical performance level of 2 and a control starts at 4, and then after training the patient reaches a level of 4 and the control reaches a level of 7, who is the better learner? If an additive score is used, then the control is better: he or she improved by 3 points whereas the patient improved by 2. If a multiplicative score is used then the patient

See page 1271

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is better: he or she improved by 100% whereas the control improved by only 75%. So what is the answer? There is no right answer—it depends on one's a priori model of learning.

In this study, the authors fit an exponential function to individual subject's RMSE data and then log-transformed the fits, i.e., they assumed a multiplicative process but then created an additive measure (no theoretical rationale was given for this choice). The stroke group showed the same slope in the log-transformed data as the iSCI group. The finding of impaired baseline skill but intact learning suggests a paradox: If stroke patients are neither weaker than the iSCI patients nor more impaired in their ability to learn, why are they more impaired at the level of skill? One possibility is that there is a limit imposed by the cortical injury, a problem of channel capacity, i.e., how much information can now project to the spinal cord, which learning cannot overcome. Another possibility is that only extensive training on the particular task will bring the stroke patients up to iSCI patients' level—learning from everyday experience does not seem sufficient to bring the stroke patients up to the iSCI patients' starting level. This raises the issue of generalization—what is the relationship between skill at a particular task and overall dexterity?

This study highlights 2 critical distinctions, and provides clues to their anatomic substrates, which are not always appreciated by neurologists. The first is between skilled movement and isometric force control; the second is between performance and learning. Studies in patients, such as the one by van Hedel et al.,[4] are crucial both for understanding normal motor control and informing mechanism-based rehabilitation strategies tailored to particular kinds of motor impairment.

DISCLOSURE

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