Editorial

Transcranial magnetic stimulation

In the past year, Brain has published an average of one article per issue on transcranial magnetic stimulation (TMS). In this issue there are two more, and they illustrate part of the range of uses to which TMS is presently being applied. The article by Magistris et al. (1998) describes a modification of its traditional use as a technique for studying the integrity of the corticospinal system in conscious humans. It has always been very easy to measure the latency of muscle responses evoked by TMS over the motor cortex, but measurements of the size of the response, which would give a way of quantifying the effectiveness of the corticospinal volley, are much more difficult to interpret. In fact, EMG responses to cortical stimulation are often only 20–50% of the size of the maximum response evoked by stimulating the peripheral nerve, so that it is not even obvious whether or not the corticospinal input can discharge all the motor neurons in a spinal pool. Marsden et al. (1983) were the first to answer this question by showing that the force of the muscle twitch produced by a single shock to the motor cortex was equal to that produced by a single supramaximal peripheral nerve stimulus. They thus argued that despite appearances, all the motor neurons in the muscle had been discharged, and the smaller EMG potential after cortical stimulation was simply due to dispersion of the volley as it was conducted through the corticomotoneuronal synapse and peripheral nerve. There was always the possibility that some motor neurons had actually fired twice in response to the cortical shock, and therefore that some had not fired at all. However, this objection was readily dealt with by showing that the twitch produced by simultaneous stimulation of cortex and peripheral nerve was no larger than that seen after peripheral stimulation alone. The antidromic peripheral nerve volley had collided completely with the orthodromic cortical volley: under the conditions of their experiment, there were no double discharges of spinal motor neurons.

Although theoretically elegant, the technique has two practical limitations. First, it is difficult to measure accurately the force of a maximal muscle twitch because of possible contributions from other neighbouring muscle groups. Second, in most circumstances, TMS tends to make some motor neurons fire twice in response to a single shock (Day et al., 1987, 1989). The technique of Magistris et al. (1998) circumvents both by applying a double collision method that allows EMG response amplitudes to be compared directly.

The second paper, by Ohtsuka and Enoki (1998), illustrates how TMS, after spending years in the hands of motor physiologists, is coming of age as a general non-invasive technique for exploring all aspects of brain function. One of the original disappointments of TMS was that single stimuli only seemed to have any effect when given over the motor cortex, when a twitch could be seen in contralateral muscles. Stimulation over sensory cortex produced no paraesthesias, nor did temporal stimulation evoke memories. The reason is probably that complex sensations and memories are evoked only by trains of several stimuli. However, while single stimuli are ineffective in producing positive phenomena, they are quite capable of interfering with the normal patterned activity that occurs during task performance. Thus, applied at the correct time and place, single stimuli can, for example, produce transient foveal blindness (Amassian et al., 1989), suppress perception of visual motion (Beckers and Zeki, 1995) or delay the onset of a voluntary movement (Day et al., 1989). It is this aspect of TMS, particularly because of its high temporal resolution, which is achieving wider recognition. When combined with PET or fMRI, we can build up a picture of not only which areas of brain are active in a task, but also the time at which each one contributes substantially to task performance. Indeed, workers in the Human Motor Control Section at the National Institute of Health, Bethesda, Md, USA recently gave this approach an elegant new twist. Sadato et al. (1996) used PET imaging to show that blood flow increased in the occipital cortex of congenitally blind subjects when they read Braille. To demonstrate that this activation contributed to task performance, they went on to show that TMS over the occiput interfered with Braille reading in blind subjects, but not in normal subjects (Cohen et al., 1997).

The target for stimulation in the paper by Ohtsuka and Enoki (1998) is a little lower on the scalp, just over the posterior vermis in the cerebellum. In the past there had been some debate as to whether it was even possible to use TMS to activate the cerebellum, since the thickness of the skull at the inion means that the cerebellar surface is several centimetres from the magnetic stimulating coil. However, this now seems to have been positively resolved (Werhahn et al., 1996), with recent work by Ohtsuka and colleagues (Hashimoto and Ohtsuka, 1995) suggesting that it may even be possible to study different subareas. Again, to observe any effect, the stimulus has to be given during task performance, since stimulation alone has no obvious effect. However, when applied during either saccades or smooth pursuit eye movements, stimulation has a direction-selective effect on the size of saccades and the velocity of smooth pursuit.

It is clear that TMS is an excellent addition to the many
new tools that we have for non-invasive imaging of the function of the human brain. Recent advances in which combined approaches have been used, such as TMS and PET (Paus et al., 1997) or TMS and EEG (Ilmoniemi et al., 1997), suggest that the applications of TMS will continue to grow rapidly.

John Rothwell

References