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Asymmetrical facilitation of motor-evoked potentials following motor practice

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Use-dependent facilitation of motor-evoked potentials evoked by transcranial magnetic stimulation with repetition of simple movements has been well established. Motor-evoked potentials were recorded from two intrinsic hand muscles before and after blocks of motor practice in which study participants made repeated ballistic pinch responses with either their left or their right hand. Despite similar increases in behavioral performance by each hand (measured by the peak acceleration of the force generated by the index finger), practice-related increases in the amplitude of the motor-evoked potentials were greater in the left than in the right motor cortex of right-handed participants. This finding supports the hypothesis that the dominant motor cortex has a greater ability to reorganize with experience than the non-dominant motor cortex. NeuroReport 17:805-807 © 2006 LippincottWilliams &Wilkins.

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Introduction

Transcranial magnetic stimulation (TMS) is a non-invasive means of studying use-dependent changes in the primary motor cortex (M1) in normal humans. Repeated non-fatiguing movements lead to a rapid increase in the amplitude of the motor-evoked potential (MEP) in the exercised muscle, which persists after motor repetition [1,2]. This use-dependent MEP facilitation is restricted to muscles involved in the movement [2] and occurs after active but not passive movements [3–5]. Facilitation is not present with transcranial electrical stimulation or with magnetic stimulation of the corticospinal tract at the brainstem and cervical levels [6], showing that the use dependent MEP facilitation reflects an increase in the excitability of the cortical representation of the actively exercised muscle.

Intrinsic horizontal connections within M1 modulate the excitability of the output cells and are thought to form a substrate for motor plasticity [7,8]. This intrinsic connectivity is more profuse in M1 of the dominant than the non-dominant hemisphere [9,10], suggesting that there may be a functional asymmetry in response to motor practice, with the dominant M1 having a greater ability than the non-dominant hemisphere to reorganize with practice [11]. Evidence for a greater engagement of the dominant than the non-dominant M1 in motor plasticity following unimanual practice on the Purdue pegboard task has been reported [12]. Although MEPs evoked by TMS over each M1 were facilitated to a similar degree by practice with the contralateral hand, MEP facilitation in the dominant M1 was correlated with behavioral improvement of the dominant hand whereas MEP facilitation in the non-dominant M1 was not correlated with behavioral improvement of the non-dominant hand, leading the authors to conclude that only changes in the dominant hemisphere were related to motor learning [12]. The Purdue pegboard task is a complex visuomotor task with a transport phase (in which the upper arm moves toward the pegboard before placement of the peg) and a manipulation phase (in which the pegs are placed in the holes in the pegboard). Evidence that the control of the dominant and non-dominant arms differs, with the former more dependent on planning and the latter more dependent on feedback [13], suggests that the two hemispheres might contribute differently to the different phases of the pegboard task, and that practice might differentially affect the performance of each hand. The aim of the present experiment was therefore to measure MEP facilitation in the left and right M1 after each of a series of practice trials of a simple motor task, a ballistic pinch response.

Materials and methods

Study participants

Eighteen volunteers (seven male volunteers) aged 18–48 years (median¼22 years) participated. The protocol was in accordance with the Declaration of Helsinki and had been approved by the Human Research Ethics Committee of the University of Western Australia. All volunteers gave informed written consent before participating. All participants were right-handed as assessed by the Edinburgh Handedness Inventory [14], with laterality quotients that ranged from 70 to 100 with a median of 81.

Procedures

The participants completed eight blocks of 25 ballistic pinch responses with each hand, with the forearm supported with the palm facing medially and the index finger and thumb fitted comfortably into plastic cups fixed to rods fitted with strain gauges that recorded flexion forces. Participants were instructed to execute ‘brisk and efficient’ pinch responses synchronized with brief tone bursts presented at 0.5Hz and to relax completely between responses. The force generated by the index finger in each pinch response was digitized at 1000Hz and the peak acceleration calculated and saved for later analysis. Visual feedback of the peak acceleration of the force generated by the index finger and thumb was displayed on the screen in front of the participant after each response.

A block of 20 TMS pulses (an alternating series of 10 single pulses and 10 paired pulses with a subthreshold conditioning stimulus delivered 3ms before the test pulse, with an 8-s delay between successive stimulations) was delivered before the first practice block and immediately after each practice block of pinch responses. Electromyogram activity was recorded from the relaxed first dorsal interosseus (FDI) and abductor digiti minimi (ADM) muscles with surface electrodes, amplified (1000x), bandpass filtered (10–1000 Hz) and digitized at 4000Hz for 500ms following stimulation. Two Magstim 200 stimulators connected through a BiStim module (The Magstim Company, Carmarthenshire, Wales, UK) were used to generate the stimuli that were delivered through a figure-of-eight coil (90-mm diameter) placed tangentially to the scalp with the handle pointing backward and held at an angle of 45° to the midline. The resting motor threshold for MEP elicitation at the optimal site for FDI was determined as the minimum stimulus intensity required to elicit an MEP greater than 50 µV in three of five successive stimuli. The test stimulus intensity was set at 1.2 times the resting motor threshold. Each practice block began 30 s after the end of the preceding TMS block. The dominant and non-dominant hands were tested in separate sessions, with the hand tested first being alternated between participants.

Data analysis

The median peak force acceleration generated by the index finger in the second and later motor practice blocks was normalized for each participant by expressing it as the ratio of the corresponding value from the first motor practice block. Similarly, the median peak-to-peak MEP amplitudes evoked in FDI and ADM by the single TMS pulses after each block of motor practice were normalized by expressing each value as the ratio of the median peak-to-peak amplitude recorded from that muscle in the baseline TMS session immediately before motor practice. The measures of short-interval intracortical inhibition obtained with the paired TMS pulses did not change with practice and are not reported here. All ratio scores were log transformed before analysis and the back-transformed means (the geometric means of the untransformed ratios) are reported. As a result of this transformation, standard errors of the mean are not symmetrical around the mean and are reported as separate negative and positive values relative to the mean in the graphs. The behavioral and TMS measures were analysed with repeated-measures analyses of variance, and partial η^2 values are reported as effect size measures.

Results and discussion

Normalized behavioral performance for each hand in each practice block averaged over the two sessions is shown in Fig. 1. Overall, the mean peak force acceleration increased with practice with a statistically significant quadratic component for the practice block [F(1,17)=6.4, *P*=0.022; η_p^2=0.27). The increase in performance with practice was similar for both hands, and neither the effect of hand nor the effect of any component of the interaction of hand and block approached statistical significance.

The normalized amplitudes of the MEPs evoked in FDI and ADM of each hand after each practice block averaged over the two sessions are shown in the left and right panels, respectively, in Fig. 2. Mean MEP amplitude in the right FDI increased systematically with practice, whereas mean MEP amplitude in the left FDI was variable and showed little systematic change.

The differential change in the left and right hands is shown in a statistically significant linear interaction of hand and practice block [F(1,17)=4.8, *P*=0.042; η_p^2=0.22]. Post-hoc analysis showed that the mean MEP amplitudes recorded from the right hand were greater than those from the left hand in practice blocks 5, 7 and 8 [Fisher’s least significant difference, all *t*(17) values ≥3.5, all *P’*s0.05]. MEP facilitation was not evident in either the left or the right ADM (Fig. 2, right panel). The changes seen in FDI were thus specific to the muscle engaged in the repetitive movements and did not reflect non-specific changes associated with practice. MEP facilitation, quantified as the change in amplitude from the baseline session to the final session for each participant, was uncorrelated with behavioral change, quantified again as the change in peak acceleration from the first to the last practice block for each participant. Correlation coefficients were near zero for both hands, indicating that individual differences in behavioural change were unrelated to MEP facilitation. Furthermore, MEP facilitation was evident in participants who did not show an increase in peak force acceleration with practice, indicating that movement repetition was sufficient to induce an increase in cortical excitability.

Despite the similar behavioral improvement of each hand, MEP facilitation was present primarily in the right FDI, showing a more pronounced plastic change in the dominant than in the non-dominant M1 with practice of the contralateral hand. The results add to those reported previously, and suggest that the dominant motor cortex has a primary function in motor learning [12] that is not confined to practice of a complex visuomotor skill but is also evident with repetition of a simple response without any requirement for spatial accuracy. Together, these results are congruent with the observation that intrinsic intracortical connections are more profuse in the left than in the right M1 [9,10] and with the hypothesized function of these connections in mediating motor plasticity [8]. The greater dexterity of the dominant than the non-dominant hand might therefore result in part from a greater capacity of the dominant M1 to reorganize with use [11].

Evidence from converging sources shows that motor preparation is asymmetrical, and that the dominant hemisphere prepares simple responses for execution by both hands [15,16]. Practice with either hand might stimulate plastic changes primarily in the dominant M1, and this lateralized movement representation, which would be subject to ongoing modification and refinement with use, might then control action of both the dominant and the non-dominant hand during subsequent performance. The data available at present do not address this possibility because practice-related changes have been assessed only in the motor cortex contralateral to the practiced hand. Measures of cortical excitability in each M1 with unilateral practice of the ipsilateral hand are needed to determine whether there are practice-related changes in the dominant M1 with practice of both ipsilateral and contralateral hands.

Conclusion

Practice of a simple pinch response results in a greater increase in the amplitude of MEPs evoked in the FDI muscle of the dominant right hand than the non-dominant left hand, suggesting that the motor cortex of the dominant hemisphere has a greater capacity to reorganize with experience than that of the non-dominant hemisphere. This result is congruent with anatomical evidence of more profuse intrinsic connections in the dominant than the non-dominant hemisphere and with physiological evidence that has implicated these connections in motor plasticity.

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Fig. 1 Mean normalized peak acceleration generated by the index finger of the left hand (open symbols) and the right hand (closed symbols) as a function of practice block. The broken line shows a normalized value of 1.0. The error bars show ± standard error of the mean. Data points are off-set slightly on the abscissa for clarity.

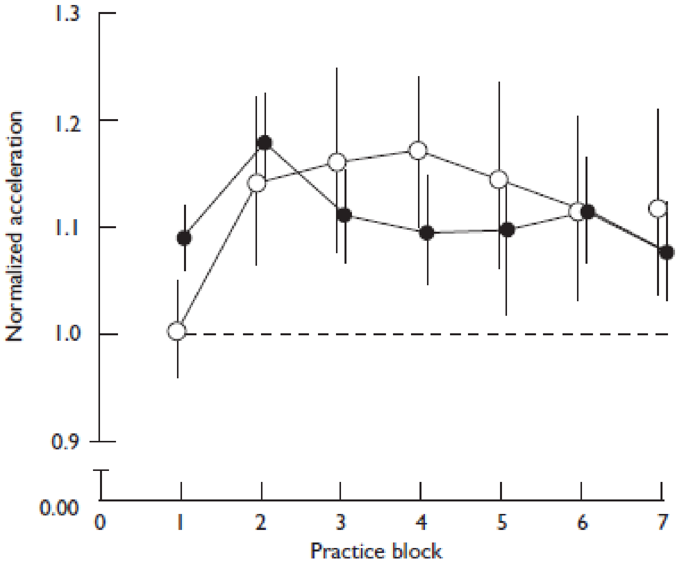

Fig. 2 Mean normalized motor-evoked potential (MEP) amplitudes after each block of motor practice from the left hand (open symbols) and right hand (closed symbols).MEP amplitudes from the first dorsal interosseus are shown in the left panel and those from the abductor digiti minimi are shown in the right panel. The broken line shows a normalized value of 1.0.The error bars show ± standard error of the mean. Data points are offset slightly on the abscissa for clarity.