Differential effects of motor task on cortical excitability induced by cutaneous input

K. Kujirai[1], T. Kujirai[3], T. Kato[2], M. Tominaga[1], and S. Ueno[4]

[1]*Dept. of Laboratory Medicine,* [2]*Third Dept. of Internal Medicine, Yamagata Univ. School of Medicine;* [3]*Dept of Neurology, National Yonezawa Hospital,* [4]*Dept. of Engineering, Univ. of Tokyo, Japan*

1 Introduction

The input-output organization has been considered to be crucial for fine and discrete movements in primates (1). The cortical sensori-motor integration in humans, in particular, plays an important role in the precise motor execution. For instance, the final execution from the cortical command definitely needs the peripheral feedback of sensory information. In view of the afferent information such as cutaneous sensory inputs, Stephens et al (2) demonstrated that cutaneous stimulation can modulate the cortical excitability in specific periods; E2, which is associated with transcoritcal pathways, known as a long loop reflex. However, the cutaneous modulation of the cortical cells in human has been controversial (3, 4).

If cutaneous afferent travels upto the motor cortex, then how does the modulation take place in the discrete movements ? Here, there are several possibilities for it; the arrival timing of cutaneous information onto the cortex, the hand tasks and different I-waves induced by transcranial magnetic stimulation (TMS).

Briefly, in monkey, pyramidal neuronal activities in the motor cortex are more active during the precision grip than during the power grip, and firing patterns of the pyramidal neurons are under the influence of the peripheral cutaneous stimulation (1). In our previous study, the area of E2 component of the cutaneomuscular reflex (CMR) was larger in the individual finger movement than in the power grip (5). So the cutaneous modulation of the cortical neuronal activity might be different between the hand task.

Taken together with the background above, in order to evaluate the effects of cutaneous stimulation on cortical excitability by TMS, we compared the two kinds of hand tasks; the precision grip and the power grip, and the different kinds of I waves.

2 Methods

Six healthy volunteers participated in this study. All gave informed consent and the procedures had the approval of the local ethical committee. All of them were right handed. They were required to maintain the abduction of the right index finger (AB) or the power grip of the right hand (GP), in the same force level by the visual feedback. Cutaneous stimulation to the right index finger was given at three times of the sensory threshold. The cutaneous stimulation was followed by the transcranial magnetic stimulation (TMS) at various interstimulus intervals (ISIs) (10-90 ms). Motor evoked potentials (MEPs) induced by the TMS were recorded from the first dorsal interosseous muscle (FDI) with the belly-tendon method. The peak-to-peak amplitudes of MEPs were compared after 8 trials at each ISIs between with (conditioned T) and without (unconditioned T) the cutaneous stimulation. In order to investigate the cutaneous stimulation on different I-waves, we changed the direction of the induced current in the brain; the posterior-anterior (PA) and anterior-posterior (AP) directions. Cutaneo-muscular reflex (CMR) was recorded from the FDI with the belly-tendon method. Cutaneous stimulation was given at the same intensity as applied in the TMS study. The surface EMG activities were band passed and full-wave rectified.

3 Results

PA direction

The area of the E2 component was larger in the AB task than in the GP ($p<0.05$) (figure 1). The size of MEPs was significantly augmented by the cutaneous stimulation only in the AB task at 55 ms of the ISI (Figure 1, 2). In the GP task, the size of MEPs was not affected significantly by the cutaneous stimulation. At 30 and 40 ms of the ISIs, the MEPs showed a small amout of inhibition which failed to have any significance, in both of them.

AP direction

In comparison to the PA direction, MEPs were significanly facilitated at 70 and 90 ms of the ISIs (Figure 3, 4).

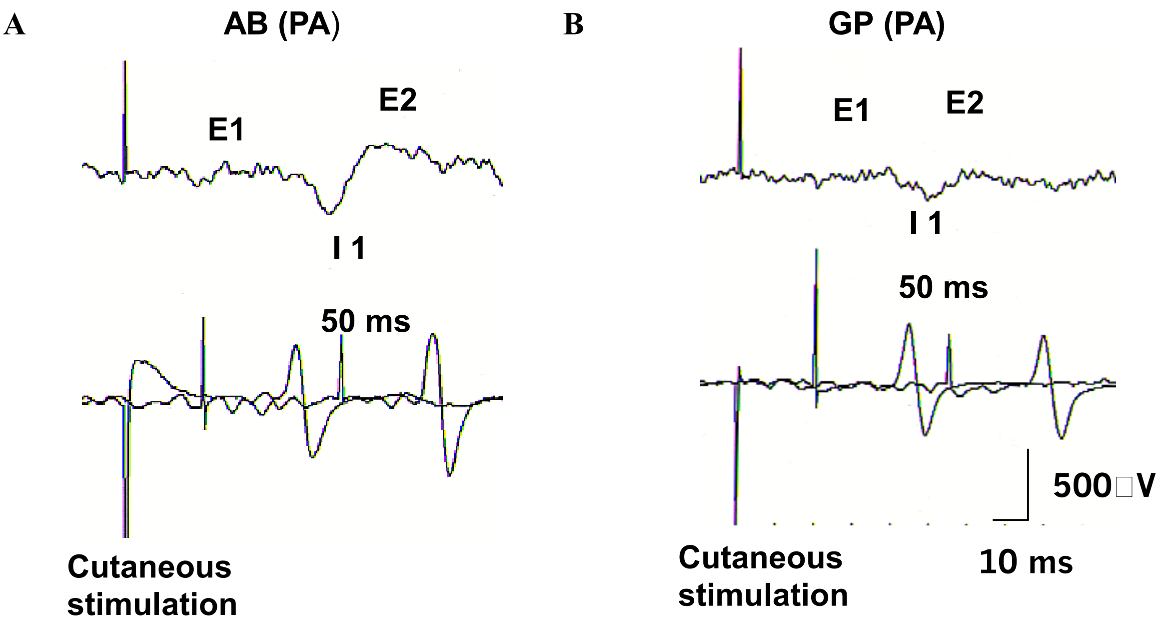

Figure 1: *The cutaneomuscular reflex (CMR) and the motor evoked potential (MEP) by the transcranial magnetic stimulation (TMS) are shown. The two tasks; A) the abduction of the right index finger (AB), B) the power grip (GP), were compared. Top: The E2 component was larger in the AB task (p<0.05). Bottom: In the AB task, the size of MEP was increased after cutaneous stimulation at the ISI of 55ms. In the GP task, the size was not increased in the size of MEP.*

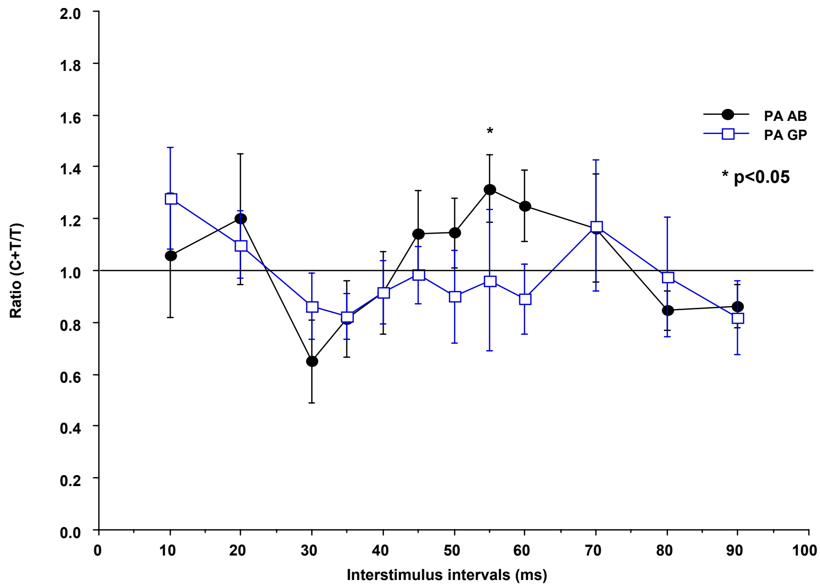

Figure 2: *The ratio of the peak-to-peak amplitude of MEPs with the cutaneous stimulation (C+T) to that of MEPs without the cutaneous stimulation (T) from six subjects. The direction of the figure-of-eight coil was posterior to anterior (PA). The size of MEPs was significantly augmented by the cutaneous stimulation only in the AB task at 55 ms of the ISI.*

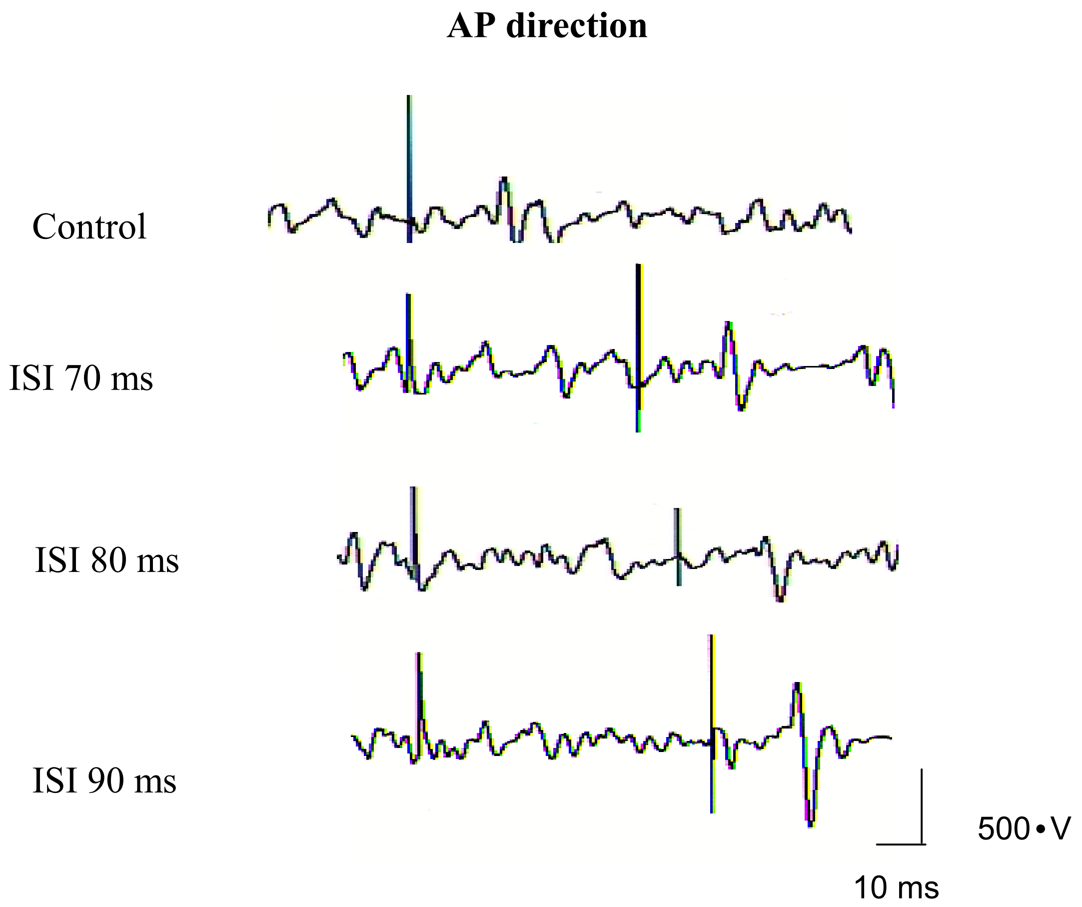

Figure 3*: The change of the I-3 wave of MEP (I-3) after the cutaneous stimulation. The direction of the figure-of-eight coils was anterior-posterior (AP). The augmentation of MEPs was observed at 70, and 90 ms of the ISIs.*

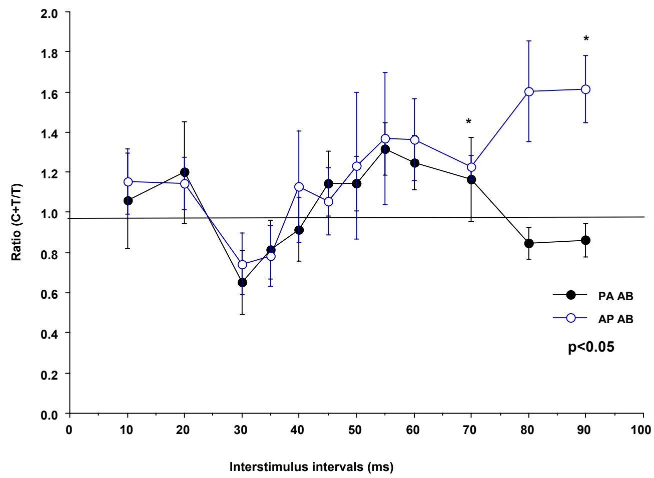

Figure 4: *The ratio of the peak-to-peak amplitude of MEPs with the cutaneous stimulation (C+T) to that of MEPs without the cutaneous stimulation (T) from six subjects. They were required to maintain the abduction of the right index finger (AB). In comparison to the curve of the PA direction, the size of MEPs were augmented by the cutaneous stimulation at the ISIs of 70 and 90 ms.*

4 Discussion

The size of MEPs was slightly inhibited at 30 and 35 ms of ISIs. Significant facilitation of MEPs by the cutaneous afferent was observed only in the AB task at the ISI of 55ms. In our previous study, electrical cortical stimulation did not facilitate MEPs even in the AB task (5). So the facilitation of MEP is probably of cortical origin. These results suggest that cutaneous stimulation probably gives rise to the excitation of the motor cortex after 55 ms from the cutaneous input. This timing is corresponding to the later component of the CMR, the E2 phase, and the E2 component is probably produced along with transcortical pathway. The modulation of the cortical excitability by the cutaneous stimulation, however, is specific to the hand motor task, partly because the pyramidal neuronal activities in humans are essential to augment the excitability during the precision grip rather than the power grip.

There was the difference of the cutaneous influence among different I-waves. The later component of MEPs, I-3, was also augmented by the cutaneous afferents. The excitation still continued toward 90 ms of ISIs. There are at least two possibilities; The motor cortical excitation behaved a prolong duration, especially in AP direction, or the sensori-motor neural networks involved are different from the conventional trascortical pathways. Further examination is needed to clarify the mechanism of producing the I-3 wave.

5 Conclusion

The effect of the cutaneous afferent on the motor cortical excitability is dependent on the hand motor task. There was the difference of the cutaneous influence among the kind of I-waves.

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