Transient suppression of primary visual cortex using transcranial magnetic stimulation

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1 Introduction

Recent advances of transcranial magnetic stimulation can provide new methods to elucidate the mechanism of higher brain function or cortical plasticity. For example, transcranial magnetic stimulation can produce transient disruption of the visual perception or modulation of cortical functions. Probably, the induced eddy current in the brain disturbs the information processing from external signals in the primary visual cortex. Then, if repetitive transcranial magnetic stimulation (rTMS) technique is applied to induce the transient disruption in V1, what would the effect be? In order to verify whether the rTMS is potential to modulate cortical functions, we studied the effect of the visual evoked potentials over the occipital lobe immediately after the rTMS.

2 Methods

We studied 7 healthy subjects who gave written informed consent. They were seated in a comfortable chair in front of a TV set screen displaying reversal checkerboard. Pattern reversal checkerboard, whose check size was 1° in terms of the visual angle for a subject, was applied at the frequency of 5 Hz in a dark room. To start with, the active threshold in the first dorsal interosseus muscle (FDI) was evaluated by transcranial magnetic stimulation (TMS). Then, a figure-of-eight coil was moved from the motor cortex onto the point of 5 cm above the inion. The intensity of the stimulus applied was 10% above the active threshold for the stimulation over the occipital lobe. The eddy current was in the posterior-to-anterior direction. Magnetic shocks were delivered at 1 Hz for 150 sec. Visual evoked potentials (VEPs) were recorded before and every 2 minutes immediately after the repetitive TMS (rTMS). Recordings were taken from LO, Oz, RO, 3 cm above (Oz+) and below (Oz-) the site of Oz, with the reference to a mid-frontal indifferent electrode. Impedances were kept below 5 kΩ. The signals were amplified with 10 μV/V and filtered between 0.2 and 250 Hz. The amplitude of VEP mean average, 75 trials in all, was evaluated for the effect of the magnetic stimulation. The evaluation of changes in VEP focused on two components: N75-P100 and P100-N145. For comparison, repetitive sham magnetic stimuli in the perpendicular direction were also applied .

3 Results

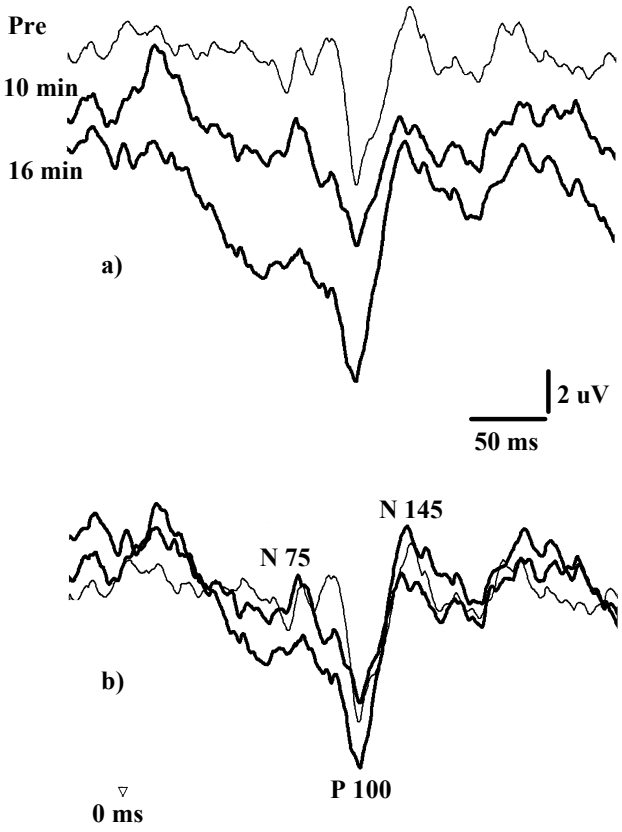

Figure 1: *a) VEPs at different time intervals after at Oz in one subject. At 10 min after rTMS, N75-P100 and P100-N145 components were greatly inhibited. In contrast, at 20 min, N75-P100 component was still inhibited even with the excitation of following P100-N145. b) Some of the VEPs were superimposed. Note that the peak latencies for each component remained unchanged.*

The stimulus intensity applied in this study was 42.0±2.6% (M±SE). During rTMS, none of subjects noticed any abnormal sign or symptom, except for the feeling of a rugged checkerboard on the screen toward the end of rTMS in one subject.This symptom disappeared completely and immediately after finishing the repetitive magnetic shocks.

Both N75-P100 and P100-N145 components were decreased as 80% as the control size. Although they were gradually recovered to the control size, the changes in the amplitude were remarkably different between the pre- and the post-inhibition periods (Fig. 2).

Briefly, the N75-P100 component presented a small amount of inhibition at first and showed another inhibition ($p<0.05$) around 20 min after rTMS. In contrast, the P100-N145 component behaved excitation at first ($p<0.0$ 5) and showed the second excitation after the inhibition period (Fig. 3). There was a significant difference between the two components in the time intervals such as from 0 to 8 min and 20 to 30 min (Fig. 4). Comparing with the data above, VEPs after the repetitive sham stimuli remained virtually unchanged throughout the study.

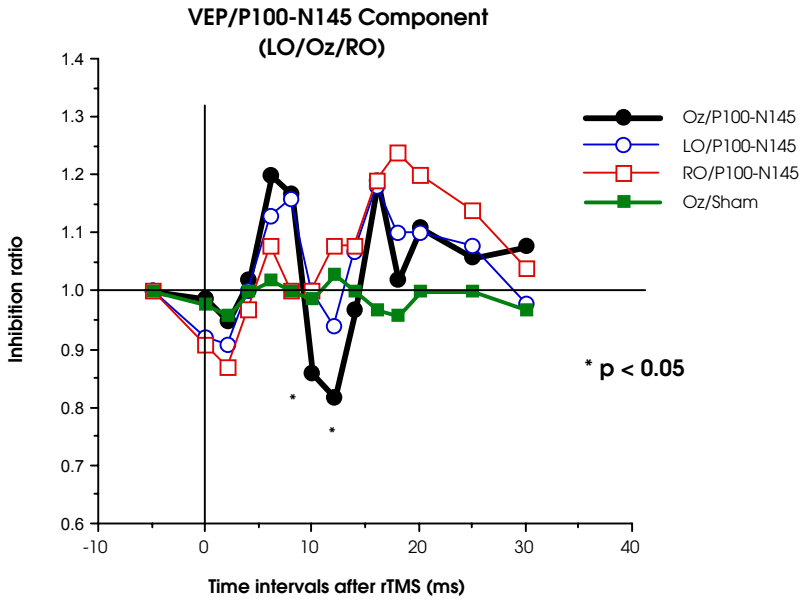

Figure 2: *This graph shows the inhibition curves for each component at different recording sites in the horizontal line like LO, Oz and RO. The inhibition or excitation at any recording site is significant compared with that by sham stimulation. Note that the inhibitory ratio around 10 min after rTMS is greater at Oz than the other sites. In particular, the P100-N145 component at Oz shows virtual excitation throughout the time course except for the significant suppression around 10 min in comparison to the others ($p<0.05$).*

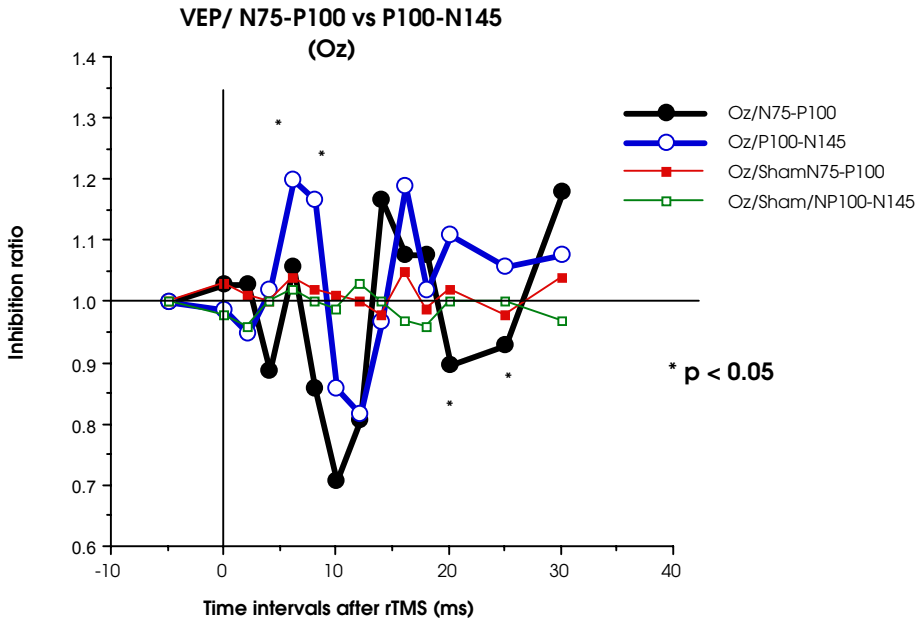

Figure 3: *This graph shows the superimposition of N75- P100 and P100-N145 components at Oz. The rTMS can induce different behaviors on the two components of VEP. Note that there are statistical differences ($p < 0.05$) at 6 to 8 min and 20 to 25 min after rTMs between the two components. These results suggest that rTMS probably affects various cortical networks for visual processing in a different degree.*

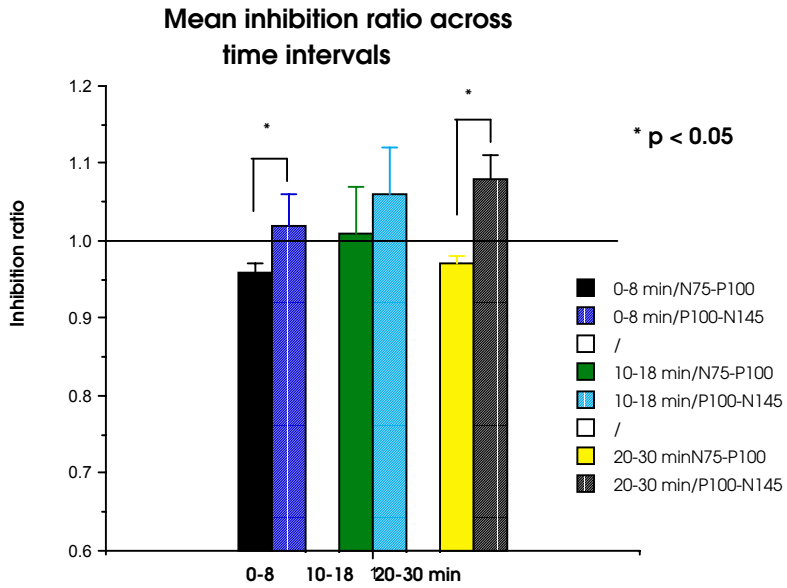

Figure 4: *The time course is divided into three blocks across 0-8, 10-18 and 20-30 min. Then, mean inhibition ratio was evaluated for comparison. It held below 1.0 in the 0-8 min and 20-30 min blocks for the N75-P100 component. Note that there are statistical differences between the two components in the two blocks*

4 Discussion

Transcranial magnetic stimulation at lower intensities favors the excitation of the inter-neurons rather than the pyramidal cells in the cortex [1,2]. Application of the TMS on the occipital lobe showed us to block the visual perception completely at 80 to 100 ms after strong TMS [3]. Kosslyn et al [4] introduced another method, in which rTMS enables us to evaluate the modulation of the visual perception with rather lower intensities. We demonstrated that short time rTMS with lower stimulus intensity produces prolonged cortical modulation such as inhibitory and excitatory functions in terms of the VEP amplitudes. As far as the changes of VEP are concerned, VEPs were affected especially at the mid-occipital recording rather than the others. VEPs at the mid-occipital recording were greatly inhibited in amplitude around 10 min after rTMS and lasted several minutes (Fig. 1). Given that the initial arrival of the visual information is disrupted or modulated like facilitation, the ongoing visual processing onto visual cognition would be under the amount of the modulation at the primary visual cortex (V1). The discrepancy between the onset and the offset of inhibition or excitation in the two components probably suggests that the interneurons in V1 play different roles in conveying the information of the initial arrival to proper cortical areas like inhibitory or excitatory behaviors. As far as the visual cortical modulation is concerned, rTMS is potential to evaluate the higher brain function such as visual perception or cognition, even with lower stimulus intensities.

5 Conclusions

Low frequency repetitive magnetic stimulation is capable of inducing transient focal cortical dysfunction. The technique is probably of great benefit to verifying the occipital lobal higher function.

Acknowledgements

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References

1. T. Kujirai et al., “Cortico-cortical inhibition in human motor cortex”, *J. Physiol*., **471**, 501-519, 1993.
2. U. Ziemann et al., “Interaction between intracortical inhibition and facilitation in human motor cortex”, *J. Physiol*., **496**, 873-881, 1996.
3. V.E. Amassian et al., “Suppression of visual perception by magnetic coil stimulation of human occipital cortex”, *Electroencephalogr. Clin. Neurophysiol.*, **74**, 458-462, 1989.
4. Kosslyn et al., “The role of area 17 in visual imagery convergent evidence from PET and rTMS”, *Science*, **284**, 167-170, 1999.