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# Relationship between pulse number of rTMS and inter reversal time of perceptual reversal

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*Abstract*— **The aim of this study is to investigate the stimulus parameter which affects the repetitive Transcranial Magnetic Stimulation (rTMS) effect. It is said that the condition under 1Hz rTMS induces the inhibition effect. On the other hand, the condition over 1Hz rTMS induces the facilitation effect. However the number of pulses of rTMS is also important factor. In this study, we focused on the number of pulses. We used the cognitive task of perceptual reversal and compared the rTMS effects of different condition under 1Hz which is the inhibition condition. It has been known that the right superior parietal lobule (SPL) has a role in perceptual reversal. We applied rTMS over the SPL and measured the inter-reversal time (IRT) of perceptual reversal. The results showed that when 0.25Hz 60pulses, 0.5Hz 60pulses and 1Hz 60pulses of rTMS was applied over the right SPL, the IRT was significantly smaller. On the other hand, when 1Hz 240pulses of rTMS was applied over the right SPL, the IRT was significantly longer. When 0.25Hz 120pulses, 0.5Hz 120pulses and 1Hz 120pulses of rTMS was applied over the right SPL, there were no significant differences. Furthermore, to investigate the rTMS effects, when rTMS are applied over the motor area, we measured the motor evoked potential (MEP). The more pulses of rTMS was applied, the smaller the amplitude of MEP became. From these results, it was found that the IRT of perceptual reversal and the amplitude of MEP primarily affected by the number of pulses of rTMS.**

## I. Introduction

Transcranial Magnetic Stimulation (TMS) is a method which stimulates cerebral nerve noninvasively by induced current. Repetitive TMS (rTMS) provides magnetic stimulation of cerebral cortex repeatedly. rTMS is possible to inhibit or facilitate neuronal activity in the brain [1]. Therefore, rTMS are not only used in the study of brain function but also in the field of clinical treatment such as depression, Parkinson's disease, stroke [2]-[4].

However, there is a problem that rTMS of variety stimulus conditions are used in the clinical treatment and the condition is not decided objectively. To date, it is found that the condition under 1Hz rTMS induces the inhibition effects. On the other hand, the condition over 1Hz rTMS induces the facilitation effects [1]. The rTMS effects on excitability of facilitative or inhibitive can be evaluated by the amplitude of MEP. Because the amplitude of MEP allows the evaluation of the functional state of the corticospinal pathway and provides valuable information about the functioning of motor pathways. However rTMS effects are also affected by the number of pulses rTMS [5].

In this study, we focused on the number of pulses. We used the cognitive task of perceptual reversal of ambiguous figures and compared the rTMS effects of different condition under 1Hz which is inhibition condition.

Ambiguous figures are visual stimuli that can be interpreted in multiple ways by the human visual system. Perceptual reversal refers to the spontaneous switches in perception between several possible interpretations for a given ambiguous figure. Past research with ambiguous figures indicated that the parietal area, especially, the SPL is involved in perceptual reversal [6]. In our previous study, we have reported that rTMS applied over the right SPL influences the IRT of perceptual reversal [7] and have suggested that the IRT of perceptual reversal might be affected by the number of pulses [8]. In this study, we focus on the pulse number of rTMS especially and investigate more closely detail the effects on the IRT of perceptual reversal. Furthermore, to investigate the rTMS effects, when rTMS are applied over the motor area, we measured the MEP.

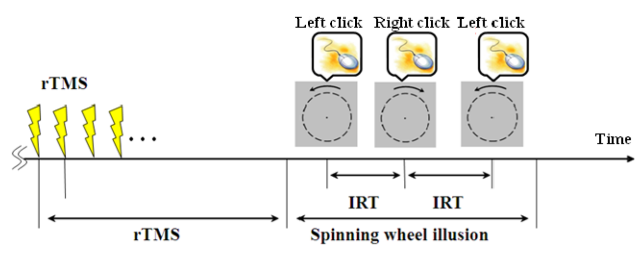


Fig.1 Time sequence of this experiment. After rTMS was applied Spinning wheel illusion was presented for 180seconds. Subjects were required to respond by clicking a mouse button to indicate the perceptual reversal in the direction of rotation. The time interval between two successive perceptual reversals was automatically recorded as the IRT.

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## II. METHODS

The time sequence of this experiment is shown in Fig.1. The experiment was started with rTMS stimulation. The TMS stimulator was a MagStim Super Rapid Stimulator (Magstim comp., Whitland, UK). A figure-of-eight 70mm coil was used. First, to investigate the effects of pulse number of rTMS, 1Hz 60pulses, 1Hz 120pulses, and 1Hz 240pulses biphasic rTMS were used in the present study. Also, to investigate the effects of stimulus frequency, 0.25Hz 60pulses, 0.5Hz 60pulses, 0.25Hz 120pulses, 0.5Hz 120pulses of rTMS were used. Stimulus strength was set at 90% of the subject's individual resting motor threshold (RMT). To estimate the RMT, we applied TMS over the motor area in the right hemisphere and record the MEP. RMT was defined as the minimal stimulus intensity that evoked a small MEP over 50μV in half of trails [9]. Based on previous findings that response time is more affected by rTMS on the right SPL than the left SPL [10], we decided to apply the stimuli over the right hemisphere. The coil was placed tangential to the surface of the skull, and the center of the coil was positioned over electrode site P4 of the international 10-20 system. The induced current in the brain was parallel to the Oz-Pz midline, and flowed from posterior to anterior regions. To compare the rTMS effect over the right SPL with that over other cortex, rTMS trains were also applied over the right posterior temporal lobe (PTL) of the subject. For this, the coil was positioned over electrode site T6 of the international 10-20 system. Thus, the induced current in the brain flowed from posterior to lateral regions. Also, these stimulus points were confirmed by the system of MRI and infrared camera (Brain Sight, Rogue Research Inc., Canada). Furthermore, to incorporate a No-TMS control condition, the same procedures were followed while no rTMS trains were applied over the subject's skull.

After rTMS was applied, the ambiguous figure was presented for 180 seconds. Spinning wheel illusion was used as the ambiguous figure in this study. All the stimuli were controlled by PC and presented on a CRT monitor with background set to gray (71.2cd/m2). All experiments were conducted in a darkroom. The subject's head was steadied by a chinrest. The stimuli were presented on a 5.8×5.8cm square (4.74°× 4.74°) at the center of the PC monitor at a distance of 700mm from the subject. Continuous repetition of this sequence yields the perception of a spinning wheel moving either clockwise or counterclockwise, with switches between these two perceptions occurring spontaneously. Subjects were required to respond as quickly and accurately as possible by clicking a mouse button to indicate the perceptual reversal in the direction of rotation. The time interval between two successive perceptual reversals was automatically recorded as the IRT.

The application sequences of SPL stimulation, PTL stimulation and No TMS were randomized across subjects. 11 subjects (aged 21-44 years) participated in all the tests of the present study. All were right handed, and had normal or corrected-to-normal visual acuity. All the subjects participated in practice trials before the experiment in order to familiarize themselves with the perceptual reversal of the spinning wheel illusion and to learn to make efficient responses. Before starting this experiment, all subjects were introduced to the aim of this study, the procedures, hazards of TMS and the management of the data. All subjects consented to participate in this experiment.

In the same day, IRTs were measured after rTMS of one condition was applied over SPL, PTL and No TMS. There are 10 minute break after measured IRT. Experiment of another rTMS condition was done one week after that experiment.

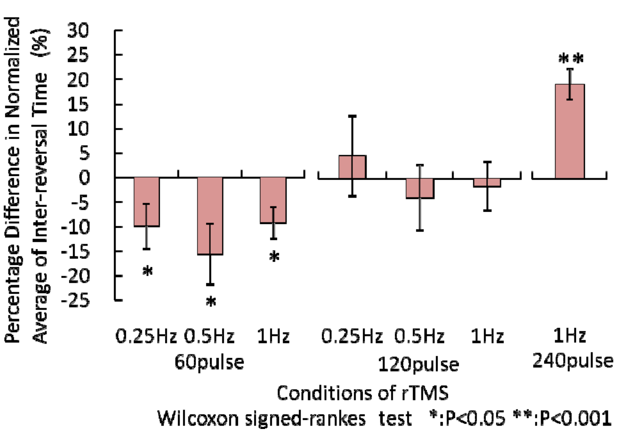


Fig.2 Percentage difference in normalized average of inter-reversal time of the right SPL. Baseline: No TMS experiment. Percentage difference was significantly smaller with 0.25Hz 60pulses, 0.5Hz 60pulses and 1Hz 60pulses. In contrast, it was significantly longer with 1Hz 240pulses.

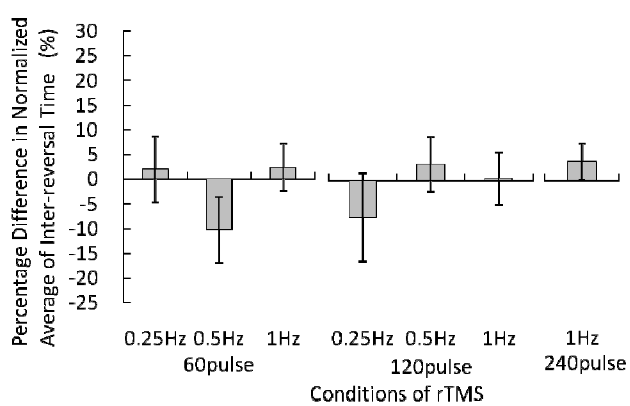


Fig.3 Percentage difference in normalized average of inter-reversal time of the right PTL. Baseline: No TMS experiment. There were no significant differences.

Table.1 Summarize of experimental results of AIRT, S.E. and P-value, when rTMS applied over SPL and PTL. The AIRT of SPL condition was significantly smaller with 0.25Hz 60pulses, 0.5Hz 60pulses and 1Hz 60pulses. In contrast, the AIRT of SPL condition was significantly longer with 1Hz 240pulses. On the other hand, there were no significant differences between IRTs of rTMS with 0.25Hz 120pulses. 0.5Hz 120pulses and 1Hz 120pulses over the right SPL. As for the right PTL, there is no significant difference in this experimental condition.

| rTMS Condition | SPL | | | PTL | | |
|---|---|---|---|---|---|---|
| | AIRT [%] | S.E. (n=11) | P-value | AIRT [%] | S.E. (n=11) | P-value |
| 0.25Hz 60pulses | -9.95 | -4.53 | 0.0310* | 2.02 | 6.69 | 0.8600 |
| 0.5Hz 60pulses | -15.58 | 6.14 | 0.0296* | -10.20 | 6.68 | 0.9220 |
| 1Hz 60pulses | -9.31 | -3.18 | 0.0170* | 2.44 | 4.82 | 0.6300 |
| 0.25Hz 120pulses | 4.69 | 8.23 | 0.7000 | -7.52 | 9.04 | 0.2780 |
| 0.5Hz 120pulses | -3.85 | -6.77 | 0.7200 | 3.32 | 5.60 | 0.1400 |
| 1Hz 120pulses | -1.49 | -5.02 | 0.7700 | 0.42 | 5.39 | 0.9400 |
| 1Hz 240pulses | 19.56 | 3.25 | 0.0001** | 3.91 | 3.74 | 0.3200 |

Wilcoxon signed-ranks test, *: P<0.05 ** : P<0.001

## III. RESULTS

We considered that the IRT would exhibit a gamma distribution in the present study, since previous studies have indicated that the intervals of perceptual alternation follow a gamma distribution in ambiguous figure perception [11]. In each experiment, averaged IRTs were calculated as AIRT. In order to remove the influence of individual differences, the ratio of the AIRT of each stimulus condition to the AIRT of the No-TMS condition was calculated as the normalized AIRT. The mean percentage difference in normalized AIRT of SPL is shown in Fig.2. The mean percentage difference in normalized AIRT of PTL is shown in Fig.3. Using Wilcoxon signed-ranks test, it was found that, compared to the No-TMS condition, the AIRT of SPL condition was significantly smaller with 0.25Hz 60pulses, 0.5Hz 60pulses and 1Hz 60pulses (SPL stimuli < No-TMS, $P<0.05$). In contrast, it was found that, compared to the No-TMS condition, the AIRT of SPL condition was significantly longer with 1Hz 240pulses (SPL stimuli>No-TMS, $P<0.001$). On the other hand, there were no significant differences between IRTs of rTMS with 0.25Hz 120pulses. 0.5Hz 120pulses and 1Hz 120pulses over the right SPL. As for the right PTL, there is no significant difference in our experimental condition. These experimental results of AIRT, standard error (S.E.) and P-value is summarized as Table.1.

## IV. MOTOR EVOKED POTENTIAL

To investigate the rTMS effects of number of pulses, we measured the MEP, when the rTMS was applied over the right motor area. rTMS conditions with 1Hz 60pulses, 1Hz 120pulses and 1Hz 240pulses of RMT 90% were used.

TMS of RMT 110% was applied over the right motor area and MEP was measured from the left first dorsal interosseous muscle (FDI). MEP was measured through Ag/AgCl electrodes by NeuropackX1 (Nihon kohden, Japan). The MEP were filtered 5Hz to 3 kHz and sampled at 1024Hz. MEP of 10 stimuli were averaged. MEP was measured before and after the rTMS. Subject was 26 years old men who participated in the experiment of perceptual reversal. Previous study showed that the amplitude of MEP also affected by the rTMS condition of number of pulses [1], [12]. We just confirmed the rTMS effects on the same condition applied over the right SPL. Therefore the motor evoked potential was recorded only for 1 subject. The result of MEP is shown in Fig.4. It was found that the more pulses of rTMS was applied, the smaller the amplitude of MEP became. Furthermore, we confirmed the effects on the condition with 0.25Hz 60pulses, 0.25Hz 120pulses, 0.5Hz 60pulses and 0.5Hz 120pulses. We calculated the normalized peak to peak amplitude of MEP and it is shown in Fig.5. It was found that MEP of after 120pulses rTMS is more decreased than that of

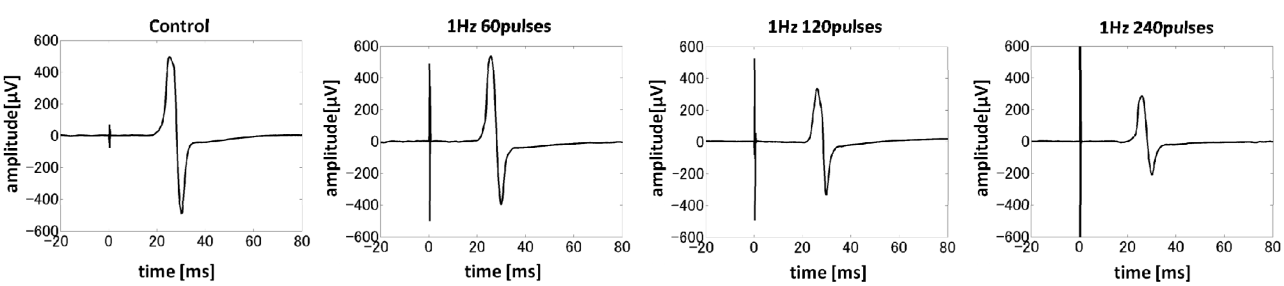


Fig.4 Measurement of MEP before and after the rTMS. rTMS condition with 1Hz 60pulses, 1Hz 120pulses and 1Hz 240pulses were used. It was found that the more pulses of rTMS was applied, the smaller the amplitude of MEP became.

after 60pulses rTMS.

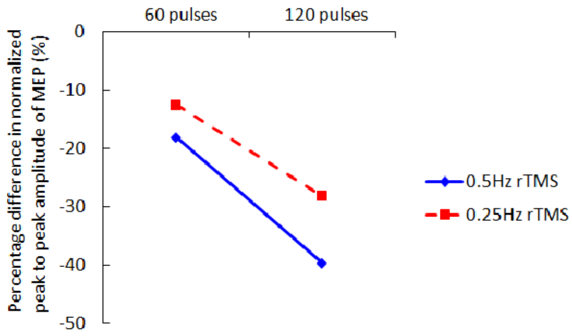


Fig.5 Percentage difference in normalized peak to peak amplitude of MEP. rTMS condition with 0.25Hz 60pulses, 0.25Hz 120pulses 0.5Hz 60pulses and 0.5Hz 120pulses were used. It was found that MEP of after 120pulses rTMS is more decreased than that of after 60pulses rTMS.

## V. Conclusion And Discussion

As to the IRT of perceptual reversal, when rTMS was applied not over the right PTL but SPL, the IRT of perceptual reversal are affected. Furthermore, these effects are primary affected by number of pulses and the stimulus frequency didn't not affect. These results support the hypotheses that the right SPL is related to the processing of switching the perception [6] [11].

As to the amplitude of MEP, it was found that the more pulses of rTMS was applied, the smaller the amplitude of MEP became. It was found that the amplitude of MEP was inhibited by the rTMS and these results agree with the previous study that effects depend on the number of pulse [1] [12]. The stimulus frequency also did not affect.

Only based on this phenomenon of inhibition of MEP, it cannot be explained why our experiment showed these results that the 60 pulses rTMS caused shorter IRT, 240 pulses rTMS caused longer IRT and 120 pulses did not affect IRT no effect. Therefore we suggest that there is not only the processing of switching the perception but also the processing of suppression of switching perception. Matsuoka suggested the phenomenon of binocular rivalry is related to the processing of neuronal threshold and the neuron suppresses each other [13]. We considered that the IRT of perceptual reversal is decided by the balancing of these processing. Furthermore, rTMS can inhibit these processing in the same way of the phenomenon in the amplitude MEP. The schematic of this hypothesis is shown in Fig.6. The switching perception were inhibited gradually depending on the number of pulses and the processing of suppression of switching were inhibited the same amount in this experimental condition. Therefore the 60 pulses rTMS caused shorter IRT, 240 pulses rTMS caused longer IRT and 120 pulses did not affect IRT no effect.

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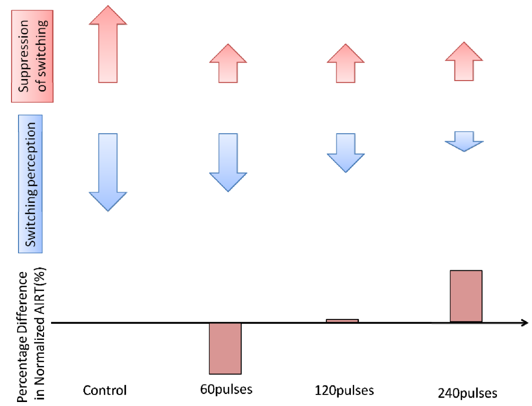


Fig.6 The schematic of hypothesis. The IRT of perceptual reversal is decided by the balancing the processing of switching the perception and the processing of suppression of switching perception.

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