Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

TMS Effect on Visual Search Task

Sheng Ge[1], Akira Matsuoka[1], Shoogo Ueno[2] and Keiji Iramina[1]

[1]Graduate School of Information Science and Electrical Engineering, Kyushu University, Japan

[2]Faculty of Engineering, Engineering, Kyushu University, Japan

Abstract: **In this study, we examined the temporal aspects of the right posterior parietal cortex in easy feature and hard feature "pop-out" visual searches using transcranial magnetic stimulation (TMS). The transcranial magnetic stimulations were applied over the right posterior parietal cortex of subjects. Subjects received 4 tests which the TMS onset times were set as 100, 150, 200 and 250msec after visual stimulus presentation. We found that, when SOA=150msec, compared to no-TMS condition, There was a significant elevation in response time when the TMS pluses were applied. However for the other SOA cases, there was no significant difference between TMS and no-TMS conditions. Therefore, we considered that "pop-out" visual search was processed in the right posterior parietal cortex at about 150msec after stimulus present.**

Ⅰ. INTRODUCTION

TMS (Transcranial Magnetic Stimulation), as a non-invasive and effective method to making reversible lesions in the human brain, can investigate not only the spatial but also the temporal characteristic of brain activation. TMS can be used to stimulate the cortex to produce visual percepts [1] or movements [2], but more readily provides reversible disrupting of activity in the cortex.

Visual search, as a traditionally visual neglect sensitive measure, was studied by many researches. Selective spatial attention [3], memory for the target [4], object-based attention and identification of the target are all required in visual search. Much is already known about the involvement of the large areas of the visual field [5][6], the right parietal cortex [7], right superior temporal gyrus [8] and the right posterior parietal cortex [8][9].

In contrast with the knowledge of the location of particular cortex areas involved in the visual search, little is known about the time course of the involvement of cortex areas. In monkey studies, neuronal responses recorded from areas V4 and IT show that selection of target stimuli can be initiated between 150 and 300 msec [10]~[12]. Ashbridge et al. [13] applied TMS over the right parietal visual cortex of subjects while they were performing "pop-out" or conjunction visual search tasks. Ashbridge et al. found that, TMS had no detrimental effect on the performance of "pop-out" search, but did significantly increase response time on conjunction search when stimulation was applied over the right parietal cortex 100msec after the onset of the visual stimuli for trials when the target was present. However, in the above-mentioned past researches, the temporal aspect of the right posterior parietal cortex (hereinafter abbreviated as PPC) in visual search was not discussed. In Ellison et al.'s rTMS study [8], they found that, TMS over the right PPC caused a significant increase in response time in the easy feature search and hard feature search. However, in their study, since the rTMS was applied before the visual search stimuli present, the involvement of the PPC in the visual search was confirmed but the time course was not addressed.

In this study, to investigate the temporal aspect of the PPC involved in the "pop-out" visual search, we used different TMS stimulus onset asynchronies (SOA) and measured the visual search response times. The relationship between the SOA and the response time was investigated.

Ⅱ. MATERIALS AND METHODS

TMS Equipment:

The stimulator was a MagStim Super Rapid Stimulator (Magstim comp., Whitland, UK). Stimulus strength was set as the subjects' individual minimal threshold for the motor evoked potential (MEP) which under 55% of the maximum output. A figure-of-eight 70mm coil was used. The coil was placed tangential to the surface of the skull. The centre of the coil was positioned over electrode site P4 of the international 10-20 system [14].

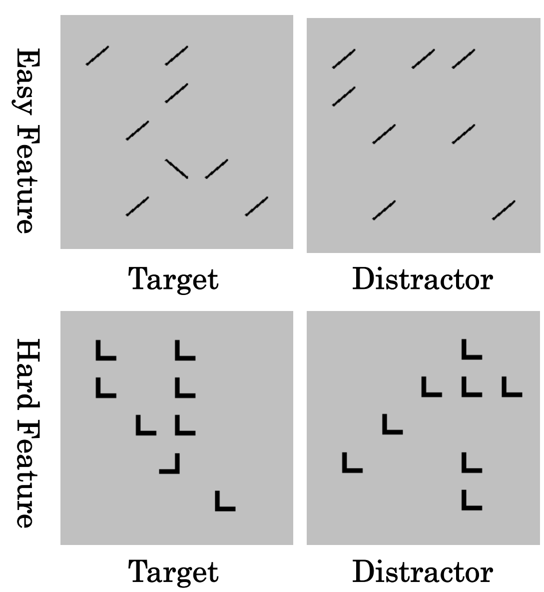

Fig.1. The examples of visual search stimuli.

Visual Search Task:

Two kinds of "pop-out" visual search tasks, easy feature search task and hard feature search task, were used in this study. In the easy feature search task, the target was a black backslash, and the distractor was black slash (Upper of Fig.1). In the hard feature search task, the target was a black rotated ‘L’ shape, and the distractor was black ‘L’ shape (Bottom of Fig.1). The background was always gray.

All the experiments were executed in a darkroom. The subject’s head and sagittal midline was aligned with the centre of the monitor, and their head position was controlled by a chinrest. A visual search stimulus was consisted of 8 items, which were presented on a 5.7×5.7mm square range (4.7°× 4.7°) on the center of PC monitor at a distance of 70 cm from the subject. The square range was divided into a 5 column×5 row array of 25 virtual boxes. On any trial, each target or distractor could appear randomly in any one of 8 of these boxes. The target was present on 50% of trials and the target was unique among distractors.

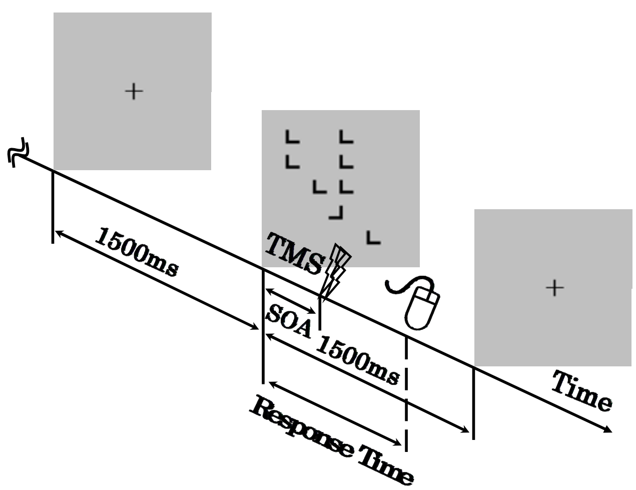

Fig.2. The time sequence of experiment.

The time sequence of experiment is shown in Fig.2. Each trial was preceded by a central fixation cross (0.9°×0.9°) for 1500msec, followed immediately by the visual search stimuli, which would be presented for 1500msec. Subjects were asked to respond as quickly and as accurately as possible on a mouse button to indicate the presence or absence of the target (left button for target present and right button for target absent). The time from the visual search stimuli presentation till the button click was recorded as the response time. Transcranial magnetic stimulations were applied over the right PPC of subject at different time intervals after the visual search stimuli presentation. These time intervals were called as TMS stimulus onset asynchronies (SOA).

To investigate the TMS effect during the visual search task, TMS and no-TMS conditions were applied. In the TMS condition, 2 pulses (20msec interval) were applied over the right PPC. In the no-TMS condition, an open circuit coil was put over the subject’s right PPC just like the TMS condition, while the TMS coil discharged 2 pulses (20msec interval) near to, but directed away from, the subject’s skull.

For easy feature search task and hard feature search task, each subject received 60 trials for 2 times for TMS and no-TMS conditions respectively as one test. Subjects received 4 tests which the TMS stimulus onset asynchronies (SOA) were set as 100, 150, 200 and 250msec after visual search stimuli presentation.

Subjects:

5 subjects (one female, four males, aged 21-31 years) took part in both easy feature search task and hard feature search task, who were experienced psychophysical observers but ignored the purpose of the experiment. All were right handed, had normal or corrected-to-normal visual acuity. All of them had previous practice before the experiment in order to native to visual search and to make stable response. All subjects reported a complete absence of epilepsy, or any other neurological condition in themselves and their known family history.

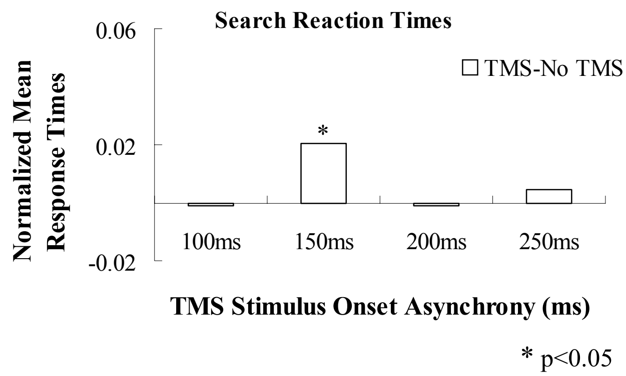

Fig.3. The target-present response time for each SOA (normalized) of easy feature visual search task.

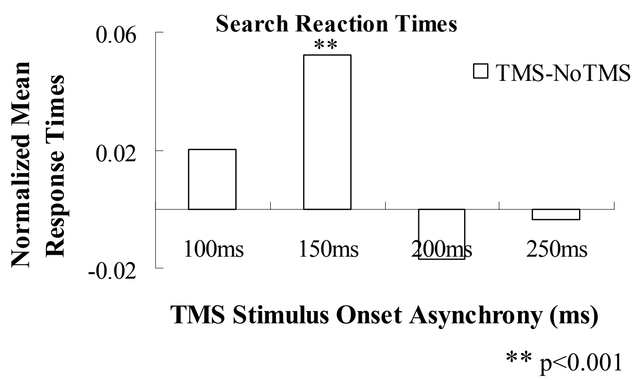

Fig.4. The target-present response time for each SOA (normalized) of hard feature visual search task.

III. RESULTS AND DISSCUSSION

The average of target-present response times of each subject in the TMS condition was normalized to the no-TMS condition (set as the baseline=1). The subtraction between the average of normalized response times of all the subjects and the baseline was taken to demonstrate the TMS effect.

For the easy feature search task, the subtraction between the average of normalized response times of all the subjects and the baseline is shown in Fig.3. In order to investigate the influence of TMS effect, one-way analysis of variance (ANOVA) was used to analyze the difference between TMS and no-TMS conditions. We found that, when SOA=150msec, compared to no-TMS condition, there was a significant elevation ($p<0.05$) in response times when the TMS pluses were applied. However for the other SOA cases, there was no significant difference between no-TMS and TMS conditions. On the other hand, for the hard feature search task, the subtraction between the average of normalized response times of all the subjects and the baseline is shown in Fig.4. Based on the ANOVA results, we found that, when SOA=150msec, compared to no-TMS condition, there was a significant elevation ($p<0.001$) in response times when the TMS pluses were applied. However for the other SOA cases, there was no significant difference between no-TMS and TMS conditions.

In the past researches, there is an evidence that the right PPC has a dominant role in distributing spatial attention [15][16] and spatial awareness [17], decision making [18][19] and visual working memory [20][21].

Corbetta et al.'s PET study reported activation of the PPC during feature conjunction search, but not during easy visual searches for single features [22]. Ashbridge et al.'s TMS study reported that TMS had detrimental effect on the performance of conjunction search but not on the feature search [13]. Whereas, both neuroimaging in humans [23] and single-unit recordings in monkeys [24] have revealed that the PPC subregions controlling spatial selection are also implicated in the selection of nonspatial features, suggesting that the involvement of the PPC in the visual search may not be binding-specific but rather reflect more general attentional mechanisms. Furthermore Leonards et al. [25] and Donner et al. [26] also reported the PPC activations during the feature search task.

In the present study, compared to the no-TMS condition, a significant elevation in response time was measured. Based on the past researches and present study, it seems reasonable to support that the right PPC plays a dominant role not only in the conjunction search but also in the easy and hard feature "pop-out" visual searches.

Furthermore, since a significant elevation in response time was only measured when SOA=150msec, we considered that "pop-out" visual search was processed in the right posterior parietal cortex at about 150ms after stimulus presentation.

This TMS study opens up several new possibilites for understanding not only the role of the PPC in visual search but also the temporal aspect of the PPC involved in the "pop-out" visual search. The contribution to theories about the visual search dynamics is expected.

REFERENCE

[1] Amassian VE, Maccabee PJ, Cracco RQ, Cracco JB, Rudell AP and Eberle L: Measurement of information processing delays in human visual cortex with repetitive magnetic coil stimulation. Brain Research, 605, pp.317-321, 1993.

[2] Day MC: Visual search by children: the effect of background variation and the use of visual cues. Journal of experimental Child Psychology, 25, pp.1-16, 1978.

[3] Posner MI: Orienting of attention. Quarterly Journal of Experimental Psychology, 32, pp.3-25, 1980.

[4] Chelazzi L, Miller EK, Duncan J and Desimone R: A neural basis for visual search in inferior temporal cortex. Nature, 363, pp.345-347, 1993.

[5] Moran J and Desimone R: Selective attention gates visual processing in the extrastriate cortex. Science, 229, pp.782-784, 1985.

[6] Motter BC: Neural correlates of feature selective memory and pop-out in extrastriate area V4. Journal of Neuroscience, 14, pp.2190-2199, 1994.

[7] Walsh V, Ashbridge E and Cowey A: Cortical plasticity in perceptual learning demonstrated by transcranial magnetic stimulation. Neuropsychologia, 36, 1, pp.45-49, 1998.

[8] Ellison A, Schindler I, Pattison LL and Milner AD: An exploration of the role of the superior temporal gyrus in visual search and spatial perception using TMS. Brain, 127, pp.2307-2315, 2004.

[9] Nobre AC, Coull JT, Walsh V and Frith CD: Brain activations during visual search: contributions of search efficiency versus feature binding. Neuroimage, 18, pp.91-103, 2003.

[10] Corbetta M, Miezin FM, Dobmeyer S, Shulman GL and Petersen SE: Selective and divided attention during visual discriminations of shape, color and speed: Functional anatomy by positron emission tomography. Journal of Neuroscience, 11, pp.2383-2402, 1991.

[11] Motter BC: Neural correlates of attentive selection for color or luminance in extrastriate area V4. Journal of Neuroscience, 14, pp.2178-2189, 1994.

[12] Motter BC: Neural correlates of feature selective memory and pop-out in extrastriate area V4. Journal of Neuroscience, 14, pp.2190-2199, 1994.

[13] Ashbridge E, Walsh V and Cowey A: Temporal aspects of visual search studied by transcranial magnetic stimulation. Neuropsychologia. 35, pp.1221-1131, 1997.

[14] Homan RW, Herman J and Purdy J: Cerebral location of international 10-20 system electrode placement. Electroencephalography and Clinical Neurophysiology, 66, pp.376-382, 1987.

[15] Corbetta M, Miezin FM, Shulman GL and Petersen SE: A PET study of visuospatial attention. Journal of Neuroscience, 13, pp.1202-1226, 1993.

[16] Nobre AC, Sebestyen GN, Gitelman DR, Mesulam MM, Frackowiak RSJ and Frith CD: Functional localization of the system for visuospatial attention using positron emission tomography. Brain, 120, pp.515-533, 1997.

[17] Marshall JC, Fink GR, Halligan PW and Vallar G: Spatial awareness: a function of the posterior parietal lobe?. Cortex, 38, pp.253-257, 2002.

[18] Glimcher PW: The neurobiology of visual-saccadic decision making. Annual Review of Neuroscience, 26, pp.133-179, 2003.

[19] Huettel SA, Song AW and McCarthy G: Decisions under Uncertainty: Probabilistic Context Influences Activation of Prefrontal and Parietal Cortices. The Journal of neuroscience, 25, pp.3304-3311, 2005.

[20] Andersen RA and Buneo CA: Intentional maps in posterior parietal cortex. Annual Review of Neuroscience, 25, 189-220, 2002.

[21] Jonides J, Smith EE, Koeppe RA, Awh E, Minoshima S and Mintun MA: Spatial working memory in humans as revealed by PET. Nature, 363, pp.623-625, 1993.

[22] Corbetta M, Shulman GL, Miezin FM and Petersen SE: Superior parietal cortex activation during spatial attention shifts and visual feature conjunction. Science, 270, pp.802-805, 1995.

[23] Wojciulik E and Kanwisher N: The generality of parietal involvement in visual attention. Neuron, 23, pp.747-764, 1999.

[24] Sereno AB and Maunsell JHR: Shape selectivity in primate lateral intraparietal cortex. Nature, 395, pp500-503, 1998.

[25] Leonards U, Sunaert S, Van Hecke P and Orban GA: Attention mechanisms in visual search--An fMRI study. Journal of Cognitive Neuroscience, 12, supplement 2, pp.61-75, 2000.

[26] Donner TH, Kettermann A, Diesch E, Ostendorf F, Villringer A and Brandt SA: Visual feature and conjunction searches of equal difficulty engage only partially overlapping frontoparietal networks. Neuroimage, 15, 1, pp.16-25, 2002.