320. Brain Area Responsible for Stimulus-driven Attention Revealed by fMRI during Singleton Search and Feature Search

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Summary

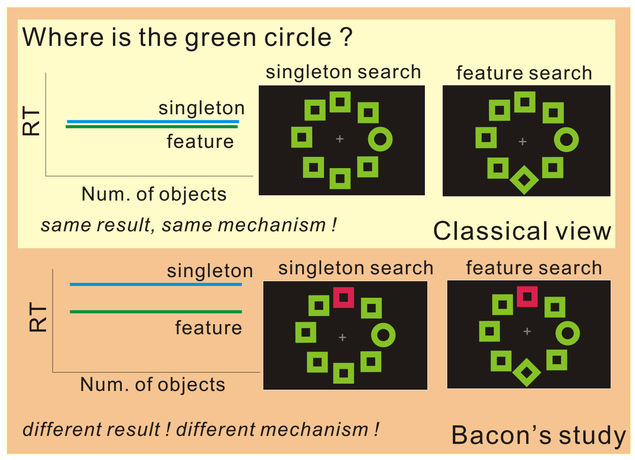
We measured brain activities responsible for stimulus-driven attention and top-down attentional setting for a shape using two types of visual search.

- Brain area responsible for stimulus-driven attention was the bilateral anterior intraparietal region.
- A top-down attentional setting for a target shape activated the left parahippocampal or medial temporal gyrus.

Background

Our goal in this study was to identify the brain region involved in the singleton search task(Search target was defined by shape singleton) and in the feature search (search target was defined by a specific shape) .

In the classical view (ref. 1), our two tasks were considered as the same task, because subjects showed same performance in these two tasks. That is, subjects could search a display with parallel/efficient way (popout); reaction time was independent of number of objects. Thus it was believed that attention was controlled by purely stimulus-driven way in these tasks (ref. 2).



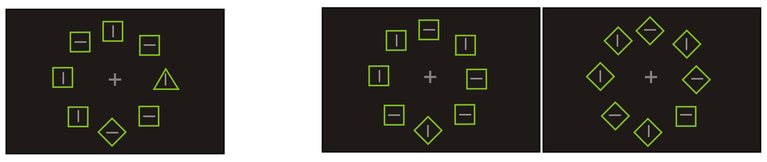
However, recently, Bacon and Egeth found that the classical view was not the case (ref. 3). They added a salient but task-irrelevant distractor to both tasks. As a result, reaction time in the singleton search condition was delayed by the distractor, but did not in the feature search task. This results clearly showed that some different mechanism were used in the each task.

In the singleton search condition, a search target was always shape singleton which makes saliency in the stimulus configuration. Thus, subjects could detect the target in the purely stimulus-driven way. Therefore when a more salient distractor was presented, it had to capture attention and caused delay of reaction time. On the contrary, in the feature search condition, because a target was not shape singleton, subjects could detect the target only by stimulus-driven way as in the singleton search condition, and were forced to use top-down attentional setting to a target shape. In the other word, saliency was almost ignored in the feature search condition.

In summary, purely stimulus-driven attention is used in the singleton search task, whereas the top-down attentional setting is used only in the feature search task. Thus, we used these two tasks to clarify the neuronal mechanism underlying stimulus-driven attention and top-down attentional setting. Each task would selectively activate brain regions closely related to the two types of attention, respectively.

General Method

In order to exclude 'absent trial', we added a secondary line orientation judgement task which was fully independent of target detection. Thus, the subjects' task was to detect a target item and to respond manually whether a line in the target item was vertical or horizontal. In the singleton search condition, to prevent subjects from using an top-down attentional setting for a target shape, we altered the target shape randomly across trials, that is, a diamond among squares or a square among diamonds.



Feature search condition

Singleton search condition

Subjects

Twelve right handed volunteers (4males) participated in the behavioral and fMRI experiments.

Experiment 1 (Behavioral part)

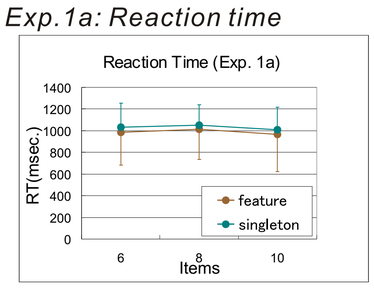
Exp. 1a: Parallel or serial ?

In Exp. 1a, to examine whether the search in each condition would be parallel or serial across the visual field, we varied the number of items in the search display(6,8,10). If the search were parallel, detection time should be independent of the

Exp. 1b: Saliency-based or intentional search ?

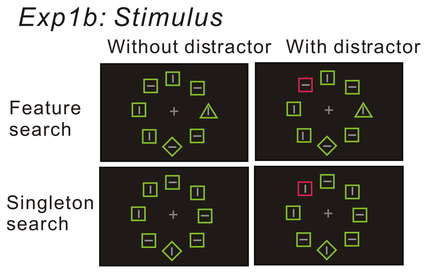
To confirm that the stimulus-driven search was induced by the singleton search task, and intentional search was induced by the feature search task, we presented a salient but task-irrelevant red distractor in half of the trials of each condition. In Exp. 1b and Exp. 2, we fixed number of the items to 8.

Exp.1a: Reaction time

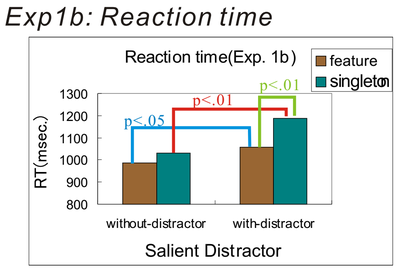


Neither significant main effect nor interaction was revealed.

Exp1b: Stimulus



Exp1b: Reaction time



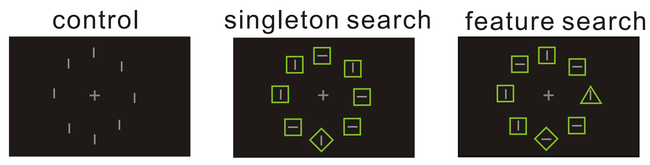
The RT for singleton search was significantly larger than RT for feature search only when the salient distractor was presented. Effect of the distractor item was also shown in both singleton and feature search conditions by the simple effect analysis.

Summary in this section

1. The parallel/efficient search was used in both the feature and singleton search tasks (Exp. 1a).
2. Stimulus-driven attention was used in the singleton search condition (Exp. 1b).
3. The top-down attentional setting for a target shape was used in the feature search condition (Exp. 1b).

Experiment 2 (fMRI part):Method

On the basis of the psychological experiments, we measured brain activity during the singleton search and feature search condition in Exp. 2. A line-orientation discrimination task was used as control task.



We used a block-diagram procedure. A session included 9 blocks (3blocks/condition),and a block included 18 scans (corresponding to 36 trials). Three scans interposed between each blocks (a fixation point and a cue were presented). All subjects performed 2 sessions. The order of conditions was counterbalanced among sessions and subjects.

MRI parameters and MRI analysis

Siemens 1.5T Vision, T2* sequence, TR = 4s, TE = 55.24ms, TD=20ms, FA = 90deg, 32 axial slices, 4 x 4 x 4 mm voxel

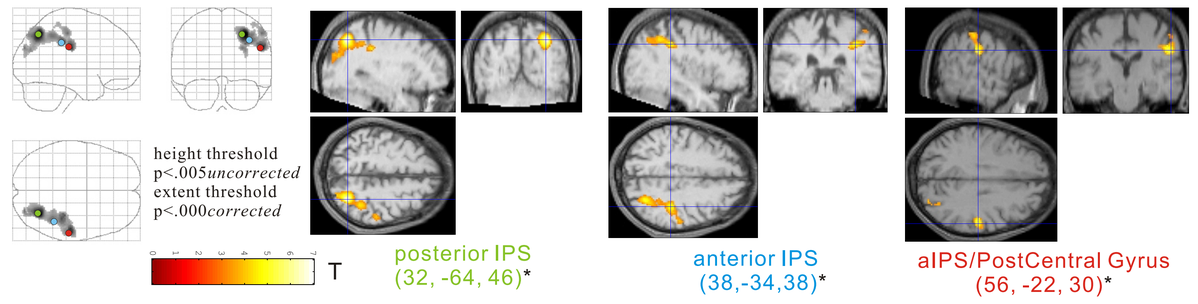
SPM99 was used to analyze fMRI. Prior to statistical calculation, images were realigned, normalized and spatially smoothed (8mm gaussian kernel). Initially, contrast images were obtained from each subject using F-C and S-C contrast.Subsequently group analysis was executed with the random effect model.

Experiment2: Result

Reaction time

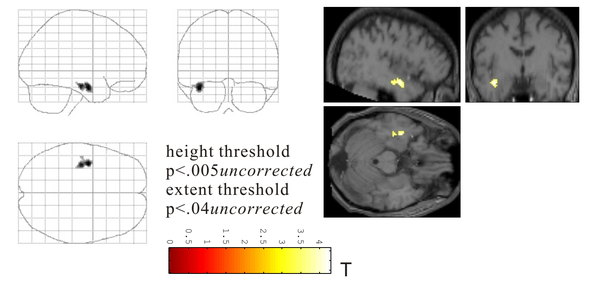
No significant difference was found between reaction time obtained in the singleton search condition (964.34ms) and that in the feature search condition (961.40ms)(t=0.14).

Contrast A: singleton search > feature search



* MNI (Montreal Neurological Institute) coordinates

Contrast B: feature search > singleton search



Contrast A

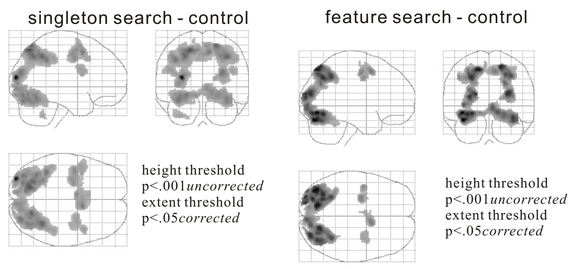
In the singleton - feature contrast (Contrast A), one significant cluster was found in the right intraparietal sulcus (IPS). This cluster contained several activation foci along the IPS. Representative tree foci were indicated above (pIPS, aIPS, and aIPS/pCG).

Contrast B

Only one significant focus was revealed in the feature - singleton contrast (Contrast B). This focus corresponds to left parahippocampal gyrus (paraHG) / medial temporal gyrus (mTG) (-40, -6,-24).

Contrast C: singleton search > control

Contrast D: feature search > control



Contrast C and D

Most of the activated regions were common to singleton - control (Contrast C) and feature - control (Control D) comparison. The difference between two contrasts was revealed in the bilateral anterior IPS which corresponds to the aIPS in the Contrast A, whereas the pIPS was revealed in both Contrast C and D.

singleton − control				feature − control		
region	cluster*	coordinates**		region	cluster*	coordinates**
L IPTO	p<.0001c	−30,−90, 14	left parietal	L IPTO	p<.0001c	−20,−90, 18
L precuneus		−18,−70, 54		L precuneus		−16,−72, 54
L pIPS		−26,−64, 44		L pIPS		−26,−64, 42
L aIPS		−40,−46, 10				
L lateral IPS		−28,−52, 42		L lateral IPS		−28,−52, 42
L fusiform	p<.0001c	−34,−78,−20	occipital	L fusiform		−38,−78,−20
R fusiform		36,−72,−18		R fusiform		36,−72,−18
R lingual		14,−82, −6		R lingual		12,−84, −8
L lingual		−10,−90,−12		L lingual		−14,−86,−10
R precuneus	p<.0001c	20,−68, 60	right parietal	R precuneus	p<.0001c	18,−70, 58
R lateralIPS		36,−52, 44		R lateral IPS		32,−52, 44
R IPTO		30,−82, 22		R IPTO		26,−84, 18
R pIPS		26,−68, 46		R pIPS		26,−60,46
R aIPS		46,−34, 40				
anterior cingulate	p<.0001c	10, 8, 50	cingulate	anterior cingulate	p<.001c	8, 6, 52
precentral/SFS		−28, 0, 62	precentral	precental/SFS	p<.01c	−26, 0, 62
precental/insula	p<.0001c	−38, 6, 18		prcentral/SFS	p<.005c	32, −6, 54
precental/insula	p<.05c	44, 8, 22		precentral/insula	p<.05u	40, 6, 24
precentral/SFS	p<.001c	32, −2, 52		precentral/insula	p<.05u	−48, 4, 28

Abbreviations: IPTO, intraparietal/transverse occipital sulcus; IPS, intraparietal sulcus; SFS, superior frontal sulcus

* cluster level threshold; c: corrected, u: uncorrected
** MNI coordinates

Summary in this section

- Activation of the bilateral posterior IPS were revealed in both search tasks (contrast A, C, and D).
- Activation of the right anterior end of IPS/pCG (contrast A) and the bilateral anterior IPS (contrast C and D)were selectively revealed in the singleton search condition.
- Activation of the left paraHG/mTG was selectively revealed in the feature search condition (contrast B).

Discussion

Brain region related to stimulus-driven attention

Several regions located in the anterior intraparietal region showed selectivity for the singleton search condition. Activation of the bilateral anterior IPS was revealed in the singleton - control subtraction (Contrast C) but not in the feature - control subtraction (Contrast D) whereas the posterior IPS was activated by both search conditions. Additionally, the singleton - feature subtraction (contrast A) clearly showed that the right anterior IPS/pCG was also selectively activated by the singleton search condition. Thus, we suggested that the anterior intraparietal region containing these regions is the most feasible as the region responsible for stimulus-driven attention in the human brain.

The anterior intraparietal region probably represented visual saliency, because in our singleton search condition, stimulus-driven attention would be guided by visual saliency. This notion seemed to be consist with some previous studies suggesting that monkey LIP neurons selectively respond to visual saliency (ref. 4, 5).

Brain region related to attentional set for a shape

The feature - singleton subtraction (contrast C), which should reflect attentional setting for a target shape, revealed left parahippocampal/medial temporal activation. This result is consistent with the previous study which reported activation of bilateral parahippocampal gyrus while subjects attended to shape (ref.6).

References

1. Treisman & Gelade, 1980, Cognitive Psychology.
2. Theeuwes, 1994, Perception & Psychophysics
3. Bacon & Egeth, 1994, Perception & Psychophysics
4. Gottlieb et al., 1998, Nature
5. Kusunoki et al., 2000, Vision Research
6. Corbetta et al., 1990, Science