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Limitations of attentional orienting Effects of abrupt visual onsets and offsets on naming two objects in a patient with simultanagnosia

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Abstract

It has been proposed that the underlying deficit for some simultanagnosics is the inability to bilaterally orient attention in space due to parietal damage. In five experiments, we examine the performance of a patient with simultanagnosia secondary to bilateral occipito-parietal lesions, IC, in naming pairs of line-drawings. With simultaneous presentation and disappearance of objects (Experiment 1), IC typically named a single object. IC's performance dramatically improved when the two drawings alternated every 500 ms (Experiment 2). This improvement was not due to the abrupt onset of the second drawing "capturing attention", as indicated by the results of Experiment 3. Experiments 4 and 5 demonstrated that the crucial factor in improving IC's performance with simultaneous presentation of visual objects was the offset of one of the two stimuli. We propose that IC's impairment in naming two objects is attributable to the inability to "unlock" attention from the first object detected to other objects in the array. Visual offset of the first object disengages attention from the first object, allowing it to be allocated to the second object.

Keywords: Simultanagnosia; Hemispace; IC

1. Introduction

Patients with bilateral lesions involving the parieto-occipital junction often exhibit a constellation of symptoms including optic ataxia, "psychic" paralysis of gaze and simultanagnosia or the inability to "see" more than one object at a time, despite at least relatively preserved ability to recognize single objects [1,2]. The impairment in the ability to report more than one object may occur in the absence of visual field deficits and is often independent of object size.

A number of accounts of simultanagnosia have been proposed. In light of the differences in behavior exhibited by simultanagnosic patients, it would appear likely that different cognitive deficits may underlie the disorder in some of these patients (see [3,4]).

Posner et al. [5] have hypothesized that three main cognitive operations underlie attentional orienting. When a new focus of attention has been localized, attention must be first disengaged from the previous focus, moved, and finally engaged to the new focus. Based on single-cell recordings in animals, as well as lesion and neuroimaging studies in humans, Posner and Petersen [6] have suggested precise anatomical substrates for these cognitive operations. They propose that the posterior parietal lobe is critical for disengaging attention, the lateral pulvinar for engaging attention, and the superior colliculus for moving visual attention. Thus, on this proposal, patients with parietal lesions would be expected to be impaired in disengaging attention from attended objects or locations.

Data from patients with unilateral parietal damage tested with the covert orienting task developed by Posner et al. [5] support this account. In this task, three horizontally arranged boxes, one in the midline and one on the right and left, were presented. One of the two lateral boxes was brightened and after a variable interval a target stimulus was presented in one of the two lateral boxes. On most trials, the target was presented at the cued location (valid trials) and in 20% of the trials, the target was presented in the box opposite from the cued location (invalid trials). Normal controls show a validity effect in this paradigm, responding faster to valid targets than to invalid targets. Patients with parietal lesions exhibited disproportionate costs for invalid trials on which the target was presented in the contralesional hemispace.

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This result was attributed to difficulty in disengaging attention from the cue in the ipsilesional hemispace.

Farah [4] suggested that simultanagnosia observed in patients with bilateral parietal lesions—i.e. "dorsal" simultanagnosia—is attributable to bilateral dysfunction in the disengage operation. According to this hypothesis, patients with simultanagnosia can move attention to a relevant object or location in the environment, engage attention on a visual object or location, but are unable to disengage and to shift attention to a new location or a new object.

Farah's [4] hypothesis predicts that patients with simultanagnosia should show a disproportionate cost in invalid trials in the covert orienting paradigm. Two studies have directly explored spatial orienting in patients with simultanagnosia. Coslett and Saffran [3] tested a 67-year-old woman with bilateral parietal infarcts and simultanagnosia. She exhibited validity effects for left targets which were similar to those of matched controls; validity effects for right-sided targets were larger but still substantially smaller than those shown by patients with right hemisphere lesions and neglect. The authors concluded that the attentional shifting deficit was too small to account for the patient's simultanagnosia. Verfaellie et al. [7] used a similar task with a 41-year-old woman with bilateral parietal-occipital lesions who exhibited a visual processing deficit characterized by difficulty in recognizing complex visual patterns made up of independent elements. In this experiment, as in Coslett and Saffran's [3] study, the patient did not show greater costs in invalid trials than a group of matched controls. Thus, the results of these two studies do not clearly support the hypothesis that simultanagnosia is the result of a bilateral impairment in the disengagement of attention.

In the present study, we further examine the issue of attentional engagement and disengagement in simultanagnosia by looking at the effect on recognition accuracy of abrupt onsets and offsets of visual objects. It has been proposed that abrupt onsets automatically attract attention [8]. It is therefore possible that simultanagnosic patients may benefit from abrupt onsets as a way to automatically draw attention to a new object. On the other hand, if at least some patients with simultanagnosia exhibit an impairment in disengaging attention, one might hypothesize that the performance of these patients would benefit from the offset of a visual object because the disappearance of the object would obviate the need to disengage attention.

We report data from IC, a patient with simultanagnosia in the context of bilateral occipito-parietal infarcts, in a series of five experiments. First, we examined IC's performance in a task that required him to name two simultaneously presented drawings. As expected, IC typically reported only one of the two line-drawings. In Experiment 2, we demonstrated that IC's performance improved when the two drawings were presented in rapid alternation. In Experiments 3–5, we investigated whether IC's improved performance in Experiment 2 was caused by attentional capture from abrupt onset of a new object, or by the offset of the object to which he had allocated attention.

2. Case description

IC was a 65-year-old right-handed man who after cardiac surgery was noted to be "confused" and to appear blind. Although the confusion and visual loss abated over the next week, neurologic examination 4 weeks later revealed a mild right spastic hemiparesis and minimal left-sided pyramidal clumsiness. He exhibited a right homonymous hemianopia and/or neglect of the right visual field. He could gaze to either side to verbal command but exhibited hypometric saccades when directing gaze to the right. IC also exhibited optic ataxia. Reaching to foveated visual targets presented in the right hemispace was inaccurate with either hand (mean error ~3.3 cm). Reaching to targets in the left hemispace was more accurate but not normal (mean error ~1 cm). IC also exhibited simultanagnosia; when shown the Cookie Theft picture from the Boston Diagnostic Aphasia Examination [9], for example, IC reported seeing only a stool and, after a considerable delay, a girl. Additionally, when asked to report two letters presented visually for an unlimited time, he was able to name at least one letter on 9/10 trials, but he reported both letters only on 2 out of 10 trials. This performance is, of course, consistent with a non-lateralized form severe form of visual extinction. IC did not exhibit tactile or auditory extinction.

A CT scan performed 7 days post-op showed a left occipital and posterior occipito-parietal infarction as well as a right posterior parietal infarction (see Fig. 1).

Neuropsychological examination revealed that naming of visual stimuli was relatively preserved. He correctly named 26/26 single letters as well as 54/60 items from the Boston Naming Test. Performance was not influenced by object size; when shown the same set of line drawings in large (8–12 cm in height) or small (2–3 cm) sizes, he named 16/19 and 15/19, respectively. He performed well on an object/non-object decision test (95% correct). He performed poorly with Navon hierarchical stimuli [10]; when presented 20 letters comprised of a smaller, different letter (e.g. "S" made up of 12 "B"s) and asked to report both letters, he named the small letter on 16/20 trials and the large letter on 4/20 trials. He never named both the large and small letter.

IC performed poorly on a variety of visual search tasks. For example, he performed at chance on a task in which he was asked to determine if a "T" was present on a stimulus card. Stimuli for this experiment included cards on which multiple vertical and horizontal lines were drawn; a "T" was present on half of the cards. In a separate task, cards on which a circle and a horizontal line were drawn were presented and IC was asked to simply indicate if the circle was above or below the line. He performed at chance with visual inspection but responded correctly on 90% of trials

Fig. 1. A CT scan image demonstrating bilateral superior occipital and posterior parietal infarcts, larger on the left, as well as bilateral small vessel ischemic changes in the white matter.

when the examiner placed has index fingers on the line and circle.

3. Methods

In the following five experiments, line drawings were presented on a computer monitor in two locations, above and below the central fixation point. The location of the stimuli was held constant across all experiments. At a viewing distance of 50 cm, the distance between the fixation point and the center of each stimulus location was 4° of visual angle. Each drawing subtended about 1° of visual angle. The stimuli were presented on a Macintosh Classic computer and consisted of 31 line drawings selected from the characters comprising the Cairo font set for the Macintosh. Each trial was initiated by the examiner after ascertaining that IC was gazing at the fixation point. The fixation point disappeared at the time of the presentation of the stimuli.

3.1. Experiment 1: two line-drawings simultaneously presented

Experiment 1 served as the baseline for the assessment of IC's deficit in reporting multiple visual objects. In this experiment, two drawings were simultaneously presented and the patient was asked to name both. IC was told that two drawings would be presented on every trial; he was encouraged to report whatever he saw and to guess is he was uncertain. IC's performance in Experiment 1 is reported in Table 1. In different blocks of trials, stimuli were presented for 2 or 5 s.

Table 1
Type, frequency, and percentage of IC's responses in the 2 and 5-s conditions of Experiment 1

	2-s presentation	5-s presentation
Two reported, both correct	2/31 (6%)	4/31 (13%)
Two reported, one correct	2/31 (6%)	3/31 (10%)
Only one reported, correct	22/31 (71%)	15/31 (48%)
Only one reported, incorrect	5/31 (16%)	8/31 (26%)
None reported	0/31 (0%)	1/31 (3%)

3.1.1. Results and discussion

IC correctly reported at least one object on 26/31 trials in the 2-s condition and on 22/31 in the 5-s condition (84 and 71%, respectively). He reported both objects in only 2/31 trials in the 2-s condition and 4/31 trials in the 5-s condition (6 and 13%, respectively). Performance in the 2 and 5-s conditions did not differ significantly in any comparison (Fisher's Exact $P > 0.35$). Note that as control subjects perform at ceiling on this and all subsequent tasks with briefer stimulus display (e.g. 500 ms), controls were not tested for this or subsequent tasks.

Experiment 1 demonstrates that IC was able to report one object relatively often (77% of the trials) but had a profound deficit in reporting more than one simultaneously presented object, succeeding on only 10% of trials. Performance did not improve with increasing exposure time of the stimuli, at least in the interval tested. These data demonstrate that IC does indeed exhibit relatively severe simultanagnosia. The processing deficit causing this disorder is explored in the following experiments.

3.2. Experiment 2: alternation of two line-drawings

Experiment 2 investigated whether IC's performance would improve when the two objects were not simultaneously presented but rapidly alternated. In this experiment, the two objects alternated every 500 ms. For example, the object at the top location appeared for 500 ms and then disappeared, followed immediately by the presentation of the object at the bottom location for 500 ms. The location of the initial object was counterbalanced across trials. As in Experiment 1, in different blocks of trials, the total exposure duration of the visual display was either 2 or 5 s.

3.2.1. Results and discussion

As demonstrated in Table 2, IC's performance dramatically improved in this condition.

IC correctly reported at least one object on 28/31 trials in the 2-s condition and 26/31 trials in the 5-s condition (90

Table 2
Type and frequency of IC's responses in the 2 and 5-s conditions of Experiment 2

	2-s presentation	5-s presentation
Two reported, both correct	12/31 (39%)	16/31 (52%)
Two reported, one correct	7/31 (23%)	3/31 (10%)
Only one reported, correct	9/31 (29%)	7/31 (23%)
Only one reported, incorrect	3/31 (10%)	4/31 (13%)
None reported	0/31 (0%)	1/31 (3%)

and 84%, respectively). He reported both objects in 12/31 trials in the 2-s condition and 16/31 trials in the 5-s condition (39 and 52%). Again, IC's performance in the 2-s condition and in the 5-s condition did not differ in any comparisons (Fisher's Exact $P > 0.40$).

Collapsing across the 2 and 5-s blocks of trials, IC's ability to report at least one object did not significantly differ in Experiment 2 as compared to Experiment 1 (87 and 76%, respectively; Fisher's Exact $P > 0.15$). However, the proportion of trials on which he correctly identified both objects was significantly greater in the alternating condition of Experiment 2 than in the simultaneous condition of Experiment 1 (11 and 45%, respectively; Fisher's Exact $P < 0.0001$).

The results of Experiment 2 show that alternating two visual objects in different locations improved IC's performance. These data are consistent with the hypothesis that IC's impairment is reflects a deficit in disengaging attention. Note also that the significant improvement in performance in the alternating condition suggests that IC is at least relatively adept at shifting attention to a different location.

There is at least one additional account of these data which needs to be considered. Better performance in Experiment 2 might be attributable to the abrupt onset of the second object "capturing" attention rather than the offset of the first stimulus releasing attention. The next three experiments examine separately the effects of offset and onset of visual objects on IC's performance.

3.3. Experiment 3: second drawing appearing after a delay

Experiment 3 examines whether abrupt onset of a second object influences IC's ability to report more than one visual object. In normal participants, the effect of abrupt visual onset on attentional allocation has been investigated in several studies. Yantis and Jonides [8], for example, have shown that abrupt onsets of peripheral visual objects capture attention and result in faster identification of the newly presented stimuli. The attentional capture effect of abrupt onsets seems to depend on the appearance of a new object and not on changes in luminance [11]. Yantis [12] has proposed that the special role of abrupt visual onset in attentional capture depends on the creation of a new object file to represent object attributes [13] rather than on the intrinsic perceptual salience of onsets. Abrupt onsets do not always capture attention, however. For example, attentional capture from abrupt visual onset is not observed when the target location is selected in advance [14] or when the expected target is not characterized by abrupt visual onset [15].

In Experiment 3, a single drawing was presented for 5 s at either the top or bottom location. Two and a half seconds after the onset of the first stimulus, a second line-drawing appeared in the other location and was displayed for 2.5 s. Both objects disappeared 5 s after the onset of the first line-drawing.

3.3.1. Results and discussion

IC's performance in Experiment 3 is reported in Table 3.

IC reported at least one object in 29/31 trials, which is slightly more than he reported in the simultaneous condition of Experiment 1 (94 and 76%, respectively; Fisher's Exact $P < 0.05$), but the same as in the alternating condition of Experiment 2 (94 and 87%, respectively; Fisher's Exact $P > 0.15$). It is important to point out that when IC reported a single object, it was always the first object presented. IC reported both objects on 5/31 trials, which is similar to his performance in Experiment 1, when both objects were presented simultaneously (16 and 10%, respectively; Fisher's Exact $P > 0.45$) but significantly less than in the alternating condition of Experiment 2 (16 and 45%, respectively; Fisher's Exact $P < 0.01$).

These results suggest that abrupt onset of a second visual object is not responsible for the improvement in naming both objects that was observed in Experiment 2. In Experiment 3, after the first object was presented, IC's attention seemed to be locked on it, and the abrupt onset of the second stimulus was not sufficient to draw his attention to the new object. The failure of abrupt onset to facilitate attentional capture might depend on the fact that attention was already focused on the first object [14] but it may also be an indication of an inability to create a second object file after the first object has been identified [12]. Further investigation is required to distinguish between these alternatives.

The data of Verfaellie et al. [7] is also of interest in this context. These investigators found that their simultanagnosic patient did not exhibit faster RTs on trials with a valid cue as compared to neutral trials (trials in which the cue was a brightening of the central fixation), whereas the matched controls did. Verfaellie et al. [7] suggested that performance was not improved by a peripheral cue because the cue failed to automatically capture attention.

Table 3
Type, frequency, and percentage of IC's responses in Experiments 3–5

	Experiment 3	Experiment 4	Experiment 5
Both drawings reported correctly	5/31 (16%)	24/31 (77%)	17/31 (55%)
Two reported, one incorrect	6/31 (19%)	7/31 (23%)	8/31 (26%)
One reported, correct	18/31 (58%)	3/31 (10%)	4/31 (13%)
None reported	2/31 (6%)	3/31 (10%)	2/31 (6%)

Another interesting result is the improvement in single object naming in this experiment as compared to the simultaneous presentation condition (Experiment 1). This finding suggests that the presence of multiple objects in the array also has an effect on single object naming. As we have previously argued based on data from another patient with simultanagnosia [3], the impairment in naming a single object presented in conjunction with a second stimulus strongly suggests that even unreported stimuli are subject to low level visual processing and that the visual resources devoted to the processing of this unreported stimulus may adversely affect performance.

3.4. Experiment 4: single alternation

In this experiment, the effect of extinguishing the attended stimulus was assessed. If IC's simultanagnosia is attributable, at least in part, to an impairment in disengaging attention, one might expect performance to improve if the attended stimulus was extinguished when the second stimulus was presented. To test this hypothesis, the first object was presented for 2.5 s and then erased as the second object was presented, again for 2.5 s. Experiment 4 was therefore identical to Experiment 3, except for the offset of the first drawing as the second drawing was presented.

3.4.1. Results and discussion

IC's performance in Experiment 4 is reported in Table 3.

The results replicated and extended the results of the alternating condition of Experiment 2. IC correctly reported at least one drawing on 28 out of 31 trials (90%), and he correctly reported both objects on 24 out of 31 trials (77%). IC's performance in Experiment 4 was remarkably better than his performance in Experiment 3. He reported both objects on 77% of the trials in this experiment and only on 19% of the trials in Experiment 3 (Fisher's Exact $P < 0.0001$). Note that Experiments 3 and 4 were identical, except that when the second object was presented, the first object disappeared in Experiment 4 but not in Experiment 3.

IC's performance in Experiment 4 was also significantly better than his performance in Experiment 2, when the two drawings alternated every 500 ms (77 and 45%, respectively; Fisher's Exact $P < 0.005$).

These results suggest that the better performance in reporting both objects in Experiment 2 did not depend on multiple alternations of the visual objects, but on the pattern of offset and onset of the two objects.

3.5. Experiment 5: second object disappearing after a delay

Experiment 5 again examines the effect of visual offsets on the perception of the second object. In this experiment, both objects were simultaneously presented, as in Experiment 1, but one of the two objects was erased after a delay of 2.5 s; the second stimulus persisted for 5 s.

Note that as the object to be extinguished was randomly chosen, IC would be expected to be attending to the extinguished object on only 50% of trials. Thus, in Experiment 5, we expect IC to perform better than in Experiment 3 but worse than in Experiment 4 in which the offset drawing was also the first presented and, therefore, the one to which IC allocated attention.

3.6. Results and discussion

IC's performance in this experiment is reported in Table 3.

IC correctly reported at least one drawing in 28/31 trials (90%). He reported both drawings correctly in 17/31 trials (55%), which was not significantly different from his performance in Experiment 2 (46%, Fisher's Exact $P > 0.35$). As predicted, IC's performance was worse in this experiment than in Experiment 4, but not so significant (55 and 77% for Experiments 5 and 4, respectively; Fisher's Exact $P > 0.1$). IC's ability to report both drawings in Experiment 5 was significantly better than in Experiment 1 (Fisher's Exact $P < 0.0001$) and in Experiment 3 (Fisher's Exact $P < 0.005$).

The results of Experiment 5 replicate those of Experiments 2 and 4 and suggest that the offset of one of the stimuli is the critical factor in improving IC's ability to report both objects.

4. General discussion

Five experiments explored the effect of target onset and offset on the report of visually presented stimuli by a patient with simultanagnosia. IC was profoundly impaired in naming two line-drawings presented simultaneously. His performance was equally poor in Experiment 1, in which the two drawings were presented simultaneously and were erased simultaneously, and in Experiment 3, in which the second drawing was presented 2.5 s after the onset of the first object. These results suggest that abrupt onset of a second object was not sufficient to draw IC's attention to the location of the visual onset.

IC's ability to name both drawings improved substantially in Experiment 2, in which the two drawings alternated every 500 ms, and in Experiment 5, in which one of two initially presented objects disappeared after 2.5 s. The effect was most dramatic in Experiment 4, in which one object was initially presented for 2.5 s and then replaced by a second object at a different location. In all of these experiments, one of the objects disappeared suggesting that visual offset is necessary to improve performance in visual identification.

As the same 31 stimuli were employed in all of the investigations, one might argue that the improved performance in the later experiments was attributable to increased familiarity with the stimuli. To test this hypothesis, Experiment 1 was repeated after the five experiments reported here were concluded. With 5 s exposure, IC reported both objects correctly on only 1 of 31 trials, a performance which did not differ significantly from that obtained on his initial exposure to the stimulus arrays. These data strongly suggest that familiarity with the stimuli did not contribute to the effects reported here.

Under circumstances in which IC allocated visual attention to an object and/or location, he was profoundly impaired in shifting attention to a different object; his performance improved dramatically when the attended object was extinguished and attention was "released" to shift to another object and/or location. In the context of Posner's model of attention shifts discussed in Section 1, IC's deficit would be characterized as an impairment in the "disengage" component.

Like the patient reported by Verfaellie et al. [7], however, IC did not appear to benefit from the abrupt onset of a novel stimulus. Although this may, of course, be attributable to a failure to disengage attention, we cannot exclude the possibility that IC also suffers from a deficit in the automatic orienting of attention to the location of an abrupt onset.

These results are also consistent with the model of attentional allocation proposed by Cohen et al. [16]. On this account, the "disengage deficit" exhibited by patients with parietal lesions in cued attention tasks may be attributable to unbalanced competition between lateralized attentional mechanisms rather than damage to a dedicated disengage mechanism. Interestingly, in a computational simulation of this model, bilateral lesions yielded a moderate reduction of attentional effects, a finding consistent with data from patients with simultanagnosia secondary to bilateral parietal occipital lesion reported by Coslett and Saffran [3] and Verfaellie et al. [7]. Cohen et al. [16] suggested that simultanagnosia may result from a damaged attentional system, which has only weak control on attentional shifting along with strong top-down influences from higher level object representations.

The present results do not speak to the distinction between space- and object-based attentional deficits in the genesis of simultanagnosia. While the accounts discussed thus far have emphasized spatial aspects of attentional orienting, other theories suggest that simultanagnosia may be attributed, at least in part, to object-based impairments. Support for the role of parietal lobe in object-based attentional deficits comes from a study by Egly et al. [17] demonstrating that patients with left parietal damage have a specific impairment in shifting attention between different objects as opposed to different spatial locations. These investigators suggested that the simultanagnosia and spatial disorientation exhibited by patients with bilateral parietal lesions can be explained as a combination of a specific deficit in object-based attention shifting caused by left parietal lesions and the spatial deficit caused by right-parietal lesions [18].

In this context, it is worth emphasizing that although we believe that IC's impairment in the identification of two objects is, at least in part, attributable to a disturbance in disengaging attention, we do not offer this as a general account of simultanagnosia. Like other investigators (e.g. [4]), we contend that different processing deficits may give rise to simultanagnosia. More specifically, we suggest that a failure to bind object identify and object location information may also give rise to simultanagnosia [3].

Finally, it is worth noting that IC's performance on single object naming was adversely affected by the presence of a second object, about which IC was usually unaware. Thus, the proportion of trials on which at least one object was reported was significantly less in Experiment 1 than in Experiments 2–5 (77 and 90%, respectively; Fisher's Exact $P < 0.03$). Although no conclusive account of these data can be provided, this observation is consistent with the hypothesis that simultanagnosia may be, at least in part, attributable to a failure to bind or link together information in the dorsal and ventral visual pathways [3]. We suggest that the adverse effect of the second, usually unidentified, object provides strong evidence that low-level visual processes identify regions of interest in the stimulus array. Under normal circumstances, the identification of two regions of interest in the visual array would be expected to result in the linking of appropriate object representations to their corresponding "location" in spatial systems. On the assumption that simultanagnosia is characterized by a restricted capacity to bind information in the ventral and dorsal streams (cf. [3]), the attempt to maintain the two linkages generated by the two item arrays would exceed the binding capacity of the impaired system and, therefore, interfere with the linking of the dorsal and ventral visual pathways.

References

[1] Balint R. Seelenlähmung des schauens optische ataxie, räumliche störung der aufmerksamkeit. Monatshrift für Psychiatrie und Neurologie 1909;25:51–81.

[2] Harvey M, Milner AD. Balint's patient. Cognitive Neuropsychology 1995;12:261–81.

[3] Coslett HB, Saffran E. Simultanagnosia. To see but not two see. Brain 1991;114:1523–45.

[4] Farah M. Visual agnosia. Disorders of object recognition and what they tell us about normal vision. Cambridge, MA: MIT Press, 1990.

[5] Posner MI, Walker JA, Friedrich FJ, Rafal RD. Effects of parietal injury on covert orienting of attention. Journal of Neuroscience 1984;4:1863–74.

[6] Posner MI, Petersen SE. The attention system of the human brain. Annual Review of Neuroscience 1990;13:25–42.

[7] Verfaellie M, Rapcsak SZ, Heilman KM. Impaired shifting of attention in Balint's syndrome. Brain and Cognition 1990;12:195–204.

[8] Yantis S, Jonides J. Abrupt visual onsets and selective attention: evidence from visual search. Journal of Experimental Psychology: Human Perception and Performance 1984;10:601–21.

[9] Goodglass H, Kaplan E. The assessment of aphasia and related disorders. Philadelphia, PA: Lea and Febiger, 1972.

[10] Navon D. Forest before trees: the precedence of global features in visual perception. Cognitive Psychology 1977;9:353–83.

[11] Yantis S, Hillstrom AP. Stimulus-driven attentional capture: evidence from equiluminant visual objects. Journal of Experimental Psychology: Human Perception and Performance 1994;20:95–107.

[12] Yantis S. Stimulus-driven attentional capture and attentional control settings. Journal of Experimental Psychology: Human Perception and Performance 1993;19:676–81.

[13] Kahneman D, Treisman A, Gibbs BJ. The reviewing of object files: object-specific integration of information. Cognitive Psychology 1992;24:175–219.
[14] Yantis S, Jonides J. Abrupt visual onsets and selective attention: voluntary versus automatic allocation. Journal of Experimental Psychology: Human Perception and Performance 1990;16:121–34.
[15] Folk CL, Remington RW, Johnston JC. Involuntary covert orienting is contingent on attentional control settings. Journal of Experimental Psychology: Human Perception and Performance 1992;18:1030–44.
[16] Cohen JD, Romero RD, Farah M, Servan-Schreiber D. Mechanisms of spatial attention: the relationship of macrostructure and microstructure in parietal neglect. Journal of Cognitive Neuroscience 1994;6:377–87.
[17] Egly R, Driver J, Rafal RD. Shifting visual attention between objects and locations: evidence from normal and parietal-lesion subjects. Journal of Experimental Psychology: General 1994;123:161–77.
[18] Rafal RD. Balint syndrome. In: Feinberg TE, Farah MJ, editors. Behavioral neurology and neuropsychology. New York: McGraw-Hill, 1997. p. 337–56.