Beware and be aware: Capture of spatial attention by fear-related stimuli in neglect

Patrik Vuilleumier[1,2,CA] and Sophie Schwartz[3]

[1]Department of Neurology, University of California, Davis, and VA Medical Center, Martinez, USA; [2]Institute of Cognitive Neuroscience, University College, Alexandra House, 17 Queen Square, London WCIN 3AR, UK; [3]Institute of Cognitive Sciences, University of California, Berkeley, CA, USA

[CA,2]Corresponding Author and Address

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Stimuli with threat significance may be privileged in summoning attention, allowing fast detection even outside the field of attention. We studied patients with unilateral neglect and visual extinction, who usually remain unaware of contralesional stimuli presented together with concurrent ipsilesional stimuli, to learn whether emotional stimuli might differentially be affected by contralesional extinction. Pictures of spiders or flowers with similar features were presented in right, left, or both fields. On bilateral trials, the patients detected emotional stimuli (spiders) on the left side much more often than neutral pictures (flowers). While mechanisms of spatial attention are impaired after parietal damage in neglect patients, intact visual pathways to the ventral temporal lobe and amygdala might still mediate distinct mechanisms of emotional attention. *NeuroReport* 12:1119–1122 © 2001 Lippincott Williams & Wilkins.

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INTRODUCTION

From an adaptive–evolutionary perspective, it is assumed that the detection of potentially threatening events should be fast and automatic, even when these occur outside the focus of attention [1]. Since the environment confronts our brain with more stimuli than it can process, attentional mechanisms must select important sensory information for conscious awareness and behavioural response. There is evidence from psychophysical observations in normal people to suggest that some preattentive or unconscious analysis may occur for emotional stimuli [1] and bias the allocation of attention to their location [2–4]. Stimuli such as angry faces, spiders, or aversive pictures can elicit skin conductance changes even when they are masked and subjects remain unaware of them [5,6].

Here we asked whether patients with right brain damage and left spatial neglect are more likely to perceive fear-relevant pictures presented in their left (contralesional) hemifield than other visually similar pictures. Unilateral spatial neglect typically follows damage to right parietal cortex and is characterized by a loss of awareness for stimuli in the opposite side of space, despite intact visual pathways in early occipital cortex [7,8]. Perceptual extinction is a common symptom associated with neglect, whereby the patients can still perceive a stimulus in their contralesional hemifield when presented alone, but often remain unaware of the same contralesional stimulus when presented with another simultaneous stimulus in the ipsilesional hemifield [8,9]. Perceptual extinction entails an abnormal bias in spatial attention in the favor of ipsilesional stimuli, with a failure to direct attention towards the left side in the presence of competing stimuli on the right side [7,8]. In the present study, we chose pictures of spiders as emotional stimuli, since several studies in normal subjects have suggested that spiders represent potent fear stimuli, known to be the most frequent determinant of phobia [1,10] and to elicit consistent emotional responses even in normal non-phobic individuals [11,12]. This also allowed us to use pictures of flowers as neutral control stimuli, which were made of the same elementary visual features. Our findings in neglect patients reveal an advantage of fear-related stimuli in overcoming contralesional inattention and extinction, as compared to neutral stimuli. This provides direct evidence for an advantage of threatening stimuli in visual processing and access to conscious awareness.

PATIENTS AND METHODS

We examined two patients (SV and EN) who suffered from chronic unilateral left neglect after a focal right parietal stroke. They had intact visual fields on both sides but showed reliable extinction on bilateral simultaneous stimulation (BSS). SV was a 60-year-old right-handed woman, 3 years post-stroke, with dense left hemiplegia and sensory loss. EN was a 58-year-old right-handed man, 3 years post-stroke, with mild left arm paresis. Both patients showed mild left neglect in standard clinical tests, such as letter cancellation (SV: 17/60 left-side omissions; EN: 21/60 left-side omissions) and line bisection (SV: 13/170 mm rightward deviation; EN: 30/170 mm rightward deviation).

Brain CT scan showed a large infarct in the territory of the right middle cerebral artery in both patients, with predominant fronto-parietal cortical damage. The patients were paid for their participation and signed informed consent statements approved by the Institutional Review Board of the Martinez Department of Veterans Affairs and the University of California, Davis. Neither SV nor EN reported a history of phobia for spiders or other animals.

The two patients were tested in a standard extinction paradigm, in which visual stimuli were briefly presented either in the right (RVF), left (LVF), or both visual fields. Stimuli were black outline drawings of spiders, flowers, or ring shapes with four possible exemplars in each category (Fig. 1a). We designed a set of spider and flower stimuli that shared exactly the same visual features by shifting the spiders' legs to make up flowers' petals, so that any difference in perception for these stimuli could not be confounded by some differences in their low-level visual attributes, e.g. degree of contrast or brightness. All unilateral and bilateral stimuli were equally probable. There were six possible types of unilateral trials (three types of stimuli in both RVF and LVF) and four possible types of bilateral trials, with either a spider or a flower on one side (right or left) and a ring shape on the other side (Fig. 1b). The critical experimental trials were bilateral displays with left spiders *vs* left flowers.

SV was tested in two separate sessions (SV1 and SV2, 400 trials in each session) and EN was tested in a single session (160 trials). All trials began with a fixation cross at the center of a computer screen, followed 800 ms later by stimuli presented on the right, left, or both sides (~7° away from fixation), in a random order. The patients had to identify and locate the stimuli on each trial (i.e., flower on the right and nothing on the left, or ring on the right and spider on the left), except for the second session in patient SV where she had only to report the location of stimuli (i.e. right, left or both) without paying attention to stimulus type. Stimulus duration was adjusted for each patient in order to obtain reliable extinction on bilateral trials, together with adequate performance on unilateral left trials (100 ms in SV, 80 ms in EN). Patients were trained to maintain fixation during a practice phase before testing. During testing sessions, an experimenter sitting opposite to the patient checked that the central cross on the screen was correctly fixated at the beginning of each trial. A few trials where eyes deviated from fixation were noted to be disregarded from subsequent analysis, and replaced by correct trials at the end of the session.

RESULTS

Across all experimental sessions, the patients reported unilateral stimuli in the contralesional field almost as accurately as in the ipsilesional field (SV missed 0/40 leftside stimuli and EN missed 2/16 left-side stimuli; no right-side stimuli were missed) and misidentifications of the stimuli were rare (only two by SV, none by EN). In contrast, both patients showed a marked extinction of contralesional stimuli on bilateral trials (EN 44%, SV1 66%, SV2 29%). Critically, however, the rate of extinction was strongly modulated by the nature of the contralesional stimulus. In the first task, where patients had to identify and locate the stimuli, extinction was significantly less for left-side spiders than for left-side stimuli in the other bilateral conditions (Fig. 1c; rank sum test, d.f. = 3, $H = 11.1$, $p = 0.009$ in SV1 and $H = 7.3$, $p = 0.041$ in EN). In particular, on bilateral displays with the same competing ring shapes on the right side, a left spider was extinguished much less often than a left flower (SV1: $9/40 = 23\%$ *vs* $29/40 = 73\%$; EN: $3/16 = 19\%$ *vs* $7/16 = 44\%$; Mann–Whitney, $U = 16$ and 14.5, $p = 0.021$ and.039, respectively), even though these stimuli were composed of the same visual features. Extinction of the left-side rings did not differ whether there was a spider or flower on the right side ($U = O$).

SV was also tested in a second task where she had to name the location of stimuli (e.g. right, left or both sides) without identifying them. This was to exclude the possibility that the advantage of spiders in extinction may result from a strategic set in which the patient may be somehow biased to search for and report these potentially more interesting and unusual stimuli [9,13]. The same pattern was observed (SV2, Fig. 1c), with a large decrease of extinction for left-side spiders ($2/40 = 5\%$) compared with other conditions ($H = 9.8$, $p = 0.016$) and, in particular, compared with left-side flowers ($11/40 = 28\%$, $U = 15$, $p = 0.036$). Thus, spiders were privileged in attracting spatial attention even when stimulus identity was irrelevant to the task.

A 2×3 ANOVA on the number of contralesional misses collapsed across patients and sessions indicated significant effects of the side of stimuli (bilateral *vs* unilateral; $F(1,82) = 58.3$, $p < 0.001$) and of the type of stimuli (spiders *vs* flowers or rings; $F(2,81) = 7.9$, $p < 0.001$), with a significant interaction ($F(1,78) = 6.8$, $p = 0.002$). This confirms that there was no significant neglect for either stimulus type on unilateral trials, but much less neglect for spiders than for flowers ($p = 0.016$, Bonferroni–Dunn) and than for rings ($p = 0.001$) on bilateral trials.

DISCUSSION

In these two patients, in two different tasks, pictures of spiders shown on the contralesional neglected side were found to suffer less extinction on bilateral trials than visually similar stimuli such as flowers or other ring shapes. These findings demonstrate that the discrimination of different stimuli can take place in the visual system based on their meaning value, rather than on their low-level components, despite a severely abnormal bias in spatial attention during bilateral stimulation, which usually gives to ipsilesional stimuli a privileged access to awareness.

Such findings converge with other results in neglect and extinction, suggesting that contralesional sensory inputs are still processed to some extent without attention or even without awareness [8,14]. Such preattentive analysis may serve to prioritize the selection of salient stimuli-like faces both in patients [13,15] and normal subjects [4,16]. More specifically, our findings indicate that emotionally relevant information can be extracted at some preattentive stage of processing and that this may allow the subsequent fast orienting of attention towards potential threat stimuli. Previous observations in normal subjects have also suggested that rapid and automatic processing can occur for fear-related stimuli such as spiders, snakes, or facial

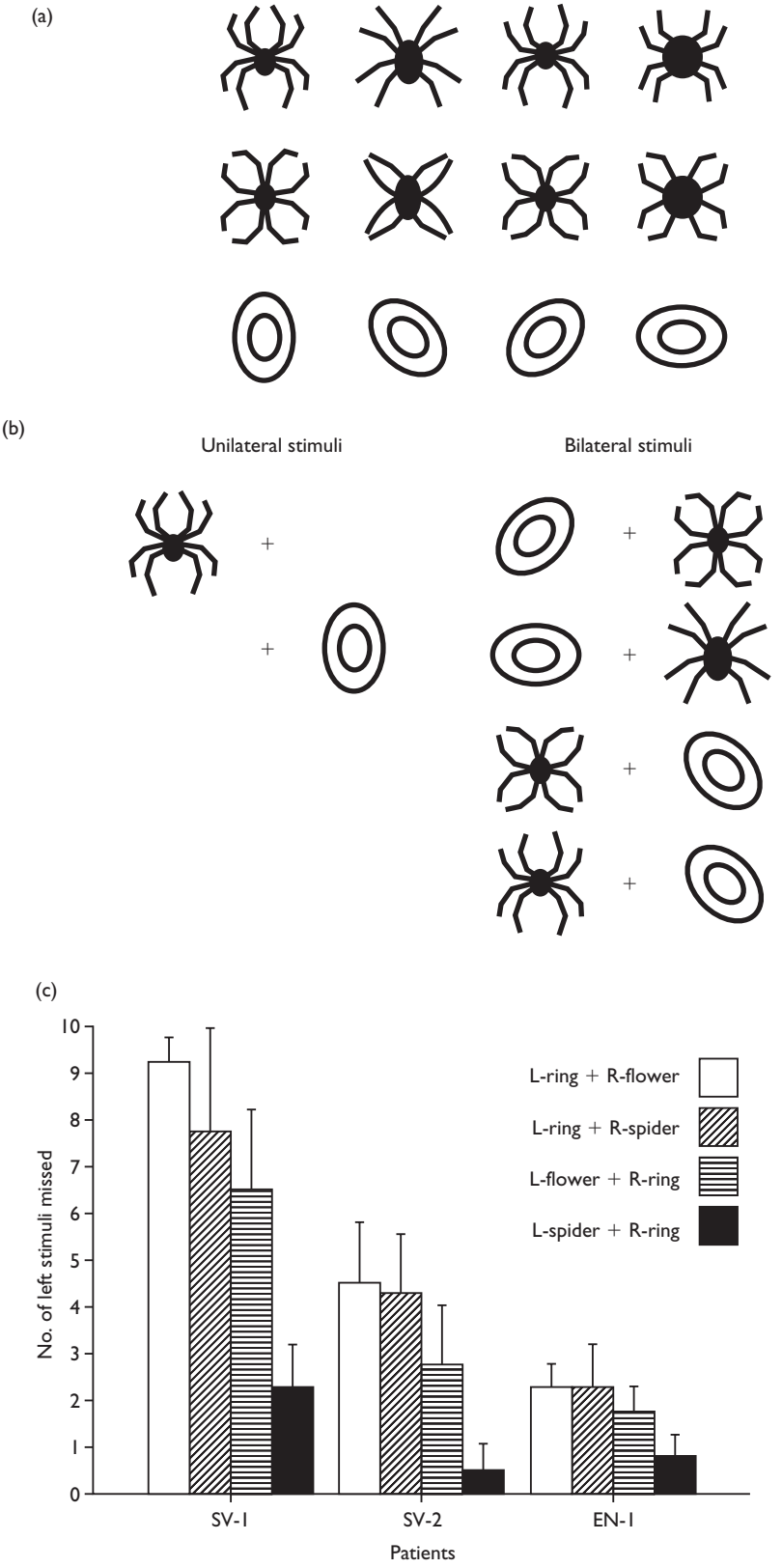

Fig. 1. (**a**) The four possible exemplars used in each stimulus category (spiders, flowers, ring shapes). (**b**) Examples of left- or right-sided stimuli in unilateral trials, and the four possible combinations for bilateral trials. Stimuli subtended ~2.5° and were presented on a computer screen ~7° away from a central fixation cross. (**c**) Number of contralesional left stimuli missed in bilateral trials for each condition in patient SV (SV-1 = session 1; SV-2 = session 2) and patient EN (EN-1).

expressions [1,17], and that the emotional value of stimuli may influence the allocation of attention and behavioural responses [2–4]. Here we show for the first time that potential threat significance can determine whether a stimulus will attract attention and reach conscious awareness in the presence of unilateral neglect and extinction. This is consistent with other recent results showing that faces with emotional expressions tend to be less extinguished than faces with neutral expressions [15]. Importantly, emotional and neutral stimuli used in the present study contained the same visual features, and our findings cannot therefore be explained by some differences in low-level properties of the stimuli, such as their degree of contrast or brightness [18].

Rapid unconscious processing of possible threats may occur in the amygdala, a structure in the anterior temporal lobe that is critical for fear-related responses and fear conditioning [19]. The amygdala might be activated by information from the contralesional unattended hemifield through direct pathways from the thalamus bypassing the primary visual cortex [19,20], or via the intact ventral occipitotemporal pathways [15,21].

Neuroimaging studies in humans have shown that amygdala activity can be elicited by fear-related stimuli without explicit attention to these stimuli (e.g. when task-irrelevant [21]), or even without actual awareness of the faces (i.e. when masked [22]). Furthermore, neuroimaging results [21,23,24], like neurophysiology studies in monkeys [25], suggest that emotional stimuli evoke enhanced neural responses in extrastriate visual areas. Activation of limbic areas such as the amygdala may exert modulatory feedback influences on the cortex to enhance visual processing [19,21,25], consistent with the view that attention and selection of sensory stimuli for awareness is mediated by reciprocal interactions between brain areas encoding different stimulus attributes in parallel within selectively distributed networks [7]. Thus, in patients with neglect, while mechanisms of spatial attention are impaired due to parietal damage, intact visual pathways into the temporal lobe and limbic areas might still mediate mechanisms of emotional attention allowing privileged detection of threat-related stimuli. These findings reveal that multiple specialized attentional processes have presumably evolved to enable the brain to cope with a limited processing capacity and select relevant stimuli for adaptive behaviour.

CONCLUSION

Our results demonstrate that in patients with unilateral spatial neglect and extinction, fear-relevant stimuli on the contralesional side can be discriminated and reach conscious awareness in spite of the pathological inattention towards contralesional space, whereas the patients usually miss other neutral visual stimuli on the contralesional side. This supports the view that emotional stimuli may have some advantage in capturing attention, perhaps due to preserved preattentive processing along the ventral temporal and/or subcortical visual pathways into the amygdala, still taking place despite damage to parietal cortical areas involved in spatial attention.

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