



## Expectation-based attentional modulation of visual extinction in spatial neglect

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### Abstract

Visual extinction, the failure of patients with unilateral focal brain damage to report the contralesional of two simultaneously presented stimuli, may be modulated by characteristics of the display such as similarity, collinearity, or connectedness. Since these factors affect the perceptual configuration of stimuli, the modulation of extinction is believed to reflect low-level perceptual grouping. In the present study, patient AG did not show any modulation of contralesional detection when the ipsilesional and contralesional stimulus grouped by colour, by form, or both (Experiment 1). In contrast, identification of the contralesional stimulus was facilitated when the stimuli grouped (Experiment 2), suggesting a modulation of extinction by specific task demands. Experiment 3 used a cueing procedure to demonstrate modulation of extinction by expectation biases. Prior to stimulus presentation, AG was cued to attend to a particular feature (e.g. colour). After stimulus exposure he was prompted to identify the expected feature on valid trials and the unexpected feature on invalid trials. AG showed a significant validity effect for contralesional stimuli i.e. he identified the expected feature (e.g. colour) significantly better than the unexpected feature (e.g. form). These results suggest that competition for selection between visual stimuli may not only be influenced by perceptual characteristics of the display, but also by high-level factors such as the response criterion or expectation biases.

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### 1. Introduction

Visual extinction is a frequent consequence of unilateral focal brain damage. Patients fail to detect or identify the more contralesional of two briefly presented stimuli although they correctly perceive isolated contralesional stimuli [8,21]. Current theories propose that extinction is a consequence of a diminished sensory or attentional processing capacity of the damaged hemisphere for the contralateral space [8,16]. According to the sensory hypothesis, this processing limitation is due to a weakened or delayed afferent input to the damaged hemisphere [12,22]. In contrast, the attentional hypothesis proposes that extinction is the result of a biased competition for attentional selection [11,20,31]. The attentional hypothesis fits well to current models of attentional selection in the healthy brain. Selective attention is limited in capacity, hence visual stimuli compete for selection in the healthy brain [5,9]. A unilateral brain lesion biases this competition in favour of stimuli pre-

sented in ipsilesional space [11]. A strong support for this attentional explanation of extinction is the finding that the ipsilesional selection bias can be moderated by perceptual factors. Ward et al. [31] found that a contralesional stimulus was better detected when it was perceptually similar (i.e. two brackets) to the ipsilesional stimulus than when it was dissimilar (i.e. a dot and a bracket). The authors argued that two similar stimuli more easily grouped to form a pair and were therefore more likely to be selected as a group than two dissimilar stimuli. Further studies found that other perceptual factors such as connectedness [7], polarity [14], or collinearity [25] also affected grouping of the ipsilesional and contralesional stimulus. However, most of these studies used detection paradigms, which have a very limited response set and do not allow a qualification of the patient's perception. The results of perceptual grouping studies therefore suggest that processing capacity for stimulus selection is allocated on an all-or-none basis: the patient either detects the presence of a contralesional stimulus or not. Based on these results, recovery of extinction by perceptual grouping is thought to result from segmentation of the visual scene into more easily perceivable elements [6,19]. However, an alternative explanation for grouping effects

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is that grouping does not affect the bottom-up perceptual processes per se, but—at least in some cases—rather modulates the decision criterion of the patient while leaving bottom-up processing unchanged. This hypothesis relies on the assumption that spatial extinction is not an all-or-none phenomenon, but that processing of the contralesional stimulus reflects a continuum between zero and total processing. If such a continuum of more or less degraded representations exists, it should be possible to modulate extinction top-down, by changing the expectancies of the patient. Evidence for a degraded representation comes from recent studies showing that the degree of extinction varies substantially with the task demands. Vuilleumier and Rafal [29,30] asked extinction patients either to localise or to enumerate briefly presented stimuli. In contrast to a severe extinction observed in the localisation task, contralesional stimuli were correctly enumerated, suggesting that they had been processed at a level allowing enumeration but not allowing the determination of their position. These results suggest that location information was essential for awareness of the stimuli as individual elements in space, but not for enumeration.

The present study was designed to investigate whether visual extinction can only be modulated by perceptual factors or whether strategic factors and expectation biases equally facilitate the access to perceptual information of competing stimuli. Some evidence for top-down influences on extinction has been presented by Baylis et al. [1], who found that the selection bias in stimulus identification and awareness was strongly affected by task demands. These authors observed a paradoxical increase of extinction when the contralesional and the ipsilesional stimulus were identical on the feature that was pertinent for the task. Thus, when asked to identify the colour of two red stimuli, the patients reported only the ipsilesional stimulus. However, when the stimuli were of different colours, patients reported both stimuli. Attending to a particular stimulus feature thus affected contralesional extinction, suggesting a top-down modulation of representations competing for attention. In the present study, we compared perceptual effects of grouping by similarity in a detection task (Experiment 1) with the effect of a criterion change in an identification task (Experiment 2). We found that a criterion change and a change of task demands facilitated processing of the contralesional stimulus. In Experiment 3, we used a cueing procedure to direct the patient's attention to a particular stimulus dimension *before* stimulus presentation and observed a modulation of extinction by biased expectations of the patient.

## 2. Methods

### 2.1. Patient

AG is a 45-year-old man who suffered a small right hemispheric cerebral haemorrhage due to a probable arteriovenous malformation 4 months before the present study,

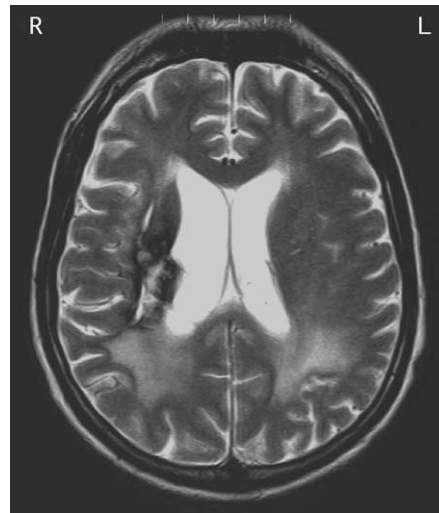


Fig. 1. T2-weighted MRI-scan of the patient showing a right periventricular white matter lesion.

resulting in a left hemiplegia and severe sensory loss of the left arm. A MRI scan documented the presence of subcortical damage of the right putamen, the external capsule, and the superior part of the internal capsule (Fig. 1). At the time of study, AG presented signs of moderate neglect in visual exploration tasks (five left omissions in the Bells-test [13]), and line bisection (mean 19.2% right deviation on 15–20 cm lines). The visual fields of the patient were intact on confrontation testing. Whereas he correctly detected stationary or moving unilateral visual stimuli, he would only report the right stimulus on bilateral stimulation. This severe left visual extinction was further examined in the present study. AG gave written consent before participating in the experiments. This study was approved by the ethical committee of the University of Geneva.

### 2.2. Experiment 1

#### 2.2.1. Material and procedure

Experiment 1 was designed to measure the rate of visual extinction in AG and its possible modulation by perceptual grouping. Stimuli were green or red, squares or diamonds. Squares were 3.5 cm wide; diamonds were created by rotating the squares by 45°. Isoluminance of the colours was determined with a light meter. The stimuli were presented on black background with the inner border presented at 1 cm from fixation (visual angle  $\sim 1^\circ$ ). Four conditions were created for the bilateral trials: stimulus pairs with the same colour and the same form (condition SC/SF), different colour—same form pairs (DC/SF), same colour—different form pairs (SC/DF) and different colour—different form pairs (DC/DF). Bottom-up grouping by similarity would predict the least contralesional extinction in the SC/SF condition and most extinction in the DC/DF condition. Based on the findings of Baylis et al. [1] we could also expect the

reverse, namely, increased extinction with similar stimuli, though only if increased extinction with similar stimuli does not depend on the task.

There were 36 unilateral left and right trials, 44 bilateral trials in either of the SC/SF or DC/SF conditions, 24 bilateral trials in either of the SC/DF or DC/DF conditions as well as 26 catch trials with no stimulus present. Stimuli were presented for 150 ms in pseudo-random order (no more than three unilateral or bilateral presentations in succession). The patient sat at a distance of ~60 cm from the screen in a dim room. Every trial was initiated by the appearance of a fixation cross in the middle of the screen. One experimenter controlled fixation and announced every trial verbally. After having checked that the patient maintained stable fixation, the experimenter released a stimulus presentation by pressing the mouse button. The patient indicated whether he saw two, one left, one right or no stimulus; colour and form were therefore irrelevant. Before starting the experiment, AG was given 50 practice trials in which one experimenter controlled the fixation and gave verbal feedback whenever the patient made an eye movement. After a few practice trials gaze fixation was reliable and eye movements were no longer observed. In this way it was assured that a stimulus would only be presented when AG fixated the central cross.

### 2.2.2. Results

The patient neither misidentified stimuli nor produced false positive responses on catch trials. All errors were misses. AG detected 28/36 unilateral left stimuli and all 36 unilateral right stimuli. The important aspect of his performance concerns his poor detection of left items in bilateral displays (13/136 trials). The critical comparison between the detection of left stimuli in unilateral left (22.2% missed) and in bilateral displays (89.7% missed) was highly significant ( $\chi^2(1) = 73.0$ ,  $P < 0.0001$ ), indicating severe left extinction. Contralesional detection performance did not differ between the four conditions (SC/SF = 4/44; DC/SF = 3/44; SC/DF = 3/24; DC/DF = 3/24; Fisher's exact test, all  $P = n.s.$ ), suggesting that similarity by colour or form did not afford significant grouping when these features were irrelevant to the task.

## 2.3. Experiment 2

### 2.3.1. Material and procedure

Experiment 2 addressed the question of whether a grouping effect would emerge when AG was forced to characterise the perceptual features of the contralesional stimulus rather than indicating only its presence. A second aim was to test whether a perceptual grouping effect would depend on the number of features reported by the patient (one or two features). The patient was explicitly told that this time always two stimuli would be presented, and that he would be asked to identify features of the left or right stimulus even if he doubted whether he had seen anything. In this way we hoped that AG would adopt a less conservative decision

criterion than in Experiment 1. Fixation was controlled in the same way as in the previous experiment. There were 96 presentations with stimuli grouped by colour (48 in conditions SC/SF and SC/DF) and 96 presentations with stimuli grouped by form (48 in conditions SC/SF and DC/SF). Note that in the SC/SF condition stimuli grouped by colour and by form. In Experiment 2a, immediately after each stimulus presentation a word indicating the side of the display (left or right) was presented at fixation, and AG was prompted to report both features (colour and form) on the relevant side (e.g. "LEFT?"). Since the patient always indicated both features, he identified 48 times the colour and 48 times the form on either display side. AG did not know in advance whether he had to identify the left or right stimulus. The stimulus to be identified was determined pseudo-randomly with no more than three times the same side in succession. AG was allowed to guess when feeling uncertain. In all other aspects the procedure was the same as in Experiment 1.

Experiment 2b followed the same procedure as Experiment 2a except that immediately after stimulus presentation a cue indicating the side (left or right) and the feature (colour or form) of the display was presented at fixation, and the patient was prompted to report the relevant feature on the relevant side (e.g. "LEFT COLOUR?"). Since the patient always indicated only one feature, he identified 24 times the colour and 24 times the form on either display side.

### 2.3.2. Results

Table 1 shows the patient's performance for the grouped and ungrouped presentations and Fig. 2 summarises the results of Experiments 2a and 2b.

*Experiment 2a:* AG identified in 68/96 trials the colour of the left stimulus correctly, which is significantly better than chance ( $\chi^2(1) = 8.7$ ,  $P < 0.01$ ). In contrast, form identification of left-sided stimuli was correct in only 54/96 trials, which is not significantly different from chance ( $\chi^2(1) = 0.8$ ). As Fig. 2 indicates, there was an advantage in performance of displays grouped by colour or form over ungrouped displays. In fact, only the grouped displays yielded a performance significantly better than chance (grouped:  $\chi^2(1) = 8.7$ ,  $P < 0.01$ ; ungrouped:  $\chi^2(1) = 0.8$ ). Importantly, the features of grouped stimuli were significantly better recog-

Table 1  
Results of Experiments 2a and 2b<sup>a</sup>

Identified feature	Experiment 2a		Experiment 2b	
	LVF	RVF	LVF	RVF
Colour				
Grouped	38/48 (79.2)	48/48 (100)	19/24 (79.2)	24/24 (100)
Ungrouped	30/48 (62.5)	48/48 (100)	12/24 (50)	24/24 (100)
Form				
Grouped	30/48 (62.5)	33/48 (68.8)	15/24 (62.5)	18/24 (75)
Ungrouped	24/48 (50)	33/48 (68.8)	12/24 (50)	19/24 (79.2)

LVF/RVF: left/right visual field.

<sup>a</sup> Percent correct is given in parenthesis.

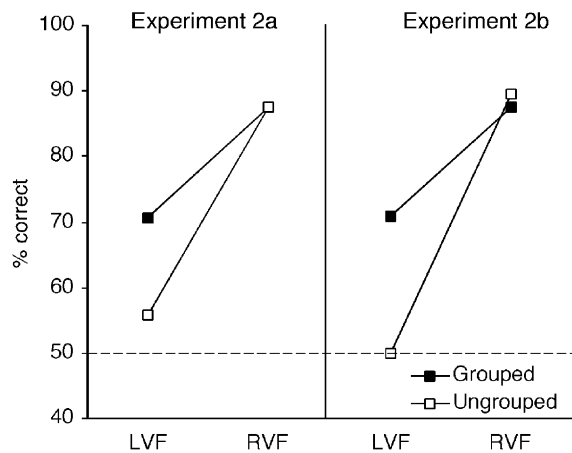


Fig. 2. Percent of trials in Experiment 2 on which stimulus features in the grouped and ungrouped displays were correctly identified in the left (LVF) and right (RVF) visual field. In Experiment 2a AG identified on each trial both features of one stimulus (colour and form), whereas on each trial in Experiment 2b he identified a single feature (colour or form). The dashed horizontal line represents chance performance.

nised than the features of ungrouped stimuli (70.8% versus 56.3%,  $\chi^2(1) = 4.4$ ,  $P < 0.05$ ; see Fig. 2). As Table 1 shows, this advantage of grouped over ungrouped displays was present for colour and form. The grouping effect was comparable between displays with identical relevant features only (SC/DF and DC/SF) and displays with identical relevant and irrelevant features (SC/SF; 68.8% versus 72.9%;  $\chi^2(1) = 0.2$ ), indicating that similarity of the irrelevant stimulus feature did not contribute to the observed grouping effect.

*Experiment 2b:* AG identified the left colour in 31/48 trials and the left form in 27/48 trials, which is not different from chance (colour:  $\chi^2(1) = 2.1$ ; form:  $\chi^2(1) = 0.4$ ). However, as Fig. 2 shows, identification of left-sided stimuli was better in grouped than in ungrouped displays. Only the grouped displays yielded a performance significantly better than chance (grouped:  $\chi^2(1) = 4.4$ ,  $P < 0.05$ ; ungrouped:  $\chi^2(1) = 0$ ). In addition, performance with grouped displays was significantly better than in ungrouped displays (70.8% versus 50%,  $\chi^2(1) = 4.4$ ,  $P < 0.05$ ; see Fig. 2). As in Experiment 2a, the advantage of grouped over ungrouped displays was present for both features (Table 1), and the grouping effect was comparable between displays with identical relevant features only (SC/DF and DC/SF) and displays with identical relevant and irrelevant features (SC/SF; 75% versus 66.7%;  $\chi^2(1) = 0.4$ ).

*Comparison of Experiments 2a and 2b:* In order to test whether reporting two features (as in Experiment 2a) and reporting only one feature (Experiment 2b) yielded different results, we performed a comparison of overall performance and performance in the grouped and ungrouped displays between both experiments. None of these comparisons reached significance (overall: 63.5% versus 60.4%,  $\chi^2(1) = 0.3$ ; grouped only: 70.8% versus 70.8%,  $\chi^2(1) = 0$ ; ungrouped

only: 56.3% versus 50%,  $\chi^2(1) = 0.5$ ), suggesting that AG had a comparable performance when reporting both or when reporting only one feature of the contralesional stimulus.

## 2.4. Experiment 3

### 2.4.1. Material and procedure

While the first two experiments examined the modulation of extinction by perceptual characteristics of the display (Experiment 1) or by task demands (Experiment 2), Experiment 3 assessed whether AG's performance would be modulated by his attentional set, i.e. expectations induced before presenting the stimuli. The critical question was whether AG's identification of the contralesional stimulus would be enhanced when his attention was oriented to a single feature before stimulus presentation.

As in Experiment 2, there were 48 bilateral presentations of each of the four conditions SC/SF, DC/SF, SC/DF and DC/DF, yielding 96 presentations with stimuli grouped by colour and 96 presentations with stimuli grouped by form. A trial was initiated by a fixation cross appearing on the screen. The cross was followed by a cue (e.g. the word "COLOUR?"), presented for 1000 ms at fixation. The stimulus display was flashed for 150 ms 1 s after disappearance of the cue, yielding a stimulus-onset asynchrony (SOA) of 2000 ms. Immediately after stimulus presentation, a question appeared on the screen indicating the side and the feature of the stimulus that the patient had to report. The question was either coherent (e.g. "LEFT COLOUR?") or incoherent (e.g. "LEFT FORM?") with the cue. On either side, there were 32 coherent (valid) questions and 16 incoherent (invalid) questions with grouped and ungrouped displays. AG was told that most of the cues were coherent with the question and that he could enhance his performance when focusing on the feature indicated by the cue.

This procedure allowed investigating two questions. The first was whether AG would show a "validity effect", that is whether his extinction on valid trials would decrease in comparison to invalid trials. The second question concerns the comparison between the influence of bottom-up and top-down processes on contralesional extinction. If bottom-up processes modulate extinction despite the biased expectations of the patient, grouped displays should produce better results than ungrouped displays. However, if the top-down validity effect is more important than the perceptual grouping effect, there should be no difference between grouped and ungrouped displays.

### 2.4.2. Results

The results are presented in Table 2 and Fig. 3. AG correctly identified the left colour in 36/48 and the left form in 25/48 trials. Only colour identification was better than chance (colour:  $\chi^2(1) = 6.4$ ,  $P < 0.05$ ; form:  $\chi^2(1) = 0.1$ ). However, as Fig. 3 shows, identification of both features of the contralesional stimulus was significantly better in valid than in invalid trials ( $\chi^2(1) = 5.8$ ,  $P < 0.05$ ),



Table 2  
Results of Experiment 3<sup>a</sup>

Identified feature	LVF	RVF
Grouped		
Valid	25/32 (78.1)	27/32 (84.4)
Invalid	8/16 (50)	15/16 (93.8)
Ungrouped		
Valid	21/32 (65.6)	27/32 (84.4)
Invalid	7/16 (43.8)	14/16 (87.5)

LVF/RVF: left/right visual field.

<sup>a</sup> Percent correct is given in parenthesis.

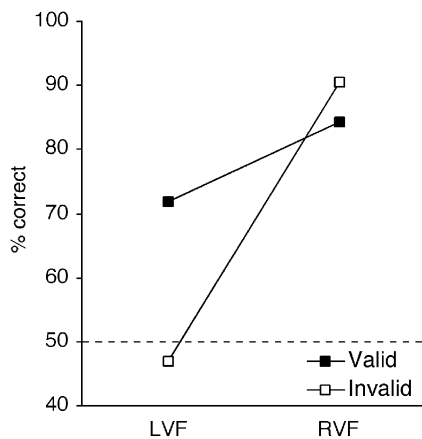


Fig. 3. Percent correct identifications of features of the left (LVF) or right (RVF) stimulus after valid or invalid cueing (Experiment 3). The dashed horizontal line represents chance performance.

consistent with a validity effect. Only performance in valid trials was significantly different from chance (valid:  $\chi^2(1) = 6.4$ ,  $P < 0.05$ ; invalid:  $\chi^2(1) = 0.1$ ). A validity effect was found for both features (size of the validity effect: 28.1% for colour and 21.9% for form) and for grouped as well as ungrouped displays (size of the validity effect: 28.2% for grouped and 21.9% for ungrouped displays).

We also examined the influence of bottom-up grouping in comparing the grouped with ungrouped displays. The performance in both of these was not significantly different from chance, although it approached significance in the grouped condition (grouped:  $\chi^2(1) = 3.5$ ,  $P < 0.07$ ; ungrouped:  $\chi^2(1) = 0.7$ ). Importantly, there was no significant difference between performance in grouped and ungrouped displays ( $\chi^2(1) = 1.1$ ). In sum, these results suggest that bottom-up grouping by perceptual factors was not of the same importance as in Experiment 2 when processing of relevant features was enhanced by top-down cues.

### 3. Discussion

Previous studies have demonstrated that visual extinction could be reduced by bottom-up grouping factors such as similarity of shape [31] or polarity [14]. Our patient's left

visual extinction was not affected by similarity of colour and shape in a task requiring detection and localisation of the contralesional stimulus (Experiment 1). In contrast, AG had reduced contralesional extinction in the identification task of Experiment 2 when both stimuli grouped by colour or form. It is unlikely that this effect reflects a bias to systematically report the features of the ipsilesional stimulus since such a bias would lead to a performance *worse* than chance in the condition with different ipsilesional and contralesional features (i.e. the ungrouped condition of Experiment 2). Since AG's performance in the ungrouped condition was at chance or slightly better (61.4% in Experiment 2a and 50% in Experiment 2b), the results rather reflect a grouping effect than the tendency to report ipsilesional stimulus features. Grouping by similarity was observed for stimuli grouped by colour and stimuli grouped by form (see Table 1), although form identification was much more difficult for AG (even for stimuli presented to his ipsilesional visual field), reflecting the severe visual-spatial deficits of the patient.

Previous studies reporting evidence for perceptual grouping by factors like collinearity [14,20,25] or polarity [14] used detection by localisation or counting as performance measure. A failure to report a contralesional stimulus in these paradigms is likely to reflect complete extinction of that stimulus from awareness. In contrast, a failure to report a contralesional feature in an identification task (Experiment 2) does not necessarily reflect complete absence of knowledge. Degraded information may still be represented, and expectations of the patient may affect further processing of this degraded knowledge. Except for the absence of unilateral displays, Experiment 2 used exactly the same (bilateral) displays as Experiment 1. Therefore, the observed grouping effect cannot be explained by perceptual factors only. An explanation in terms of a subjective criterion shift may better account for these findings. Our results suggest that a weak representation of the contralesional stimulus was not sufficient to generate a response in Experiment 1. In contrast, in Experiment 2 the patient was explicitly told that always two stimuli would be presented, and that he would be asked to identify features of the left or right stimulus even if he doubted whether he had seen anything. This advance knowledge and the fact that he gave forced-choice answers may have facilitated AG's attempts to identify weakly represented contralesional stimuli. The contrast between the results of Experiment 1 and 2, using the same displays, but differing with respect to the instructions and task demands, suggests that the observed grouping effect was due to a shift of AG's subjective response criterion. Comparable adjustments of response criteria have been reported in healthy subjects expecting a pre-specified number of targets [15]. The present experiments specifically tested grouping by similarity, but it would be interesting to examine whether a comparable modulation of extinction could be observed with other grouping factors.

The present results contrast with the observations of Baylis et al. [1] and Vuilleumier and Rafal [30], who

observed a significant *increase* of extinction by stimulus similarity when patients identified features of contralesional and ipsilesional stimuli. The difference in results reflects how task demands may affect the processing of stimuli competing for attention. Baylis et al. [1] presented red or green letters and asked their patients to report the colour or the form of both stimuli. When both stimuli were identical (e.g. both red) with respect to the feature that patients attempted to identify (e.g. colour) the patients showed increased contralesional extinction in comparison to when the stimuli were different (e.g. red and green). Vuilleumier and Rafal [30] instructed their patients to count the number of stars present among one, two, or four stars or triangles. Similarly, these authors observed increased extinction when a contralesional star was paired with an ipsilesional star in comparison to when the ipsilesional stimulus was a triangle. In contrast to these two studies our patient identified only one stimulus on each trial. Thus, both studies observing *increased* extinction with identical items required the patient to identify the ipsilesional and contralesional stimulus on each trial, whereas in our study *decreased* extinction was associated with processing limited to the contralesional stimulus. The identity of an ipsilesional stimulus which the patient attempts to identify thus seems to interfere with the identification of the contralesional stimulus, whereas it facilitates its identification when the patient is not required to identify the ipsilesional stimulus. These results suggest that preattentive parsing by stimulus similarity may affect performance positively only when patients do not explicitly process the ipsilesional attributes involved in the parsing process. This conclusion is in accord with findings of decreased extinction when patients performed detection or localisation tasks [14,19–30,31] and with the observation of decreased extinction when patients were instructed to ignore the ipsilesional stimulus [21].

A further finding of this study is that AG's identification of a contralesional stimulus feature was better when he expected to identify this feature than when he expected to identify the other feature (Experiment 3). The cueing paradigm used in Experiment 3 resembles the paradigm originally applied by Posner et al. [26] to study spatial orienting of attention. These authors used spatial cues in a simple reaction task to provoke covert ipsilesional or contralesional shifts of attention before the appearance of the target and observed an increased cue-validity effect (i.e. an advantage of ipsilateral cueing over contralateral cueing) in patients with parietal damage when targets appeared on the contralesional side after ipsilesional cueing. In contrast to the paradigm of Posner et al., the cues in the present Experiment 3 did not provoke a *spatial* shift of attention, but rather facilitated processing of relevant object attributes in comparison to attributes that had not been cued (feature-validity effect). A possible mechanism of this effect is that focusing of attention on a stimulus feature primed the perceptual trace of this feature compared to a condition where the patient's attention was divided between two features, again suggesting a

performance cost due to any additional processing with limited attentional resources.

Similar top-down effects on processing of neglected or extinguished information have been observed in other studies. For example, Smania et al. [27] observed that predictability of the location of visual stimuli speeded up detection times of stimuli both in the unaffected as well as the affected visual field, indicating spared voluntary shifting of attention. Duncan et al. [10] found that neglect patients were able to use colour as top-down cue to identify contralesional targets in a partial report task despite being unable to identify the colour of contralesional stimuli explicitly. Concerning extinction studies, consider again Baylis et al. [1] observation of a paradoxical increase of extinction when the ipsilesional and contralesional stimulus were coherent on the feature that the patient was attempting to identify. In this study, whether the colour of the two stimuli was identical or not, did not affect identification of form (and vice versa), suggesting that once attention was engaged with processing of a particular feature (form), the other feature (colour) did not interfere with processing of the display. In another study, Danckert et al. [4] found that flankers in the neglected visual field of a patient with parietal damage affected his identification of a central target only when they were identical with the target on the attended feature. In control participants, Corbetta et al. [3] found that attention focused on one of three stimulus features enhanced sensitivity to detect a slight change in this feature in comparison to a condition in which attention was divided between all three features. These results are consistent with our observation that contralesional identification of a stimulus feature was enhanced only, when attention had been focused on this feature prior to stimulus presentation.

Our results have two implications. First, they demonstrate that expectations of the patient may influence his identification of the contralesional stimulus. In situations of double simultaneous stimulation, contralesional stimuli may activate a weakened representation rather than being completely "extinguished". This weakened representation might be revealed when using a more sensitive task [30] or when modulating the decision criterion of the patient, suggesting that competition between stimuli is not only influenced by perceptual characteristics of the display but also by task demands and expectations of the patient.

Second, the validity effect observed in Experiment 3 suggests that advance information may facilitate processing of specific object attributes. This effect implies that processors of particular stimulus dimensions (e.g. form or colour) may be primed to enhance the identification of this dimension even if the stimulus location is not a priori known. The facilitation of contralesional recognition when attention is focused on a single feature might reflect the liberation of resources initially engaged in processing of the uncued feature. Comparative effects of enhancement of processing by selective attention have been found in recent neurophysiological studies. For example, when an animal directs his at-

tention to a preferred stimulus of a cell in V4 or the inferior temporal lobe, the activity of the cell will increase whereas it will decrease with a shift of attention to a non-preferred stimulus, although both stimuli are within the receptive field of the cell [2,23,28]. Since V4 and the inferior temporal lobe are involved in form, pattern, and colour analysis, such attention-dependent modulations of cell activity suggest a possible neurophysiological mechanism for attentional selection of objects that are pertinent to a task. Functional brain imaging studies [17,18,24] found activity associated with spatial cueing in the superior frontal cortex, the superior temporal cortex, and the posterior cingulate cortex, suggesting that a network of regions outside the parietal lobe is involved in top-down modulation of attention. Further, recent studies suggest that non-spatial allocation of attentional resources specifically activates regions of the parietal lobe and thalamic pulvinar, structures that were not activated by spatial cues [18]. It is possible that the preservation of these regions in our patient was crucial for the occurrence of a non-spatial cueing-effect.

In summary, our study shows that bottom-up modulation may not always be strong enough to enhance contralesional detection. We observed a recovery of extinction based on a criterion shift of the patient (Experiment 2) or on the expectation of a specific stimulus feature (Experiment 3). These results demonstrate that attention may enhance processing of specific object features and thus diminish a severe spatial attentional bias.

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