

VISUAL EXTINCTION OF SIMILAR AND DISSIMILAR STIMULI: EVIDENCE FOR LEVEL-DEPENDENT ATTENTIONAL COMPETITION

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Repetition blindness (RB) is the failure to report a visual stimulus presented shortly after a first occurrence of the same stimulus (Kanwisher, 1987). A similar phenomenon is that visual extinction, the failure to identify a contralesional stimulus presented simultaneously with an ipsilesional stimulus, increases with increasing similarity between the contralesional and ipsilesional stimulus (Baylis, Driver, & Rafal, 1993). We report a patient who, after a right parietal stroke, presented increased extinction for letters in repeated (e.g., A + A) than in unrepeated (e.g., T + U) displays. Increased extinction due to RB was observed in all experimental conditions probing item identification and varied between 5.4% and 40.6% across conditions. RB was unaffected by temporal modulation of the display, but was significantly reduced when stimuli grouped by a surrounding contour. Identification of contralesional repeated and unrepeated letters could be enhanced by auditory cues presented prior to the visual display. These results suggest that perceptual processing of extinguished stimuli that are similar to the stimulus presented on the preserved side is relatively unimpaired, but that the patient fails to ascribe to the stimulus a separate identity, supporting the distinction between type recognition and token individuation (Kanwisher, 1987). The extinction patterns for similar and dissimilar stimuli indicate that competition for attentional selection does not only occur at low (perceptual) levels, but also at higher processing levels, suggesting the presence of attentional competition on different levels of analysis.

INTRODUCTION

Current theories of selective attention posit that the limited capacity of the visual system leads to a competition for attention between different elements of a visual display (Corbetta, Miezin, Dobmeyer, Shulman, & Petersen, 1991; Desimone, 1999; Duncan, 1999; Duncan, Humphreys, & Ward, 1997; Kastner & Ungerleider, 2001). Among the multitude of sensory signals processed by the visual system, only those capturing sufficient attention

will be selected for conscious vision (Desimone & Duncan, 1995). However, since the visual system prefers some stimuli to others, this competition for selection is biased. Support for this theory comes from clinical studies of patients showing visual extinction following unilateral brain damage. These patients report single visual stimuli briefly presented in the ipsilesional or contralesional visual field. However, they fail to report a contralesional stimulus presented simultaneously with an ipsilesional stimulus (Driver & Vuilleumier, 2001; Karnath,

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1988). Thus, visual extinction represents a pathological selection bias in favour of the ipsilesional stimulus due to diminished processing capacity of the damaged hemisphere for the contralateral space.

Several studies demonstrated that visual extinction might be modulated by manipulations affecting the relation between the two simultaneously presented stimuli. The majority of these studies examined modulation of extinction by low-level (perceptual) manipulations. For example, Ward, Goodrich, and Driver (1994) found that extinction of a contralesional bracket diminished significantly when the bracket was paired with an ipsilesional bracket than when it was paired with a dot. This result suggests that two similar stimuli may be perceived as belonging to a group and hence be selected together more easily than two dissimilar stimuli. Similar results have been reported with other grouping factors, such as connectedness (Driver, Mattingley, Rorden, & Davis, 1997; Humphreys, 1998), brightness (Gilchrist, Humphreys, & Riddoch, 1996), collinearity (Gilchrist et al., 1996; Pavlovskaya, Sagi, Soroker, & Ring, 1997), or surroundness (Humphreys, 1998).

Other studies examined modulation of extinction by high-level factors. Ward et al. (1994) found that two stimuli in a familiar configuration (an arrow: →) grouped better than the same stimuli in an unfamiliar configuration (e.g., |^). Vuilleumier (2000) reported that faces are less likely to be extinguished than equivalent oval shapes in which eyes, nose, and mouth have been scrambled. A comparable finding has been reported by Ward and Goodrich (1996), who found an advantage of intact objects in comparison to nonobjects consisting of scrambled parts of real objects. Finally, Vuilleumier and Sagiv (2001) reported a reduction of extinction when two identical stimuli (e.g., two circles) were seen as parts of a larger configuration (the eyes of a face) than when seen as an isolated display. In sum, these studies suggest that extinction might be modulated at different processing levels: a structural level (dealing with perceptual characteristics) and a conceptual level (dealing with high-level perceptual or semantic characteristics).

In most of these studies extinction was examined with discrimination or localisation paradigms:

Patients were required to answer whether they saw none, one, or two stimuli (discrimination) or whether something appeared on the left, right, or both sides (localisation). Since no identification was required, it is not clear whether the examined low-level and high-level grouping factors enhanced only basic sensory processing or also affected stimulus recognition. One of the first studies (Baylis et al., 1993) examining identification of stimuli grouped by perceptual factors (colour or form) reported a surprising finding. The authors presented red or green letters and asked patients to report their colour or form. When the identified feature (e.g., colour) was identical (e.g., both letters were red), the extent of extinction *increased* in comparison to when the feature was different (e.g., red and green). Thus, perceptual grouping lead to increased extinction in identification, which contrasts with findings of decreased extinction of grouped stimuli in discrimination/localisation (e.g., Gilchrist et al., 1996; Humphreys, 1998; Ward et al., 1994).

As other studies using different paradigms showed, this increased extinction of repeated stimuli is a robust finding (Vuilleumier & Rafal, 1999, 2000), and closely resembles the phenomenon of *repetition blindness* (RB) described by Kanwisher (1987). In this initial study, Kanwisher presented sentences in rapid serial visual presentation to healthy subjects (e.g., "When she spilled the ink there was ink all over") and instructed them to report all words. She found that when the first occurrence of a target was attended to, participants had difficulty in detecting its second occurrence shortly later. RB has since been found with other types of material, such as colours, forms, or letters distributed across time and space (Kanwisher, 1991). Further, using masked stimuli, Kanwisher, Driver, and Machado (1995) found similar results to Baylis et al. (1993) with healthy participants, with the difference that RB affected discrimination accuracy and not detection performance. Thus, RB seems to represent a general failure of the visual system to cope with repeated occurrences of the same item. In order to account for her results, Kanwisher (1987, 1991) made a distinction between *type recognition* and *token individuation*: according to her, participants were able to recognise the *type*

of the repeated stimulus (i.e., its physical properties such as form or colour), but they were unable to individuate it as a separate token (i.e., to give it an identity separate from the first target).

In analogy to Kanwisher's token individuation hypothesis, Baylis et al. (1993) concluded that their extinction patients had recognised the type of the stimuli, but were unable to individuate the contralesional stimulus and were therefore unaware of a separate contralesional stimulus sharing a feature with the ipsilesional stimulus. Since only identification requires token individuation, this hypothesis would explain the fact that stimulus similarity leads to increased extinction in identification (Baylis et al., 1993; Vuilleumier & Rafal, 1999, 2000), but not in detection/localisation (Gilchrist et al., 1996; Humphreys, 1998; Pavlovskaya et al., 1997; Vuilleumier & Rafal, 2000; Ward et al., 1994). In accord with these results, Kanwisher (1987) observed RB when participants attempted to identify a repeated word, but better identification (i.e., repetition priming) of a repeated word when its first occurrence had been ignored. Thus, RB seems to occur only when participants attentively process the identity of the first (or ipsilesional) stimulus. However, if the crucial difference explaining a detrimental effect of item similarity in some extinction studies and a beneficial effect in other studies is whether patients direct their attention to the ipsilesional item, it should be possible to observe a grouping effect in identification when the ipsilesional stimulus is ignored. This is what we found in a recent study with left extinction patient AG (Ptak, Valenza, & Schnider, 2002). The patient was shown unilateral or bilateral displays of red or green squares and diamonds. Similarity of the bilateral displays was systematically varied and the displays were coherent with respect to form (e.g., both squares) or colour (e.g., both red), or incoherent. On single trials, the patient identified one feature (e.g., colour) of the contralesional or ipsilesional stimulus. In significant difference to the studies reporting increased extinction with repeated stimuli (Baylis et al., 1993; Vuilleumier & Rafal, 1999, 2000), our patient was requested only to identify the contralesional stimulus (regardless of the presence of an ipsilesional stimulus), and was thus not required to

attend to the identical ipsilesional stimulus. AG identified a contralesional feature significantly better when it was identical with the ipsilesional feature (e.g., colour, when both stimuli were red). This effect reflected a real benefit of stimulus repetition and could not be explained by a bias to simply report the ipsilesional feature, since such a tendency was not evident in identification of dissimilar displays. These findings suggest that RB in extinction may reflect a capture of attention by the ipsilesional stimulus only when explicit identification is requested. In accord with this conclusion is the finding that extinction may decrease when patients are instructed to ignore the ipsilesional stimulus (Karnath, 1988). Further, the finding of RB only when patients attempted to *identify* the contralesional item (and not when they simply detected targets) suggests that RB might be due to competition at post-perceptual levels of analysis. The aim of the present study was therefore to examine to what extent low-level and high-level manipulations affect the detrimental effect of item similarity on identification of the contralesional stimulus. In several experiments, we evaluated extinction of identical or different letters in TG, a patient with visual extinction following right parietal stroke. In Experiment 1 a baseline of extinction with the material used in all experiments was established. Experiment 2 examined whether RB depended on the presentation times of the stimuli. We further investigated in Experiment 3 whether temporally asynchronous presentation of the stimuli affected RB. Experiments 4 and 5 evaluated to what extent RB could be modulated by perceptual or conceptual factors. Based on the results we will argue that identification of similar and dissimilar stimuli is subject to competitive interactions at different levels of analysis.

CASE REPORT

TG is a 75-year-old woman who suffered a right hemispheric stroke 3 months before this study. Her lesion is localised in the right posterior parietal region, sparing the optic radiations (see Figure 1). She has no motor deficits except for slight left arm

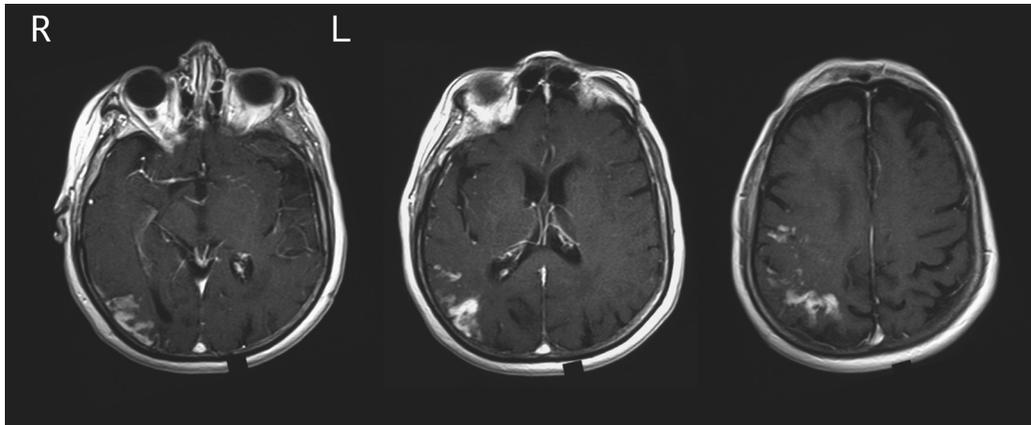


Figure 1. T1-weighted MRI scans of TG showing her right posterior parietal damage anterior to the intraparietal sulcus. The lesion comprised inferiorly the posterior part of the superior temporal sulcus (left) and superiorly the angular gyrus (middle) as well as the superior parietal lobule (right).

paralysis. Since her stroke, TG presented a moderate, but consistent, left spatial neglect across a range of tasks. Drawings were characterised by omissions of details on their left side. On line bisection, she showed a cross-over effect (Anderson, 1996), bisecting shorter lines (8–12 cm) on average 13% to the *left* of the middle and longer lines (20–24 cm) 7% to the *right* of the middle. In a cancellation task (the “Bells test”: Gauthier, Dehaut, & Joannette, 1989) the patient omitted 6/15 targets on the left, but none on the right side of the sheet. She showed neglect dyslexia with frequent omissions of entire words on the left side of the page and the left part of long words.

TG has full visual fields and detects a moving finger or a still object in her left visual field without difficulty. In contrast, she shows marked extinction of the left stimulus on double simultaneous stimulation. Extinction was evaluated systematically with small white dots ($\sim 0.8^\circ$) presented at three different eccentricities ($\sim 5^\circ$, 10° and 14°) for 150 msec on black background. TG was instructed to report whether she saw something on the left, on the right, or on both sides. The patient detected 17/24 (70.8%) isolated left, 23/24 (95.8%) right stimuli, and made no false positive responses in 20 catch trials. However, in 34/36 (94.4%) bilateral trials she reported the right stimulus only and in 2/34 (5.6%) trials the left stimulus only, showing severe contralesional extinction.

TG gave written consent before participating in this study. The study was approved by the ethical committee of the University Hospitals of Geneva.

EXPERIMENT 1: EXTINCTION MEASURED BY SPATIAL DISCRIMINATION OR IDENTIFICATION

The purposes of Experiment 1 were to measure the extent of TG’s extinction with the material that would be used in all following experiments (capital letters), and to evaluate whether discrimination and identification performance would differ for identical and different letters. Given the previous findings of RB only when patients attempted to identify stimuli, we expected increased extinction of identical contralesional letters in the identification task only.

Method

Stimuli were the capital letters A, B, F, H, L, P, T, and U. Half of these letters were symmetrical (A, H, T, and U) and the other half asymmetrical (B, F, L, P). Letters were 4.2 cm high and 2.6 cm wide,

except P and B, which were 1.6 cm wide. Letters were white on black background and were presented with their inner border at 8.5 cm left or right from fixation. In the bilateral trials, every letter was paired seven times with an identical letter (SAME-condition: e.g., A-A) and once with every other letter (DIFFERENT-condition: e.g., A-B). Thus, every letter was presented seven times on each side in both double conditions. There were five different display types: 20 catch trials (no letters present), 32 single left trials, 32 single right trials, 56 bilateral SAME trials, and 56 bilateral DIFFERENT trials.

Displays were generated on an Apple Macintosh computer with PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993) and presented on a 17 in VGA monitor with a refresh-rate of 75 Hz. TG was seated at 80 cm from the screen. At this distance, the stimuli subtended a visual angle of approximately $3^\circ \times 1.9^\circ$, with a distance of the inner border to fixation of 6° . TG was tested in a dim room. Stimuli were presented in pseudorandom order with no more than three presentations of the same condition in succession. Every trial was initiated with the appearance of a central fixation cross. The patient fixated the cross, the experimenter pressed the mouse button, and the fixation cross was replaced by a display for 50 msec. In the *discrimination task* the patient was asked to indicate the number of stimuli and to localise them. In the *identification task* she was asked to identify the stimuli and to localise them. TG was not requested to report the items in a specific order. Thus, for the display A-B, the patient was required to say "one left and one right" in the discrimination task and "A left, B right" in the identification task. TG received 20 practice trials on each task. Discrimination and identification were tested in two different sessions on the same day.

Results and discussion

The results are presented in Table 1. TG showed nearly perfect detection of unilateral left or unilateral right stimuli and she never reported a letter on catch trials. In contrast, she missed 95/112 (84.8%) left letters presented in bilateral displays.

The difference between detection rates with unilateral left and bilateral displays was highly significant (Fisher's test, $p < .0001$), indicating severe left extinction. The extinction rate for the left stimulus in SAME and DIFFERENT displays did not differ significantly, $\chi^2(1) = 0.6$.

Comparably severe extinction was found in the identification task (Table 1). TG never reported a letter on catch trials, but missed or misidentified 87/112 (77.7%) left stimuli. The difference between identification rates with unilateral left and bilateral displays was highly significant (Fisher's test, $p < .0001$). In contrast to the discrimination task, identification of the left letter in DIFFERENT displays was better, though not significantly, than identification in the SAME condition, $\chi^2(1) = 1.3$.

As Table 1 shows, the performance in the DIFFERENT condition differed according to whether the patient attempted to make a discrimination judgment or to identify the left letter. Whereas there was no task-effect in the SAME condition, identification was marginally better than discrimination in the DIFFERENT condition, $\chi^2(1) = 3.6$, $p = .057$.

When considering the identification performance of TG, it is important to exclude any systematic guessing bias that would not reflect "extinction" (i.e., the absence of awareness) but rather misidentification. One possibility is that the patient had a bias to different letters and therefore systematically reported a different letter on SAME trials. A more sensitive strategy would be to report the identical letter even on DIFFERENT trials, since on half the bilateral trials the identity of the contralesional stimulus was the same as the

Table 1. Number and percentage (in brackets) correct responses in Experiment 1

	Localisation	Identification
Catch (of 20)	20 (100%)	20 (100%)
Unilateral left (of 32)	30 (93.8%)	30 (93.8%)
Unilateral right (of 32)	31 (96.9%)	32 (100%)
Bilateral SAME (of 56)	10 (17.9%)	10 (17.9%)
Bilateral DIFFERENT (of 56)	7 (12.5%)	15 (26.8%)

ipsilesional, while every other letter combination was presented on 1/7 of the DIFFERENT trials. However, of the 46 errors that TG made in the SAME condition, the majority (41 or 89%) were omissions while only 3 (6.5%) were substitutions by another letter, excluding a strategy to report a different letter (see Table 3). Also, of the 41 errors made in the DIFFERENT condition, 31 (75.6%) were omissions and only 2 (4.9%) were substitutions of the contralesional letter by the ipsilesional letter, excluding a strategy to report the same letter. These results show that TG had no tendency to deduce the identity of the contralesional letter from the ipsilesional letter, excluding any guessing account. Thus, whether discrimination or identification is tested, TG's performance reflects "extinction" in the sense of complete unawareness.

Experiment 1 thus confirms that TG has a severe ipsilesional selection bias in discrimination and identification of visual stimuli. In contrast to her performance with unilateral left displays, TG only detected approximately 15% of the contralesional letters in double displays. Although the patient did not show significant RB, her results are in accord with previous studies (Baylis et al., 1993; Vuilleumier & Rafal, 1999, 2000) in that she shows a greater extent of extinction when identifying SAME stimuli than when identifying DIFFERENT stimuli.

Importantly, the patient presented nearly perfect localisation and identification of unilateral left stimuli, indicating that her ipsilesional bias is due to an attentional rather than a sensory deficit. Because of the latter finding, we felt confident that in the following experiments we could accurately measure attentional competition using bilateral presentations only, as has been done in previous studies (Ptak et al., 2002; Volpe, LeDoux, & Gazzaniga, 1979). Experiment 2 examined whether the absence of unilateral trials would yield different extinction rates to those found in Experiment 1. Since a difference between SAME and DIFFERENT displays tended to appear only in identification tasks (compare the results of Baylis et al., 1993; Vuilleumier & Rafal, 1999, and the present study), all the following experiments used identification as measure of extinction.

EXPERIMENT 2: THE INFLUENCE OF EXPOSURE DURATION ON RB IN EXTINCTION

Experiment 2 examined whether TG would show a comparable pattern of extinction as in Experiment 1 when unilateral presentations were omitted. This experiment further tested whether different exposure durations would create distinct patterns of extinction in the SAME and DIFFERENT conditions. Increasing the exposure time should be accompanied by an increasing degree of awareness of the contralesional stimulus, and should therefore enable better individuation of the contralesional stimulus.

Method

The material and method were the same as in Experiment 1 except that only bilateral displays (56 in the SAME and 56 in the DIFFERENT condition except for the 150 ms presentation time with 112 trials per condition) were presented, and that the exposure duration was varied: 50 ms, 150 ms, or 300 ms, tested in different trial blocks. The patient was instructed to identify every letter presented on the screen, but was not informed that two letters were always present.

Results and discussion

Table 2 presents the results. TG showed nearly perfect identification of the right letter, but identified only between 14% and 30% left letters correctly. The mean extinction rate at 50 ms exposure duration (85/112 trials, or 75.9%) was very similar to the rate found in the identification task of Experiment 1 (87/112 trials, or 77.7%). Thus, whether TG was shown bilateral displays mixed with unilateral displays or bilateral displays alone did not change her extinction rate. As Table 2 shows, at all three durations did TG identify more left letters in the DIFFERENT condition than in the SAME condition. A loglinear analysis with the two factors presentation time (50, 150 and 300 ms) and condition (SAME, DIFFERENT) was performed on the data (since the cell frequencies

Table 2. Number and percentage (in brackets) correct responses in Experiment 2

Presentation time	Side	SAME	DIFFERENT
50 ms (of 56)	Left	10 (17.9%)	17 (30.4%)
	Right	56 (100%)	54 (96.4%)
150 ms (of 112)	Left	18 (16.1%)	30 (26.8%)
	Right	111 (99.1%)	112 (100%)
300 ms (of 56)	Left	8 (14.3%)	11 (19.6%)
	Right	55 (98.2%)	56 (100%)

in a loglinear analysis are based on the same number of trials, the values in the 50 and 300 ms condition were doubled). Tests of partial association revealed a main effect of condition, $\chi^2(1) = 7.22$, $p = .01$, but not of exposure duration, $\chi^2(2) = 2.79$, and no significant interaction, $\chi^2(2) = 0.28$, indicating that an increase of exposure duration had no effect on RB in extinction.

As in Experiment 1, the majority of errors (87–100%) in the different experimental conditions were omissions (see Table 3 on p. 123). Also, only rarely did the patient report the ipsilesional letter in the DIFFERENT condition (6% across all presentation durations) or false identifications in the SAME condition (1.6%).

Thus, identification by TG is equivalent in Experiment 1, which included bilateral and unilateral trials, and the present experiment, which included only bilateral trials. The fact that the number of correct responses and the distribution of errors remained comparable suggests that TG did not attempt to base her answers more on guessing strategies in Experiment 2 than in Experiment 1 and that continuous presentation of bilateral trials does not appear to influence the overall level of extinction.

This experiment also shows that the increase of presentation time does not influence identification in the SAME and DIFFERENT condition differently. The absence of an effect of exposure duration suggests that changes in temporal characteristics of the display do not affect RB significantly in our patient. In order to examine the time-course of RB in extinction further, in Experiment 3 we modulated extinction by asynchronous presentation.

EXPERIMENT 3: THE INFLUENCE OF ASYNCHRONOUS PRESENTATION ON RB

Several studies have reported biased temporal order judgments of extinction patients when these were asked to indicate which of two stimuli was presented first. For example, in the study by Rorden et al. (Rorden, Mattingley, Karnath, & Driver, 1997) two extinction patients continued to say on most of the trials that the right item appeared first even when the left item led by 100–150 ms, and in a study by Robertson et al. (Robertson, Mattingley, Rorden, & Driver, 1998), the point of subjective simultaneity was achieved when the contralesional stimulus led by nearly 500 ms. Other studies found that the order of presentation not only influences temporal order judgments, but also the identification of contralesional stimuli (Baylis, Simon, Baylis, & Rorden, 2002; Di Pellegrino, Basso, & Frassinetti, 1997). The interesting aspect of these studies is that the highest levels of extinction were observed when the two stimuli were presented simultaneously, while the extent of extinction gradually decreased with increasing contralesional or ipsilesional lead (Baylis et al., 2002; Cate & Behrmann, 2002). These results indicate that the spatial bias of extinction patients might partly be due to slowed processing of visual stimuli in the contralesional visual field, and that temporally asynchronous presentation with the contralesional stimulus leading should affect the perceived salience of the contralesional stimulus. Experiment 3 examined whether an increase of perceived salience by asynchronous presentation would affect processing of contralesional stimuli in the SAME and DIFFERENT conditions to the same extent. The rationale for the manipulation of presentation asynchrony is that if extinction is due to low-level processes, an increase of contralesional stimulus salience should facilitate processing and enhance identification. In contrast, if extinction is due to post-perceptual processes it should less be affected by manipulations of the perceptual characteristics of the display. Based on these considerations, the present experiment attempted to evaluate whether extinction in the SAME and DIFFERENT

condition is due to competition at the same level of processing.

Method

The method was the same as in the 150 ms duration condition of Experiment 2 except that the stimulus onset asynchrony (SOA) varied. On one third of trials, the left and right stimulus were presented simultaneously (SOA 0), on one third the left stimulus led by 50 ms (SOA 50), and on one third the left stimulus led by 100 ms (SOA 100). There were 32 trials in each condition (SAME and DIFFERENT) at each SOA, yielding a total of 192 trials.

Results and discussion

Identification of the right stimulus was perfect in both conditions and at all three SOAs. The results for identification of the left stimuli are presented in Figure 2. As predicted, overall identification rate increased with increasing SOA (SOA 0: 27/64 or 42.2%; SOA 50: 29/64 or 45.3%; SOA 100: 32/64 or 50%). This increase in performance was mainly due to performance in the DIFFERENT condition, whereas identification of SAME stimuli remained stable (or even slightly decreased) across the three SOAs. A loglinear analysis with the factors SOA (0, 50, 100 ms) and condition (SAME, DIFFERENT) was performed. Tests of partial association revealed a main effect of condition, $\chi^2(1) = 10.08$, $p = .01$, but not of SOA, $\chi^2(2) = 0.42$. Although the interaction between SOA and condition did not reach significance, $\chi^2(2) = 1.11$, RB (i.e., the difference in extinction rates between the SAME and DIFFERENT conditions) appeared to increase with increasing SOAs (SOA 0: 15.6%; SOA 50: 40.6%; SOA 100: 37.5%). Therefore, we further compared the performances in the two conditions for every SOA. This comparison missed significance with SOA 0, $\chi^2(1) = 1.6$, but reached significance with SOA 50, $\chi^2(1) = 10.66$, $p < .01$, and SOA 100, $\chi^2(1) = 9$, $p < .01$, i.e., when attentional competition at the perceptual level diminished.

The distribution of error types did not differ between SOAs and conditions (SAME: 95–100%

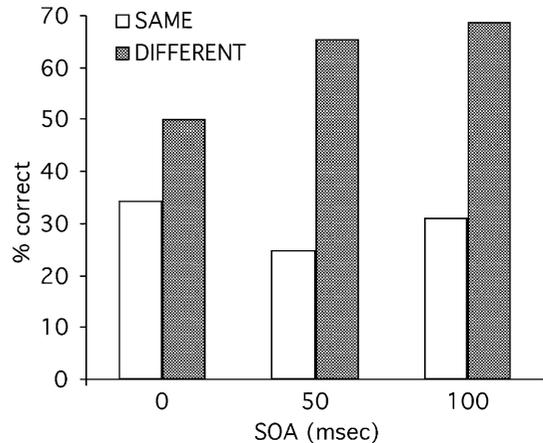


Figure 2. Percentage of left stimuli correctly identified depending on stimulus onset asynchrony (SOA) in the SAME/DIFFERENT conditions in Experiment 3.

omissions; DIFFERENT: 90–100% omissions) and was comparable to the previous experiments (Table 3 on p. 123).

Again, these results confirm that a contralateral letter in a display consisting of two identical stimuli is more easily extinguished than a letter that is different from the ipsilesional item. Across all three SOAs, TG showed a robust repetition effect on extinction. However, the extent of RB differed between SOA conditions, with most RB when the contralateral letter led by 50 or 100 ms, suggesting that an increase of perceptual salience does not eliminate, but rather increase the difference in extinction between identical and different items. Further, there was no evidence for a decrease of extinction in the SAME condition with increased SOA whereas there was a slight decrease of extinction in the DIFFERENT condition. Since increased SOA (and stimulus salience) should facilitate perceptual processing, these results do not support the conclusion that extinction in the SAME condition is due to competition between perceptual characteristics of the display. The question therefore is: At what level does competition between identical stimuli occur? The following experiments attempted to specify further the processing level that leads to competition between two identical stimuli.

EXPERIMENT 4: MODULATION OF RB BY PERCEPTUAL GROUPING

One possibility why an increase of stimulus salience did not lead to better individuation in the SAME condition of the previous experiment is that the manipulation of stimulus salience did not affect the *relation* between the ipsilesional and contralesional stimulus. According to Kanwisher (1991), token individuation of two identical stimuli necessitates the connection of one type with two tokens and thus takes into account the spatiotemporal relationship between two stimuli with identical properties. In the previous experiments the stimulus display consisted of two letters without any objective relation. It is possible that such a display encouraged local processing of each letter as a separate element. Kanwisher (1991) has shown that two repeated letters that were parts of a word (e.g., R in "transport") were less subject to RB than two letters in a nonword, suggesting that participants had processed the entire word rather than its individual letters. In Experiment 4 we tested whether encouraging global processing by perceptual grouping of the visual display would lead to diminished RB. As outlined in the Introduction, similar stimuli already share many of the low-level factors that lead to decreased extinction in detection tasks. For example, consider a display consisting of two white letters T; it is characterised by similarity, symmetry, brightness, and collinearity. Therefore, in order to increase perceptual grouping of the stimuli, we used a factor that does not directly affect perceptual characteristics of the stimuli, but rather their background, namely surroundness. It has been shown previously that surroundness can be a very potent grouping factor (Humphreys, 1998), even if the surrounding contour is illusory (Mattingley, Davis, & Driver, 1997).

Method

The method was the same as in the 50 ms duration condition of Experiment 2, except that half of the displays were presented surrounded by a white rectangle 18° wide and 8.5° high. There were 64 surrounded and 64 unsurrounded displays in the

SAME and the same number of presentations in the DIFFERENT condition, yielding a total of 256 trials.

Results and discussion

TG made only 3 errors in 256 trials (98.8% correct) when identifying ipsilesional stimuli. In contrast, her overall identification of contralesional stimuli was only 61/256 (23.8%). Across SAME and DIFFERENT displays, surroundness had no effect on contralesional extinction (surrounded 32/128 or 25% correct; unsurrounded 29/128 or 22.7% correct). However, as Figure 3 shows, surroundness affected identification in the SAME and DIFFERENT condition differently. We therefore performed a loglinear analysis with the factors surroundness (surrounded, unsurrounded) and condition (SAME, DIFFERENT). Tests of partial association revealed a nonsignificant main effect of surroundness, $\chi^2(1) = 0.14$, but a significant effect of condition, $\chi^2(1) = 8.59$, $p = .01$, and a significant interaction between both factors, $\chi^2(1) = 4.9$, $p = .05$. This interaction was due to the fact that there was a nonsignificantly detrimental effect of surroundness on DIFFERENT stimuli, $\chi^2(1) = 1.28$, but a significant facilitation of identification by surroundness in the SAME

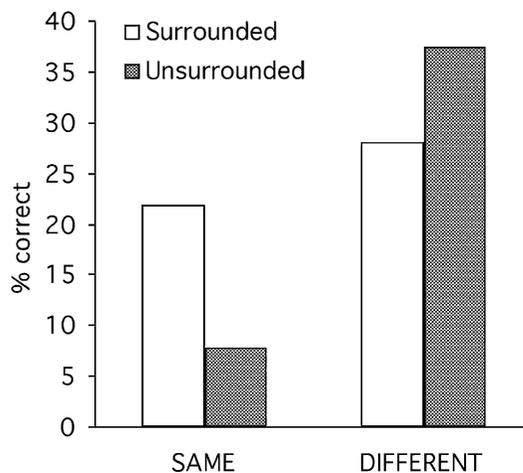


Figure 3. Percentage of left stimuli correctly identified in Experiment 4. Perceptual grouping by a surrounding contour enhanced performance only in the SAME condition.

condition, $\chi^2(1) = 5.01$, $p < .05$. Accordingly, the extent of RB was only significant when displays were not surrounded, $\chi^2(1) = 16.09$, $p < .0001$, and was significantly larger with unsurrounded (29.7%) than surrounded (6.3%) displays (Fisher's test, $p < .001$).

Before considering the implications of these results, it is important to exclude any guessing bias. In particular, the facilitation of identification in the SAME condition by surroundness might be due to a bias to systematically report the right stimulus whenever stimuli were surrounded. Such a bias should lead to a high number of ipsilesional letters reported in the DIFFERENT condition. However, as can be seen in Table 3 (see page 123), TG never did report the ipsilesional letter in the DIFFERENT condition, either with surrounded or unsurrounded displays. Indeed, the distribution of error types was comparable to the previous experiments with most of the errors omissions (SAME 90.8%; DIFFERENT 88.4%). We can therefore exclude a systematic bias and conclude that surroundness affected grouping of the display in the SAME condition.

The important finding of this experiment is that RB was significantly diminished when the contralesional and ipsilesional stimulus in the SAME condition were surrounded. Among different perceptual grouping variables affecting perception of contralesional stimuli in extinction patients, surroundness has a particular status because, unlike similarity, symmetry, brightness, or collinearity it does not directly manipulate perceptual features of the stimuli, but their background. Grouping by surroundness might be based on the fact that two stimuli in the environment that are surrounded by a contour are more likely to be two parts of the same object than two distinct objects. We could thus account for the significant grouping effect in the SAME condition in terms of a natural preference of the visual system to interpret surrounded stimuli as objects. The cognitive basis of this preference appears to be an automatic spread of attention from the edges of a figure across the whole segmented shape, which facilitates selection of the stimuli included within the shape (Driver & Baylis, 2000). The observed

decrease of extinction in the SAME condition could therefore reflect the allocation of attentional resources to the surface delimited by the boundaries of the surrounding shape, rather than to the individual letters. In other words, the decrease of RB reflects a shift from a local level of analysis (individual letters) to a global level (letters as parts of a segmented object). This effect of surroundness is similar to the observed decrease of RB when healthy subjects reported letters that were embedded in a word and appeared simultaneously, hence belonged to the same perceptual group (Kanwisher, 1991). A shift to a more global level of analysis could influence individuation by facilitating the spatial distinction of the two items and thus prevent their identities being assigned to a single stimulus.

Given that previous studies found that grouping by surroundness decreased extinction of dissimilar stimuli (Humphreys, 1998; Mattingley et al., 1997), it is more difficult to explain the absence of a grouping effect in the DIFFERENT condition. One possibility is that once analysis is shifted to a global level, perceptual grouping factors such as symmetry or similarity come at play and start to influence competitive interactions between the ipsilesional and contralesional stimulus. Since these grouping factors were much less present in the DIFFERENT condition, it did not profit from surroundness. However, it is also possible that TG was already performing at an optimal level in the unsurrounded condition, hence that no improvement was possible.

EXPERIMENT 5: TOP-DOWN INFLUENCES ON RB

In the Introduction, we discussed the finding that RB in extinction was only observed when patients identified the ipsilesional and contralesional stimulus on each trial, whereas grouping by similarity was associated with processing limited to the contralesional stimulus. Similarity thus impairs individuation of the contralesional stimulus when the patient identifies the ipsilesional stimulus (Baylis

et al., 1993), but it facilitates individuation when the ipsilesional stimulus is not identified (Ward et al., 1994). One way to explain this finding is that individuation of the contralesional stimulus fails because the attempt to generate a response to the ipsilesional stimulus necessitates too much attentional capacity. In accord with this hypothesis is the observation of Karnath (1988), that extinction decreases when patients are instructed to ignore the ipsilesional stimulus (although the effect appears to vary considerably across patients; see Vuilleumier & Rafal, 2000).

This hypothesis could be tested with an experimental manipulation in which attentional allocation is biased towards the ipsilesional or the contralesional stimulus. In our previous study, an extinction patient was cued to attend more to one of the two features (colour or form) of the stimuli (Ptak et al., 2002). The patient recognised the validly cued dimension of the contralesional stimulus better than an invalidly cued dimension, suggesting that focusing attention onto one dimension enabled allocation of relatively more attentional resources and hence better recognition. In Experiment 5, prior to stimulus presentation, the patient heard an auditory cue that was coherent with the ipsilesional stimulus (in the DIFFERENT condition only; ipsi-valid), the contralesional stimulus (in the DIFFERENT condition only; contra-valid), both stimuli (in the SAME-condition only; both-valid), or neither stimulus (both-invalid). Since one half of the auditory cues were valid and the other half invalid they did not predict the occurrence of a particular letter. The finding of a significant cueing effect would thus suggest that facilitation of contralesional identification did not depend on controlled shifts of attention.

Two comparisons were of interest: First, it was evaluated whether valid cueing of the contralesional letter would improve contralesional identification in comparison to valid cueing of the ipsilesional letter. This comparison provides a test of the hypothesis that the letter cues affect the distribution of attention across space. Second, we compared the effects of valid contralesional cueing (both-valid or contra-valid) with invalid cueing (both-invalid) in

the SAME and DIFFERENT condition. Since the letter cues and targets were presented in different modalities, a positive cueing effect would reflect post-perceptual activation of abstract letter-exemplars or facilitation of selection of the appropriate response. The finding of different cueing effects in the SAME and DIFFERENT condition would therefore indicate that competitive interactions occur at different levels in the two conditions.

Method

In this experiment, only those letters were used that TG could identify without difficulty when presented auditorily. Of the previously used letters, five were retained (A, H, L, and P), and two were added (E and K). The resulting stimulus set for the auditory cues (A, E, H, K, L, P, and U) was spoken by a male voice and recorded with sound sampling software. As the length of these cues varied between 300–400 ms, a silent period was included as filler at the end of the shorter cues in order to equalise their lengths to 400 ms. A pilot trial showed that TG was able to recognise each of these stimuli on each of six presentations. Auditory cues correctly predicting a visual stimulus are termed *valid* cues, whereas cues not predicting a stimulus are termed *invalid* cues. In the SAME condition, every letter was paired 10 times with an identical letter (e.g., A–A) for valid and for invalid trials. In the DIFFERENT condition, every letter was paired twice with every other letter (e.g., A–E) and appeared on either side on the same number of trials. In the SAME condition, cues were either identical with both stimuli (both-valid: 70 trials) or different from both stimuli (both-invalid: 70 trials). In the DIFFERENT condition, cues were either identical with the ipsilesional stimulus only (ipsi-valid: 84 trials), identical with the contralesional stimulus only (contra-valid: 84 trials), or different from both stimuli (both-invalid: 42 trials).

A single trial of the experiment consisted of the following sequence of events: TG first fixated a cross in the middle of the screen. The experimenter then pressed the mouse button, which released a presentation of the auditory cue (e.g., “A”). The

cue was displayed through the internal computer loudspeaker placed under the computer monitor in the midsagittal line of the patient; then, 800 ms after end of the cue, two letters were presented for 300 ms on the screen. The patient was told that before seeing letters on the screen, she would hear a letter that could either be the same as or different to one of the letters on the screen. She was then instructed to identify all letters presented on the screen. TG participated in two different sessions separated by one week for a total of 350 trials.

Results and discussion

In 350 trials, TG made only three errors in identification of the ipsilesional letter. In contrast, identification of the contralesional letter was severely and consistently impaired (66/350, or 18.9% contralesional letters were correctly identified). As Figure 4 shows, the degree of impairment strongly depended on the cueing condition. In the DIFFERENT condition, identification was significantly better with valid contralesional cues (30/84 or 35.7%) than with valid ipsilesional cues (7/84 or 8.3%); $\chi^2(1) = 18.34$, $p < .0001$. In the SAME condition, identification was significantly better with a valid cue (15/70 or 21.4%) than with an invalid cue (4/70 or 5.7%; Fisher's test, $p < .05$). In comparison, TG had identified 14.3% contralesional letters without cueing in the SAME condition and 19.6% in the DIFFERENT condition in Experiment 2, suggesting that valid cues had facilitatory and invalid cues inhibitory effects. These results could not be attributed to a guessing bias (e.g., to systematically report the cue letter) since the proportion of omission errors remained high in all cueing conditions (92–100%; see Table 3). To test the allocation of attention between stimuli in the various cueing conditions, we first compared the influence of both-invalid cues with ipsi-valid cues in the DIFFERENT condition. This comparison revealed a significant difference, $\chi^2(1) = 5.75$, $p < .05$, indicating that ipsilesional cues enhanced attentional allocation to the ipsilesional stimulus. Second, we evaluated the effect of a valid contralesional cue in a situation where ipsilesional cueing was constantly valid by

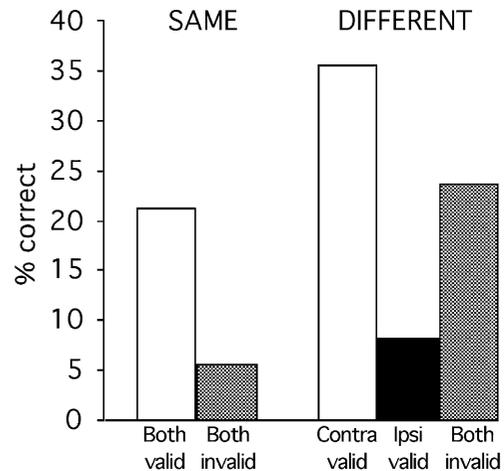


Figure 4. Percentage of left stimuli correctly identified in Experiment 5. Valid cueing of the left letter led to an increase of identification performance in the SAME and DIFFERENT condition in comparison to invalid cueing.

comparing performance with both-valid cues in the SAME condition with ipsi-valid cues in the DIFFERENT condition. This analysis also revealed a significant difference, $\chi^2(1) = 5.35$, $p < .05$. Valid ipsilesional cueing thus enhanced allocation of attention to the ipsilesional stimulus and exacerbated competition between stimuli only when the contralesional stimulus was invalidly cued. When, in addition to the ipsilesional letter, the contralesional letter was also validly cued, competition between stimuli was attenuated. The letter cues clearly affected distribution of attention between the ipsilesional and the contralesional stimulus.

Our second question was whether the size of the cueing effect was comparable between the SAME and DIFFERENT conditions. The size of the cueing effect was evaluated by comparing the both-invalid with the both-valid cue in the SAME condition and the both-invalid with the contra-valid cue in the DIFFERENT condition. In the SAME condition, the comparison was significant (Fisher's test, $p < .02$), while it missed significance in the DIFFERENT condition, $\chi^2(1) = 1.83$, $p = .18$. These results indicate that extinction in the SAME condition was more affected by between-modality

cueing than in the DIFFERENT condition, suggesting that competitive interactions between identical stimuli are more influenced by post-perceptual processes than the competition between dissimilar stimuli.

ANALYSIS OF ERROR TYPES IN ALL EXPERIMENTS

Table 3 provides a detailed analysis of errors made by TG when attempting to identify contralesional items. Error types were classified according to the following rules. An omission error was counted when TG said that she saw nothing. Identification errors were differentiated with respect to whether the same as the ipsilesional letter was reported (SAME substitution; only in the DIFFERENT

condition) or whether a false letter was reported (false identification). The last type of error was retained when TG reported seeing *something*, but could not identify the letter. Table 3 shows that the distribution of error types was very constant across the different experimental conditions. In all experiments, omission errors were the most frequent error types while the three other error types were relatively rare. Across the SAME conditions in all experiments, TG made 504 of 531 (94.9%) omission errors, 24 (4.5%) false identifications, and perceived, but could not identify, 3 (0.6%) items. Nearly identical results were observed in the DIFFERENT conditions. TG made 450 of 493 (91.3%) omissions, 21 (4.3%) substitutions of the contralesional by the ipsilesional letter, 17 (3.5%) false identifications, and 5 (1%) detections without identification. This distribution of errors

Table 3. Analysis of errors in all experimental conditions testing identification

<i>Experiment and condition</i>	<i>Total no. of errors</i>	<i>Omission</i>	<i>SAME substitution</i>	<i>False identification</i>	<i>Not identified</i>
<i>Experiment 1</i>					
50 ms (SAME)	46	41	–	3	2
50 ms (DIFF)	41	31	2	4	4
<i>Experiment 2</i>					
50 ms (SAME)	46	44	–	2	0
50 ms (DIFF)	39	34	4	1	0
150 ms (SAME)	94	90	–	3	1
150 ms (DIFF)	82	77	4	0	1
300 ms (SAME)	48	48	–	0	0
300 ms (DIFF)	45	42	2	1	0
<i>Experiment 3</i>					
0 ms (SAME)	21	20	–	1	0
0 ms (DIFF)	16	16	0	0	0
50 ms (SAME)	24	24	–	0	0
50 ms (DIFF)	11	10	1	0	0
100 ms (SAME)	22	21	–	1	0
100 ms (DIFF)	10	9	1	0	0
<i>Experiment 4</i>					
Surrounded (SAME)	50	44	–	6	0
Surrounded (DIFF)	46	39	0	7	0
Unsurrounded (SAME)	59	55	–	4	0
Unsurrounded (DIFF)	40	37	0	3	0
<i>Experiment 5</i>					
Both-valid (SAME)	55	55	–	0	0
Both-invalid (SAME)	66	62	–	4	0
Contra-valid (DIFF)	54	53	1	0	0
Ipsi-valid (DIFF)	77	71	6	0	0
Both-invalid (DIFF)	32	31	0	1	0

excludes two guessing accounts of the results of the patient, namely (1) that TG systematically reported the ipsilesional letter (which would lead to a high percentage of ipsilesional letters reported in the DIFFERENT condition; this error type accounted only for 4.3% of errors), and (2) that TG systematically reported a different than the ipsilesional letter (which would lead to a high percentage of false identifications in the SAME condition; this error type accounted only for 4.5% of errors).

GENERAL DISCUSSION

The finding that visual extinction can be modulated by perceptual grouping has repeatedly been interpreted as evidence for the preservation of early perceptual processing in spatial extinction (Gilchrist et al., 1996; Humphreys, 1998; Ward et al., 1994). Several grouping factors known to decrease extinction are present in displays consisting of two identical items (e.g., brightness, contrast, collinearity, or symmetry). The finding of *increased* extinction with similar stimuli is therefore of particular interest for theories of visual attention and selection.

Adding to previous reports (Baylis et al., 1993; Vuilleumier & Rafal, 2000), the present study provides further evidence that increased extinction of repeated stimuli is a behaviourally significant phenomenon. Eleven experimental conditions probed item identification in this study, and all found that identification was inferior in the SAME condition in comparison to the DIFFERENT condition, with the difference (i.e., the size of RB) varying between 5.4% and 40.6% across conditions. RB was independent of manipulations of the presentation time (Experiment 2) or of temporal asynchrony (Experiment 3) between the two stimuli. However, extinction of similar stimuli diminished when stimuli grouped by surroundness (Experiment 4) and when top-down cues affecting expectations of the patient were given (Experiment 5).

According to Kanwisher (1987) the mere finding of RB suggests that some characteristics of repeated stimuli must be relatively well recognised.

The relative preservation of perceptual processing (i.e., type recognition) of similar stimuli is a major point of her token individuation theory. The reason for concluding on relatively preserved item recognition is that in order to find a disadvantage in token individuation, similarity between two stimuli has first to be recognised. In accord with Kanwisher's proposal, we will argue that perceptual processing of similar contralesional stimuli is relatively more preserved than perceptual processing of dissimilar stimuli.

First, if processing of similar and dissimilar stimuli was absolutely equivalent, no difference in extinction between similar and different stimuli should ever be found. In order to observe increased extinction with similar stimuli, similarity must first be recognised. Second, RB was only observed in tasks probing stimulus identification (Baylis et al., 1993; Vuilleumier & Rafal, 1999, 2000). A study examining localisation and identification with the same material reported less extinction of identical stimuli in the localisation task and more extinction in the identification task, relative to dissimilar stimuli (Vuilleumier & Rafal, 1999, 2000; consider also the results of the present Experiment 1). This finding suggests that RB in extinction can only be observed in tasks requiring recognition and individuation, that is, a post-perceptual level of analysis. Third, repeated stimuli are characterised by equivalent brightness, symmetry, collinearity and, of course, similarity of shape. These grouping factors are less present (e.g., collinearity) or absent (e.g., symmetry) in dissimilar displays. For example, the letters in the display L+H are not similar, not symmetrical, not collinear, and even have slightly different brightness (because an H consists of relatively more primitive shape features than an L). All these grouping factors have been shown to enhance processing of the contralesional stimulus in extinction and neglect patients (symmetry, Driver, Baylis, & Rafal, 1992; brightness and collinearity, Gilchrist et al., 1996; similarity, Ward et al., 1994). Based on these findings we conclude that TG processes low-level perceptual features of contralesional similar stimuli better than those of dissimilar stimuli, indicating that RB in extinction is not due to more impaired perceptual processing

of similar than dissimilar stimuli. A fourth reason supporting our claim is the finding of intact top-down modulation of contralesional extinction in the SAME condition (Experiment 5), in accord with our previous report of top-down modulation of extinction (Ptak et al., 2002). Since cues and targets were presented in different modalities and the target displays remained constant across cueing conditions, we suppose that the auditory cues in Experiment 5 primed an abstract letter identity at the level of a modality-independent letter store. The observed cueing effect is therefore of a phonological or conceptual rather than a perceptual nature. Further, when comparing the sizes of the cueing effects we found evidence that the patient profited slightly more from between-modality cueing in the SAME condition, suggesting that extinction in this condition may be more modulated by phonological or conceptual factors than in the DIFFERENT condition.

These considerations do not only suggest that perceptual analysis of contralesional stimuli in identical displays is relatively well preserved, but also that it is more preserved than the analysis of the same stimuli in dissimilar displays. Based on the theoretical proposals by Kanwisher (1987, 1991) it could be concluded that extinction reflects impaired token individuation, with a greater impairment for identical displays. However, the assumption of a quantitative rather than a qualitative difference between processing of similar and dissimilar displays does not explain the differential effects found in Experiments 4 and 5, namely a decrease of extinction with a shift of the analysis level only in the SAME condition and a slightly greater cueing effect in this condition. These qualitative differences may better be explained by differential involvement of competition at higher processing levels. As we have argued, low-level perceptual processing of the contralesional stimulus appears to be relatively better preserved in similar displays than in dissimilar displays. However, if perceptual processing is better preserved, yet the degree of extinction of similar stimuli is higher, the performance drop with similar stimuli must be due to competition at higher processing levels. This conclusion is also supported by a recent

extinction study by Rafal et al. (Rafal, Danziger, Grossi, Machado, & Ward, 2002). These authors tested whether the higher extinction rates found with repeated items were maintained when the perceptual format of stimuli changed. Three extinction patients attempted to identify bilateral displays of the words "one" or "two" presented either in the word format (e.g., ONE) or in the digit format (e.g., 1). In accord with other findings of repetition effects on extinction (Baylis et al., 1993; Vuilleumier & Rafal, 1999), extinction increased with identical ipsilesional and contralesional items (e.g., ONE-ONE vs. ONE-TWO). However, the critical finding was that the disadvantage of identical stimuli remained significant even if their perceptual format changed, that is when items were perceptually different but identical with respect to their meaning (e.g., ONE-1 vs. ONE-2). According to the authors, this finding implies that competition between similar stimuli affects object representations established for the selection of actions. Since the stimuli used by Rafal et al. were perceptually different, but shared the same phonological and semantic representations, the results might reflect increased competition at the level of a phonological or a semantic store. Indeed, the results of a second experiment of Rafal et al. (2002) provide evidence for the first possibility, finding increased extinction not only with repeated stimuli in the word format (e.g., ONE-ONE), but also with homophones (e.g., ONE-WON). Thus, it appears that the factor determining whether stimulus repetition leads to increased extinction is phonological similarity. In accord with this conclusion, we found cueing effects with letters presented in a different modality, but generating the same phonological code (Experiment 5), indicating facilitated processing of contralesional stimuli at a phonological level.

In conclusion, our results indicate that RB in extinction is not due to low-level competition, since the manipulation of perceptual salience does not modulate extinction of similar stimuli. In accord with findings of Rafal et al. (2002) the present study rather indicates that RB reflects attentional competition at a phonological processing level. The different extinction patterns of

similar and dissimilar stimuli across several task manipulations suggest that the degree of attentional competition between perceptual features of stimuli (e.g., symmetry) is independent of the degree of competition between features defined at higher levels of analysis (e.g., phonology). In accord with this, several other authors proposed that for any given set of visual stimuli, competition may arise between several cortical visual areas representing different levels of information (Desimone & Duncan, 1995; Duncan et al., 1997; Kastner & Ungerleider, 2001). Recent functional neuroimaging studies have reported that extinguished stimuli may activate the primary visual cortex at least to a certain degree (Rees, Wojciulik, Clarke, Husain, Frith, & Driver, 2000; Vuilleumier et al., 2001), suggesting that visual extinction does not result from attentional competition in this area, but rather from competition in higher association cortex. This finding supports the notion that extinguished stimuli may be processed to a considerable degree outside of awareness. At the behavioural level, dividing attention between two stimuli nearly always leads to a decrease of identification performance irrespective of the level of analysis (Corbetta et al., 1991; Duncan, 1984; Pashler, 1998; Vecera & Farah, 1994). Spatial extinction is thus an example of exaggerated competition for attentional resources between multiple processors of basic physical properties as well as higher-level object attributes.

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