

## **On the Processing of “Extinguished” Stimuli in Unilateral Visual Neglect: An Approach Using Negative Priming**

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We report experiments examining the processing of “extinguished” stimuli in a patient showing visual extinction to double simultaneous stimulation. The experiments used a matching paradigm, designed so that extinguished stimuli cannot benefit from priming from non-extinguished stimuli presented simultaneously. The task involved matching for physical identity central targets in prime and probe displays, flanked by distractors. On “different” trials, distractors in primes could re-appear as targets in probe displays (the ignored repetition condition). Experiments 1 and 3 used normal subjects and established negative priming in the ignored repetition condition. Negative priming occurred both when stimuli in the prime and the probe displays were the same case and when they differed in case. Experiment 2 used a patient manifesting left-field neglect. Like control subjects, he showed negative priming from right-field distractors. In contrast, however, he showed positive priming from left-field distractors. Positive priming also occurred when distractors and targets differed in case (Experiment 2b). Experiment 4 showed that the patient showed marked left-field extinction under conditions equivalent to those used in the matching task. The data indicate both that “extinguished” stimuli can be processed to activate internal representations and that inhibitory processes may not be applied unless conscious attention is involved.

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## INTRODUCTION

A common phenomenon in the neuropsychological literature is extinction to double simultaneous stimulation associated with parietal damage (Critchley, 1953). When parietal patients are presented with a single visual stimulus on the side opposite the lesion, they may be able to recognise it; however, when a second stimulus is presented simultaneously ipsilateral to the side of the lesion, then patients may fail to recognise the contralesional stimulus. Different explanations have been proposed to explain why patients neglect contralesional stimuli in the presence of double simultaneous stimulation (see Riddoch & Humphreys, 1987, for a critical review), several of which assume that responses to the neglected stimulus are impaired because the stimulus fails to engage visual attention (e.g. either because patients cannot disengage attention from the ipsilesional stimulus or because the contralesional stimulus "loses" in competition with the ipsilesional stimulus to attract attention; Humphreys & Riddoch, 1993; Posner, 1988; Posner, Walker, Friedrich, & Rafal, 1987; Riddoch & Humphreys, 1983, 1987). Parietal-damaged patients showing extinction may therefore allow us to address one of the most controversial issues in the literature on selective attention: Namely, the fate of (unattended) stimuli that fail to engage attention.

Several studies involving parietal-damaged patients assessed the level of processing reached by neglected stimuli presented contralateral to the lesion. Volpe, Ledoux, and Gazzaniga (1979) documented four right parietal-damaged patients who could name single drawings or written words when presented alone to the contralesional visual field, but who failed to report the same items when simultaneous pairs of drawings or words were displayed. However, despite their poor report of the contralesional stimuli, the patients were able to perform above chance when a *same/different* judgement was required in the double simultaneous stimulation condition. Volpe et al. suggested that perceptual processing was intact in their patients, and that the lesion affected the flow of information from non-conscious systems to conscious awareness. Replications of the basic Volpe et al. result (i.e. good performance in *same/different* matching along with extinction in identification) have been reported with parietal-damaged patients by Berti et al. (1992), Farah, Monheit, and Wallace (1991), Karnath (1988), and Karnath and Hartje (1987). Karnath and colleagues showed this even when the patients were unable to identify the contralesional stimulus presented in isolation condition (Karnath, 1988; Karnath & Hartje, 1987). However, the suggestion that patients show normal perceptual processing of extinguished stimuli, advanced by Volpe et al. (1979), has been subject to serious challenge. For example, Farah et al. (1991) demonstrated that

differences in accuracy between identification and same/different matching are eliminated when forced-choice identification is used for both tasks. The authors concluded that same/different matching and forced-choice identification require less information to be performed accurately than does a free identification task. Thus, the former would be less affected by any perceptual impairment than the latter. Consequently, any dissociation between same/different matching and identification in patients with neglect cannot be taken to indicate intact perceptual processing.

Another study that calls into question Volpe et al.'s (1979) claim for normal perception in extinction and neglect has been reported by Berti et al. (1992). These authors point to the failure in Volpe et al. to characterise the level of processing achieved by "extinguished" stimuli. Volpe et al. used a same/different matching task in which the "same" trials involved two identical stimuli. Discrimination between "same" and "different" stimuli could be based on information coded at various levels of representation: including visual features, object identity, or even general category information. Berti et al. tried to separate these possibilities by having subjects perform "name" matches on photographs of objects which (on same trials) could be physically identical, the same object but in a rotated view, or a physically different object with the same name. They reported one patient who was above-chance at matching "extinguished" stimuli in all of these cases. This pattern of results suggests that stimuli in the "extinguished field" reached categorical representation, consistent with Volpe et al.'s claims. However, as the authors noted, an alternative explanation can be accommodated without inferring intact visual processing. In particular, it is possible that contralesional stimuli were partially activated. The ipsilesional stimulus could "prime" the contralesional stimulus, generating good same-different matching performance even if the priming were not sufficient to enable contralesional stimuli to be identified. This is similar to "early selection" accounts of apparent "high level" processing carried out on unattended stimuli by normal subjects. For instance, several studies have shown that responses to a central target can be disrupted by simultaneous presentation of a parafoveal semantically related distractor (Fuentes & Ortells, 1993; Gatti & Egeth, 1978; Miller, 1991; Shaffer & LaBerge, 1979; Underwood, 1981); however, such interference effects may be brought about by the target activating (priming) the parafoveal word, which then disrupts target processing (Broadbent & Gathercole, 1990; Johnston & Dark, 1986; Kahneman & Treisman, 1984). A way to prevent priming between attended and unattended (or ipsilesional and contralesional) stimuli is to use successive prime-probe presentations in which prime stimuli are not related to each other (see Fuentes & Tudela, 1992;

Fuentes, Carmona, Agis, & Catena, 1994 for evidence), a procedure that we adopted in the present study. So far, however, the level of processing achieved by stimuli presented to the “extinguished” visual field of parietal patients is far from clear.

### THE PRESENT STUDY

The present research assessed this question, but using a somewhat different paradigm to that used previously. We used a sequential identity-matching task in which the patient matched stimuli presented at fixation on the basis of whether they were the same or different letters. These target letters could be flanked either by two plus signs or by one plus sign and one letter (the distractor), presented left or right of the target. The first display on each trial was termed a prime, the second display was termed a probe. In the critical conditions, the distractor in the prime display became the target in the probe display. This enabled us to measure the effects of a prime distractor presented either to the contra- or the ipsilesional field, on responses to a subsequent target. The successive presentation of primes and probes is useful, since any interpretation of distractor processing in the prime display being due to a priming mechanism similar to that discussed by Berti et al. (1992) can be ruled out: In prime displays the target and distractor were always different letters.

Several conditions were investigated, and the experiment was conducted with normal subjects and with a patient with right parietal damage who showed extinction to double simultaneous stimulation.

With normal subjects (Experiment 1), the conditions were as follows. On some trials, the target could be flanked by neutral distractors on both prime and probe displays (e.g. + A + → + A + ) (neutral same trials, condition N same), or it could be flanked by different distractors (e.g. MAM → TAT) (different distractor, same trials, condition DD same). The target was always blue, the distractors green. On different trials, there were three conditions: (1) the target was flanked by neutral distractors on prime and probe displays (e.g. + A + → + M + ) (neutral different trials, condition N different); (2) the distractor in the prime display became the target in the probe display (MAM → TMT) (ignored repetition, different trials, condition IR different); and (3) the distractors differed in prime and probe displays (MAM → LTL) (different distractor, different trials, condition DD different). Of particular interest is the contrast between performance in the three types of different trials. Worse performance in the different distractor relative to the neutral condition could be due to flanking letters interfering with responses to the central letter target (e.g., Eriksen & Eriksen, 1974; Eriksen & Hoffman, 1973; Humphreys, 1981;

Miller, 1991).<sup>1</sup> The contrast between the ignored repetition and the different distractor condition, however, allows us to assess whether ignored distractors (in prime displays) were actively suppressed. If so, then responses should be slower in the ignored repetition than in the different distractor condition: That is, there should be negative priming (cf. Allport, Tipper, & Chmiel, 1985; Tipper, 1985).

With the right parietal patient, DW, these conditions were amended to allow distractors to be presented selectively to the contra- and ipsilesional visual fields (Experiment 2). On same trials, there were three conditions: (1) neutral same (N same) (+ A + → + A + ); (2) different distractor, left (DD-L same) (M A + → T A + ); (3) different distractor, right (DD-R same) (+ A M → + A T). The contrast between each of the different distractor conditions and the neutral same condition tests for interference effects from a left- or right-field distractor in responses to the central target. On different trials there were five conditions: (1) neutral different (N different) (+ A + → + M + ); (2) ignored repetition, left (IR-L different) (M A + → T M + ); (3) ignored repetition, right (IR-R different) (+ A M → + M T); (4) different distractor, left (DD-L different) (M A + → L T + ); (5) different distractor, right (DD-R different) (+ A M → + T L). The contrast between the ignored repetition and the different distractor conditions enables us to assess whether negative priming occurred. In Experiment 3, the conditions used with DW were replicated with control subjects, to ensure that any differences between DW and the controls were not due to the use of a single distractor letter (and a plus sign) for DW.

To foreshadow the results, negative priming was obtained with normal subjects (Experiment 1). With DW, we ask whether he shows normal processing of items in his neglected field by evaluating whether negative priming occurred in the ignored repetition, left condition, relative to the different distractor, left condition. Note that two negative results are possible: (1) DW shows no difference between the latter two conditions, consistent with a failure to discriminate left- (neglect-) field items; (2) DW shows a difference between the conditions, but, in contrast to normal, responses are facilitated in the ignored repetition, left condition relative to the different distractor, left condition. Fuentes et al. (submitted) showed that normal subjects can manifest facilitation from ignored, repeated primes under conditions where there is not sufficient time to suppress irrelevant prime information (e.g. with short exposure durations and short intervals between the prime and the probe stimuli). Evidence for facilitated processing in the ignored repetition, left condition for DW would indicate

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<sup>1</sup>Interference effects from distractors can also be assessed by comparing the neutral and different distractor condition on same trials.

some processing of items within his neglected field, along with a failure to bring to bear inhibitory (suppressive) processes on those items. DW's performance with stimuli presented in his right (ipsilesional) field serves as a within-subject control for his performance with left (contralesional) field stimuli.

In order to provide a test for extinction under conditions closely matched to the presentation conditions for primes in the letter-matching task, DW also performed a second experiment (Experiment 4). In Experiment 4, DW performed either of two tasks. Single displays were presented for the same duration as prime displays in the letter-matching task (Experiment 2). The displays contained either two green plus signs and a central blue letter (+ A + ) (on half the trials), or (on the other half of the trials) a blue central and a green flanking letter (A M + or + A M, each presented on 25% of the trials). For one task, DW was asked to name the central letter and to ignore the flanking distractor (the *what* task); for the other he had to decide whether one or two letters were present (the *how many* task). The *what* task assessed whether a simultaneously presented distractor disrupted DW's identification of a central letter under brief exposure conditions. The *how many* task tests for extinction, that is whether DW can judge the presence of a left-field distractor at an above-chance level.

Experiments 1 and 2 were each carried out twice. In Experiments 1a and 2a primes and probes were both in upper case. In Experiment 1b, primes were in lower case and probes in upper case. In Experiment 2b distractors were in lower case and targets in upper case.<sup>2</sup> This latter cross-case manipulation allowed us to test the form of representation mediating the effects of the distractor on responses to the target in the probe display. Effects at the level of physical features should occur only with physically identical stimuli, but not with stimuli differing in case.

A final point is that the first experiment with normal subjects (Experiments 1a and 1b) used two different stimulus onset asynchronies (SOAs) between prime and probe displays (100msec and 800msec, respectively). This was done in order to reassess the finding reported by Fuentes et al. (submitted; see also Yee, 1991) that negative priming occurs only when subjects have sufficient time to suppress irrelevant information in prime displays (i.e. with a relatively long rather than a relatively short SOA).

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<sup>2</sup>Targets were presented in upper case so that DW performed a physical match task. Pilot work suggested that DW had difficulty performing name matches (used for the control subjects in Experiment 1b), and his RTs were then too variable to generate reliable results. Nevertheless, the use of lower-case distractors in Experiment 1b enables us to assess whether the effects of these distractors transfer across case (to upper-case targets).

## EXPERIMENTS 1A AND 1B: NORMAL SUBJECTS

In Experiment 1a we tested the performance of normal subjects in a letter-matching task with upper-case letters in prime and probe displays; in Experiment 1b prime letters were in lower case and probe letters were in upper case.

**Method**

*Subjects.* Twenty-eight students of the University of Birmingham (14 in each experiment) participated. The students received course credit for their participation, and all of them had normal or corrected-to-normal vision.

*Apparatus and Stimuli.* All stimuli were presented on a colour monitor (VGA card) of an IBM compatible computer. The computer controlled all stimulus events and timing operations. Keypress responses were made on the computer keyboard.

The letters *A*, *L*, *M*, *T*, and *X* were used as stimuli. In 40-column text mode, stimuli averaged 5mm high and 4mm wide, and at a distance of 60cm subtended on average  $0.48^\circ$  by  $0.38^\circ$  of visual angle.

*Procedure.* Subjects were presented sequentially with prime and probe displays. In each display, the target was a central blue letter, whilst the distractors were green letters or green plus signs. Distractors were displaced 1cm ( $0.96^\circ$ ) from fixation. In Experiment 1a, prime distractor letters (when present) were in upper case; in Experiment 1b they were in lower case. Example display configurations for the normal controls are given in Table 1.

Each trial started with a fixation point (\*) lasting 500msec, followed by the prime display. Primes were exposed for 60msec. In Experiment 1, primes were followed by an interval of either 40msec (100msec of SOA) or 740msec (800msec of SOA), after which the probe display was presented until the response was made. The two SOAs occurred equally often and were orthogonally crossed with the experimental conditions. The inter-trial interval was 1000msec.

Subjects were told to respond "same" by pressing a key with their dominant hand if the targets in both the prime and the probe displays were the same letter. "Different" responses were made with the non-dominant hand and were required if targets were different letters.

Instructions stressed speed, accuracy, and the benefit of ignoring distractors.

Subjects were given 3 blocks (the first for practice) of 100 trials. On 40 trials the target in the prime display was repeated in the probe display (20

TABLE 1  
 Examples of the Conditions Used in the Matching Task Used in Experiments 1a  
 (Normal Subjects) and 2a (DW)<sup>a</sup>

<i>Experiment 1a</i>					
<i>"Same" Trials</i>	<i>DD</i>	<i>N</i>			
Prime Display	M A M	+ A +			
Probe Display	T A T	+ A +			
<i>"Different" Trials</i>	<i>IR</i>	<i>DD</i>	<i>N</i>		
Prime Display	M A M	M A M	+ A +		
Probe Display	T M T	L T L	+ M +		
<i>Experiment 2a</i>					
<i>"Same" Trials</i>	<i>DD-L</i>	<i>DD-R</i>	<i>N</i>		
Prime Display	M A +	+ A M	+ A +		
Probe Display	T A +	+ A T	+ A +		
<i>"Different" Trials</i>	<i>IR-L</i>	<i>IR-R</i>	<i>DD-L</i>	<i>DD-R</i>	<i>N</i>
Prime Display	M A +	+ A M	M A +	+ A M	+ A +
Probe Display	T M +	+ M T	L T +	+ L T	+ M +

<sup>a</sup>Experiments 1b and 2b varied the case in which some stimuli were displayed (see text for details).

in the different distractor and 20 in the neutral conditions); on 60 trials the target in the probe display was different to that of the prime display. In the different target condition, there were 20 trials, in which the distractor in the prime display became the target in the probe display (ignored repetition condition), 20 in which distractors in the prime display differed from those in the probe display (different distractor condition), and 20 in which targets were flanked by plus signs (the neutral condition).

## Results

Reaction times (RTs) above 2000msec and below 250msec were eliminated from the statistical analyses. The percentage of RTs discarded was negligible. Also, conservative Fisher's LSD tests were performed for post-hoc comparisons in all experiments.

The mean RTs and error percentages over subjects for Experiments 1a and 1b are shown in Table 2. Two different analyses were performed on both RT data from correct trials and on errors. The first analysis compared the two "same" response conditions (different distractor [DD] and neutral [N]). This analysis assessed interference from flanking distractor letters on responses to the central target. The second analysis involved the "different"



TABLE 2  
 Mean Reaction Times (RT) and Percentage Errors (Er) as a  
 Function of SOA and Condition (Experiments 1a and 1b)

Response:	Same		Different		
	DD	N	IR	DD	N
<i>Experiment 1a</i>					
100msec SOA					
RT	609	548	546	547	536
Er	18.8	10.4	3.8	4.6	3.8
800msec SOA					
RT	538	510	556	536	533
Er	10.0	8.9	3.0	3.4	3.2
<i>Experiment 1b</i>					
100msec SOA					
RT	628	590	593	592	599
Er	12.7	7.1	2.7	3.8	4.8
800msec SOA					
RT	560	541	566	548	541
Er	6.3	3.9	2.0	1.1	2.1

DD = different distractor, N = neutral distractor, IR = ignored repetition.

response data (in conditions N, DD, and ignored repetition [IR]). This analysis assessed both interference and negative priming effects.

Because Experiment 1b is a replication of Experiment 1a, *Fb* and *Fa* respectively will be used to identify the statistical analyses carried out on each sub-experiment.

*Interference on "Same" Trials.* A 2 × 2 within-subjects analysis of variance (ANOVA) showed reliable differences between conditions DD and N, and between the short (100msec) and the long (800msec) SOAs in both experiments. For the condition effect,  $F_a(1, 13) = 10.24$ ,  $MSe = 2637$ ,  $P < 0.01$ , and  $F_b(1, 13) = 22.7$ ,  $MSe = 485$ ,  $P < 0.001$ . For the effects of SOA,  $F_a(1, 13) = 4.8$ ,  $Mse = 8621$ ,  $P < 0.05$ , and  $F_b(1, 13) = 13.5$ ,  $MSe = 3553$ ,  $P < 0.01$ . However, the SOA × condition interaction did not reach statistical significance [ $F_a(1, 13) = 3.08$ ,  $P > 0.05$ ,  $F_b(1, 13) = 2.35$ ,  $P > 0.05$ ]. RTs were faster with the long relative to the short SOA, and they were slower when interfering distractor letters were present (in condition DD relative to the neutral baseline, N).

The analysis of the errors also revealed reliable main effects of both condition and SOA. For SOA,  $F_a(1, 13) = 6.2$ ,  $MSe = 58.5$ ,  $P < 0.05$ , and  $F_b(1, 13) = 7.5$ ,  $MSe = 43.2$ ,  $P < 0.05$ . For condition,  $F_a(1, 13) = 7.2$ ,  $MSe = 43.5$ ,  $P < 0.05$ , and  $F_b(1, 13) = 13.05$ ,  $MSe = 16.6$ ,  $P < 0.01$ . The

SOA  $\times$  condition interaction was reliable in Experiment 1a [ $F_a(1, 13) = 11.6$ ,  $MSe = 16.2$ ,  $P < 0.01$ , but  $F_b(1, 13) = 1.32$ ,  $P > 0.05$ ]. Additional analyses of this interaction showed that the different distractor condition (DD) produced more errors than the neutral condition (N), but only for the short SOA [ $F_a(1, 13) = 12.7$ ,  $MSe = 38.8$ ,  $P < 0.01$ ].

*Priming on "Different" Trials.* A  $2 \times 3$  analysis of variance (ANOVA) was performed on correct RTs, with SOA (100msec, 800msec) and condition (IR, DD, and N) as the within-subject factors. Across both Experiments 1a and 1b there were only two reliable effects: a main effect of condition in Experiment 1a [ $F_a(2, 26) = 4.21$ ,  $MSe = 448.36$ ,  $P < 0.05$ ] and an SOA  $\times$  condition interaction in Experiment 1b [ $F_b(2, 26) = 4.04$ ,  $MSe = 393$ ,  $P < 0.05$ ]. However, the pattern of results was identical in both experiments: There was negative priming (revealed by a difference between conditions IR and DD) at the long but not at the short SOA. At the short SOA, there was no main effect of the conditions [ $F_a(2, 26) < 1$ ,  $F_b(2, 26) < 1$ ]. With the long SOA, the condition effect was reliable for both experiments [ $F_a(2, 26) = 3.57$ ,  $MSe = 622$ ,  $P < 0.05$ ,  $F_b(2, 26) = 7.99$ ,  $MSe = 275$ ,  $P < 0.01$ ]. Post-hoc comparisons showed that responses were longer in the ignored repetition (IR) condition relative to both the different distractor (DD) and the neutral (N) conditions ( $P < 0.05$  in Experiment 1a,  $P < 0.01$  in Experiment 1b). There were no differences between conditions DD and N.

Analysis of the error rates failed to reveal any reliable effects in Experiment 1a. In Experiment 1b, there was only a main effect of SOA [ $F_b(1, 13) = 7.9$ ,  $MSe = 10.9$ ,  $P < 0.05$ ]. The error rate was higher with the short than with the long SOA.

Overall, the error rate was higher in the same than in the different trials. That counterintuitive pattern could be due to a certain bias to respond "different" since the percentage of different trials was higher than the percentage of same trials (60% vs. 40%). Nevertheless, we did not expect any response bias to affect either interference or negative priming, since the relevant comparisons to measure those effects were conducted among conditions belonging to the same category of response.

#### ***Experiment 1a vs. 1b***

In order to determine the level of processing distractor letters reached in Experiment 1, a comparison between Experiments 1a and 1b would be desirable. We conducted a further analysis of variance (ANOVA) on both "same" and "different" trials. Experiment (1a, 1b) was the between-subjects factor, and SOA (100msec, 800msec) and condition (DD and N for "same," and IR, DD, and N for "different" trials).

*Interference on "Same" Trials.* The effects of SOA and condition were reliable. The short SOA produced longer RTs than the long one (594msec vs. 537msec), [ $F(1, 26) = 14.66$ ,  $MSe = 6087$ ,  $P < 0.001$ ]. Also condition DD produced longer RTs than condition N (584msec vs. 548msec), [ $F(1, 26) = 23.22$ ,  $MSe = 1561$ ,  $P < 0.001$ ]. This interference effect was larger for the short SOA than for the long one (49msec vs. 23msec) as stated by the reliable SOA  $\times$  condition interaction [ $F(1, 26) = 5.34$ ,  $MSe = 899$ ,  $P < 0.05$ ]. No other effects were reliable.

Error analysis showed a main effect of both SOA and condition. Percentage of errors with the short SOA was larger than with the long one (12.2 vs. 7.3) [ $F(1, 26) = 13.5$ ,  $MSe = 51.9$ ,  $P < 0.01$ ]. Condition DD produced more errors than condition N (11.9 vs. 7.6) [ $F(1, 26) = 17.47$ ,  $MSe = 30$ ,  $P < 0.001$ ]. The SOA  $\times$  condition interaction showed that the differences between DD and N were larger with the short SOA [ $F(1, 26) = 8.9$ ,  $MSe = 21.9$ ,  $P < 0.01$ ]. No other differences were reliable.

*Priming on "Different" Trials.* The main effect of SOA and the Experiment  $\times$  SOA interaction were reliable [ $F(1, 26) = 5.34$ ,  $MSe = 3787$ ,  $P < 0.05$ ; and  $F(1, 26) = 4.93$ ,  $MSe = 3787$ ,  $P < 0.05$ , respectively]. Again the short SOA produced longer RTs than the long one, but it was only true for Experiment 1b (595msec vs. 552msec). For Experiment 1a SOAs did not differ each other (543msec vs. 542msec). Condition was also reliable [ $F(2, 52) = 5.64$ ,  $MSe = 436$ ,  $P < 0.001$ ]. Condition IR produced longer RTs than conditions DD and N, as indicated by post-hoc comparisons ( $P < 0.05$ ). However, the SOA  $\times$  condition interaction was reliable [ $F(2, 52) = 3.75$ ,  $MSe = 524$ ,  $P < 0.05$ ], that is, the negative priming effect (DD minus IR) was only observed with the long SOA (-19msec), but not with the short one (1msec) (see Fig. 1).

The analysis of error rates showed only a main effect of SOA [ $F(1, 26) = 7.15$ ,  $MSe = 11.99$ ,  $P < 0.05$ ]. Error percentage was larger with the short than with the long SOA (3.9 vs. 2.5).

## Discussion

Normal subjects showed both interference effects from simultaneously presented distractor letters (on same trials) and negative priming effects (on different trials). There was no evidence for interference effects on different trials (cf. the comparison between conditions DD and N), presumably because the main effect of a different, irrelevant distractor is to disrupt a matching response when the target is the same in the prime and the probe displays (Eriksen & Eriksen, 1974).

Interference effects (on same trials) tended to be smaller in Experiment 1b than in Experiment 1a (28.5 vs. 44.5msec, averaged across the two

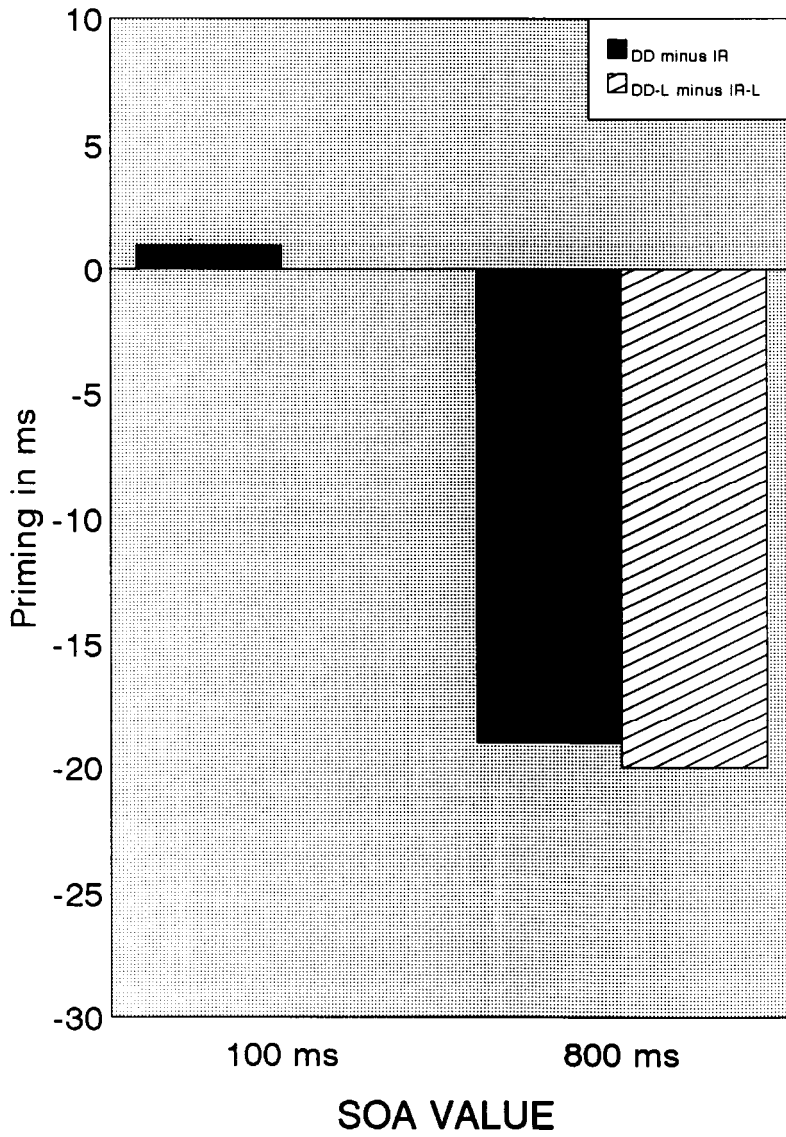


FIG.1. Priming effects (DD minus IR for Experiment 1, and DD-L minus IR-L for Experiment 3) as a function of SOA for "different" responses. See text for details.

SOAs). This may be because the irrelevant distractors, on probe trials, disrupt the easier (physical) matching task most.

Fuentes et al. (submitted) used a similar task to that used here, except that subjects had to decide whether the central stimuli were both letters or both numbers (rather than physical or name matching, as used here). They found evidence for negative priming not only in the ignored repetition condition (as here) but also in the different distractor condition (they termed it the unrepeated condition), when performance was compared with the neutral distractor condition. They suggested that, when matching was performed at a category level, inhibition could apply to all items within a category (see also Neumann & DeSchepper, 1992), when those items had to be suppressed as distractors in primes. In Experiment 1 here, either physical (Experiment 1a) or name (Experiment 1b) matching was required. In this case, inhibition seems to be applied only to the particular distractors in prime displays; hence negative priming occurs only when the letter distractors in primes are re-presented as central target letters (in condition IR). Interestingly, negative priming occurred here even though an explicit (overt) response was not required to prime displays. This suggests that negative priming reflects the inhibition of internal representations of stimuli and not simply inhibition of a particular response that might be paired with the ignored prime.

One additional result was that, in both sub-experiments, negative priming emerged at the long but not the short ISI (see Fig. 1). This replicates previous studies by Fuentes et al. (submitted), using the present matching paradigm. It suggests that inhibitory processes take some time to apply to distractors in primes, consistent with such processes being dependent on controlled visual attention (Posner & Snyder, 1975; see also Yee, 1991 for a similar contention).

Finally, the lack of any difference between Experiments 1a and 1b suggest that distractor letters reached a rather abstract level of processing.

## **EXPERIMENT 2: PRIMING IN A PATIENT WITH A PARIETAL LESION**

In Experiment 2 we examined whether similar results to those found with normal subjects occurred in a patient with a right parietal lesion.

### **Case Report**

DW is a 60-year-old right-handed man who suffered a right cerebrovascular accident (CVA) in 1990. Initial clinical testing indicated left neglect

across a range of tasks: copying, line cancellation, line bisection, and reading. By the time of testing (three years after his CVA), however, the clinically apparent neglect had resolved, though his report of left-field stimuli remained impoverished under conditions of double simultaneous stimulation. No field deficits were apparent in perimetric testing, and DW's report was good when he was presented with single left-field stimuli. DW had a mild left hemiparesis, affecting his arm more than his leg. CT scan showed a right parietal lesion.

### Experiment 2a

In Experiment 2a, DW performed the same letter-matching task as the normal subjects, although only the long interval (800msec SOA) was used. DW was given 8 blocks (the 2 first blocks for practice) of 100 trials. For him the experimental conditions (different distractor same, ignored repetition, and different distractor different) were subdivided within each block so that on 30 trials a single left distractor was presented (DD-L same, IR-L and DD-L different, 10 trials respectively); on another 30 trials only the right distractor was present (DD-R same, IR-R and DD-R different, 10 trials respectively). There were 40 neutral trials (20 same, 20 different) (see bottom of Table 1).

The experimenter hit the appropriate key, immediately after DW made a verbal response ("same" or "different"). "Blind" responding by the experimenter was ensured by sitting him in a position where he could not see the screen.

### Results

Table 3 (top) presents the data for DW in the matching task. As with normal subjects, two different analyses were performed: one on "same" responses to assess letter interference, the other on "different" responses to assess interference and negative priming effects.

RTs above 4000msec and below 500msec were eliminated from the analyses. A negligible number of data (less than 1%) were discarded following that criterion.

*Interference on "Same" Trials.* A one-way analysis of variance (ANOVA) was performed, with condition (DD-L, DD-R, and N) as a between-subjects factor. Individual RTs were treated as independent of one another, and as originated from different subjects, a procedure appropriate for single-case analyses of RT data (see De Haan, Young, & Newcombe, 1987). The main effect of condition was not reliable [ $F(2, 166) = 2.16, P > 0.10$ ]. There was also no effect of condition on error rates [ $\chi^2_{(2)} > 1$ ].

TABLE 3  
 DW's Mean of Reaction Times and Percentage Errors in the Matching Task as a  
 Function of Conditions (Experiments 2a and 2b)

Response:	Same			Different				
	DD-L	DD-R	N	IR-L	IR-R	DD-L	DD-R	N
<i>Experiment 2a</i>								
RT	1117	1340	1146	1322	1683	1607	1420	1466
SD	443	692	530	418	706	697	516	625
Er	25.0	31.6	30.8	10.0	10.8	10.0	8.3	10.8
<i>Experiment 2b</i>								
RT	1013	1122	1100	1117	1135	1277	1233	1230
SD	183	393	296	208	265	350	317	369
Er	8.3	15.0	19.2	8.3	6.7	11.6	11.6	7.5

*Priming on "Different" Trials.* A one-way ANOVA was performed, with condition (IR-L, IR-R, DD-L, DD-R, and N) as a between-subjects factor. In this case the main effect of condition was reliable [ $F(4, 316) = 3.04, MSe = 365167, P < 0.025$ ]. Post-hoc comparisons showed that RTs in condition IR-L were reliably faster than those in both conditions IR-R and DD-L ( $P < 0.05$ ). RTs were slower in condition IR-R than in conditions DD-R and N ( $P < 0.05$ ). No other comparisons were reliable.

There were no reliable effects on errors [ $\chi^2_{(4)} = 4.31, P > 0.10$ ].

**Discussion**

DW's performance contrasted with those of the normal subjects in several ways. First, and most important, relative to when a different distractor was in his left field, RTs were facilitated when left-field distractors in primes became targets. This was not due to a simple speed-error trade-off, since the error rate was low in condition IR-L. Nor did the effect occur because DW failed to apply inhibitory processes to distractor letters in primes in other conditions; "normal" negative priming occurred in the ignored repetition condition when right-field distractors became targets. Rather the data suggest that: (1) left-field distractors were processed sufficiently to produce positive priming when they were repeated as targets; (2) DW failed to apply inhibitory processes to left-field distractors. This last observation is consistent with inhibitory processes being dependent on conscious visual attention, and with left-field stimuli being processed unconsciously by DW. This last possibility was investigated directly in Experiment 4, where DW was required to decide

how many stimuli were presented in displays presented for the same exposure duration as prime displays in Experiment 2.

Our interpretation of these data is based primarily on comparisons between conditions IR-L and DD-L. These conditions are matched, both having a flanking letter different to the central target. The neutral condition N fell mid-way between conditions IR-L and IR-R, but the plus signs were not matched for visual similarity to the flanking letters. Also, only in condition N were right- and left-field distractors identical (both plus signs). This means that the target may have been easier to match in condition N because “+” distractors caused less interference than letter distractors, and because right-field items may have tended to suppress the similar left-field items (see Baylis, Rafal, & Driver, 1993). The comparison between conditions IR-L (or IR-R) and DD-L (or DD-R) is better matched for the similarity of the distractors, and in neither case were right- and left-field items identical.

DW, unlike the normal subjects in Experiment 1, also failed to show reliable interference on some trials when different relative to neutral distractors were present. Nevertheless, a trend for interference in RT was apparent when the distractor was in the right visual field, although DW's matching performance was too variable to establish statistical significance. This was assessed again in Experiment 2b, which also examined whether priming occurred between distractors and targets differing in case.

### **Experiment 2 b**

In this experiment, targets were in upper case and distractors were in lower case. DW was given 8 blocks (the 2 first blocks for practice) of 100 trials.

#### *Method*

This was the same as in Experiment 2a, except that distractors were in lower, not upper case. DW was again instructed to carry out physical matches of targets. A physical match task was maintained with DW because he found it difficult to carry out the cross-case matching task reliably (cf. Experiment 1b). Nevertheless, the level of representation involved in priming can be assessed since distractors in primes differed in case from targets in probe displays even when they were the same letter.

#### *Results*

RTs above 4000msec and below 500msec were eliminated from the analyses. In doing this, a negligible number of trials (less than 1%) were discarded. Data are shown in Table 3.



By the time Experiment 2b was conducted, DW had received considerable practice at the task, leading both to faster RTs and to a lower error rate.

*Interference on "Same" Trials.* As in Experiment 2a, a one-way analysis of variance (ANOVA) was performed, with condition (DD-L, DD-R, and N) as a between-subjects factor. The main effect of condition was not reliable [ $F(2, 200) = 2.1, P > 0.10$ ]. There was also no effect of condition on error rates [ $\chi^2_{(2)} = 3.6, P > 0.10$ ].

*Priming on "Different" Trials.* A one-way ANOVA was performed, with condition (IR-L, IR-R, DD-L, DD-R, and N) as a between-subjects factor. The main effect of condition was reliable [ $F(4, 323) = 2.67, MSe = 101,521, P < 0.05$ ]. Post-hoc comparisons showed that RTs in condition IR-L were reliably faster than those in conditions DD-L and N ( $P < 0.05$ ), and RTs were marginally faster in condition IR-R than in condition N ( $P < 0.06$ ). No other comparisons were reliable.

The results showed the fastest RTs in condition IR and the slowest in condition DD, irrespective of the field where the distractor was presented. To provide a more direct test of the differences between conditions IR and DD, data from ignored repetition (IR-L, and IR-R) and different distractor conditions (DD-L, and DD-R) were collapsed across the visual fields. A further one-way ANOVA was conducted with conditions IR, DD, and N as the between-group factor. The effect of condition was then reliable [ $F(2, 325) = 5.06, MSe = 101,076, P < 0.01$ ]. Post-hoc comparisons showed that RTs were faster in condition IR than in conditions DD and N. No differences were observed between the two latter conditions.

There were no reliable effects on errors [ $\chi^2_{(4)} = 1.82, P > 0.10$ ].

### *Discussion*

Experiment 2b sought to assess the level of processing conducted on distractors in DW's left visual field, by using distractors that differed in case from targets. Under these circumstances, we found that distractors in the ignored repetition condition facilitated target responses, and this was the case irrespective of whether distractors were in the left or the right visual field (although the effect was largest with left-field distractors). In addition, the data show that left-field stimuli do not need to be identical to targets to facilitate responses. In an analysis comparing conditions IR-L and DD-L across Experiments 2a and 2b, there was a main effect of condition [ $F(1, 212) = 12.97, MSe = 206,146, P < 0.001$ ], but no interaction with the experiment [ $F(1, 212) = 1.04, P > 0.30$ ]. This last result suggests that left-field

stimuli are coded to a level of either abstract letter identities (cf. Evett & Humphreys, 1981) or name representations (Posner, 1978).

The only contrast with Experiment 2a was that facilitation in the ignored repetition condition also occurred when distractors were presented in the right visual field. This result may be expected if the suppression of distractor information is contingent on the form of target coding required for the task. In Experiment 2b, form-matching of upper-case targets was required. In that case, there may be relatively little need to suppress lower-case distractors, since they present a less potent source of interference relative to when upper-case distractors are used. Tipper, Weaver, and Houghton (1994), for instance, have recently argued that inhibition is linked to properties of distractors that compete for goal actions. In the present procedure, lower-case distractors appear not to compete for the goal action of form-matching to upper-case targets. Note that the task we were forced to use with DW, with targets in prime and probe displays being matched for physical identity, differs from that used with control subjects (Experiment 1b, where name matching was used). Hence different processes may be expected to operate, even for distractors that can be perceived consciously (e.g. in condition IR-R). Our finding of positive priming in condition IR-R relative to condition DD-R, although interesting, is independent of the main result relevant to our present concerns: Left-field distractors of different case to targets still facilitate target responses, relative to when a different distractor letter is used.

### EXPERIMENT 3

Data from DW in the physical matching task of Experiment 2 revealed that, when the left-field distractors in primes became targets, facilitation instead of inhibition was observed. We suggest that, contrary to normals, DW failed to apply inhibitory processes to stimuli that he did not perceive consciously. However, data from the control subjects are not completely comparable to those of DW. In the critical conditions of Experiment 1 (IR and DD), normal subjects were presented with displays containing two distractor letters, whereas DW was presented with displays containing one distractor letter and one plus sign (see Table 1). Thus, it is possible that the lack of negative priming from left-field stimuli for DW is due to the presence of only one distractor letter. The way in which a single distractor could affect DW's performance is not clear, but one possibility is that the distractor shifted the centre of mass of the display, causing attention to move to the periphery (see Grabowecky, Robertson, & Treisman, 1993). Even so, we would still need to explain why RTs were faster when the left-side distractors in prime displays became targets, relative to when left-side distractors and targets were different letters.

A second possibility is that reading habits could bias DW's attention to the left when only the left-field distractor was present. Possibly, this bias to attend to left-side stimuli may lead to activation rather than inhibition of these representations. If that is true, we expect that normal subjects should also be affected by reading habits, and therefore they should not show negative priming when only left distractor letters are displayed. This was examined in Experiment 3.

In Experiment 3, normal subjects were presented with some of the conditions of Experiment 1a, but the right-field distractor letter was replaced by one plus sign.

### **Method**

*Subjects.* Fourteen students of the Universidad de Almería participated. The students received course credit for their participation, and all of them had normal or corrected-to-normal vision.

*Procedure.* Subjects were given 3 blocks (the first for practice) of 50 trials. Distractor letters were presented only in the left visual field. The right-field distractor was always a plus sign. On 20 trials ("same" trials) the target in the prime display was repeated in the probe display (10 in the condition with a different distractor, DD-L, and 10 in the neutral condition, N); on 30 trials ("different" trials) the target in the probe display was different to that of the prime display. In the different target condition, there were 10 trials, in which the left distractor in the prime display became the target in the probe display (the ignored repetition condition, IR-L), 10 in which the left distractor in the prime display differed from that in the probe display (the different distractor condition, DD-L), and 10 in which targets were flanked by plus signs (the neutral condition, N).

The remaining conditions matched those in the previous experiments.

### **Results**

As in Experiment 1, RTs above 2000msec and below 250msec were eliminated from the analyses.

*Interference on "Same" Trials.* A one-way analysis of variance (ANOVA) was conducted with condition (DD-L, N) as a within-subjects factor. The mean RTs were 471msec in condition DD-L, and 462msec in condition N. The main effect of condition was not reliable [ $F(1, 13) = 1.65$ ,  $P > 0.10$ ]. There was also no effect of condition on error rates (3.2 in DD-L and 3.9 in N), [ $F < 1$ ].

*Priming on "Different" Trials.* A one-way ANOVA was performed, with condition (IR-L, DD-L, and N) as a within-subjects factor. The mean RTs were 493msec in condition IR-L, 473msec in condition DD-L, and 470msec in condition N. The main effect of condition was reliable [ $F(2, 26) = 3.66$ ,  $MSe = 606$ ,  $P < 0.05$ ]. Post-hoc comparisons showed that RTs in condition IR-L were reliably longer than those in condition DD-L and N ( $P < 0.05$ ). Conditions DD-L and N did not differ from each other.

The error percentage was 2.5 in each of the three conditions (IR-L, DD-L, and N).

### *Discussion*

Contrary to DW, normal subjects showed inhibition even when just a single left-field distractor was present (see Fig. 1). This does not fit with the contention that reading habits could bias DW's attention to the left visual field, preventing inhibition from being applied to those stimuli. Rather, the results of Experiment 3 suggest that conscious perception is a necessary condition for inhibition to occur. Because there is extinction of left-field distractors for DW, inhibition is not applied to those stimuli. The results from "same" trials are also interesting. Contrary to the results of Experiment 1, normal subjects did not show interference effects in this experiment, matching the findings with DW (Experiment 2). It seems that interference is observed more easily when two letters are presented as distractors rather than one, perhaps because there is then increased activation for the competing (distractor) letter identity.

## EXPERIMENT 4: EXTINCTION TESTS

From the results of Experiment 2 with DW we suggested that left stimuli were processed to a rather abstract level. However, DW failed to apply inhibitory processes to those stimuli. We concluded that: (1) inhibitory processing is contingent upon conscious visual attention; and (2) DW processed left distractors unconsciously. In Experiment 4, we went further to test whether left field distractors, presented as briefly as primes in Experiment 2, were really extinguished for DW.

### **Extinction Tests**

Two kinds of tests were used. For both, displays were comprised of three characters. On half the trials a central blue letter (the target) was flanked by two green plus signs (the no-distractor condition). On the other half, one of the plus signs was replaced by a green letter (the distractor).

The distractor appeared randomly and with equal probability either on the left (left-distractor condition) or on the right (right-distractor condition). For the *what* test, DW was told to report the central blue letter. For the *how many* test, DW was told to report the number of letters present irrespective of their identity, colour, or location. Prior to the experimental sessions, DW was told which letters could appear. The same letters were used as in the matching task.

Each trial started with a fixation point lasting 500msec, followed by a display for 60msec. After the display, a message saying "What" was presented until the response was made, then the message "How many" was presented until the new response was made. The inter-trial interval was 1000msec.

DW received 3 blocks of 40 trials. Within each block there were 20 trials in the control condition, 10 in the left-distractor condition, and 10 in the right-distractor condition. On each trial, DW performed the *what* test, and then he was asked to report the number of letters that had appeared (the *how many* test).

The extinction tests were run before DW completed the last three blocks of trials of Experiments 2a and 2b.

### Results

Table 4 shows the percentage of correct responses in both the *what* and *how many* tests. When the patient was asked to identify the central blue letter (in the *what* test), no differences were observed between the three conditions: no, left-distractor, or right-distractor. When DW was asked to report the number of stimuli in the display (the *how many* test), reliable differences emerged between the conditions [ $\chi^2_{(2)} = 114.87$ ,  $P < 0.001$ ]. Performance was worse with a left-field distractor, relative to that in the no distractor and the right-field distractor conditions [ $\chi^2_{(1)} = 85.6$  and  $60.0$ ,  $P < 0.001$ , respectively]. There was no difference between the right-distractor and the control condition [ $\chi^2_{(1)} < 1$ ]. DW missed the left distractor on all trials (see Table 4).

### Discussion

There was no effect of either a left-field or right-field distractor on the accuracy of identifying the central target letter. This result meshes with the lack of interference effects we observed on "same" trials in the matching task in Experiments 2a and 2b. The data indicate that "neglected" stimuli (in DW's left field) did not compete for responses with central targets. In addition, DW was extremely poor at deciding that two letters were present when the distractor was in the left field; he failed to report any "2-letter" trials in that condition. This was not due to a general bias to report "1"

TABLE 4  
 Percentage Responses by DW in the *What* and *How Many*  
 Tasks

<i>Test Type</i>	<i>Conditions</i>		
	<i>No-distractor</i>	<i>Left-distractor</i>	<i>Right-distractor</i>
What	100	100	93
How Many	98	0	100

over “2-letter” trials, since he performed perfectly when the second letter was in the right visual field. Rather the data confirm that left-field distractors are extinguished, due to simultaneous presentation of the central target.

### GENERAL DISCUSSION

DW showed marked extinction to left-field stimuli presented for relatively brief exposures under conditions of double simultaneous stimulation. Using the same exposure durations as those used for prime displays in the matching experiments, DW failed to detect even the presence of any left-field letters (Experiment 4). Despite this, data from the matching experiments (Experiments 2a and 2b) demonstrated that left-field letters were processed; in particular, left-field distractors in primes facilitated “different” responses to identical targets in probe displays (in the ignored repetition condition), relative to when different distractor letters were used. This occurred even when distractors in primes were in lower case and targets in upper case (Experiment 2b). The data suggest that there can be relatively high-level processing of neglected stimuli (e.g. to a level of abstract letter identities; Evett & Humphreys, 1981). Note that this evidence for high-level processing occurred under conditions designed to minimise “priming” of left-field items from right-field or central stimuli, and it extends that of other similar studies which used a different task (see Berti & Rizzolatti, 1992; McGlinchey-Berroth et al., 1993). Our evidence is for high-level processing of distractors in prime displays, with targets in prime displays always different from distractors; such distractors should not benefit from priming from targets (cf. Berti et al., 1992).

The data also indicate a qualitative difference between the processing of distractors in the left and right fields for DW. In Experiment 2a, irrelevant distractors in the right field were suppressed, leading to negative priming from distractors that were re-presented as targets on “different” response trials. This same result was found with normal subjects (Experiment 1). As noted earlier for DW, left-field distractors facilitated performance in this

condition, relative to the different-distractor baseline. The contrast between negative and positive priming from (respectively) right- and left-field stimuli suggests that, in neglect, patients may be unable to bring inhibitory processes to bear on "extinguished" stimuli. This is consistent with inhibition being contingent on the conscious representation of distractors. We suggest that, under conditions of double simultaneous stimulation, DW attended to centre or to right-field stimuli but not to left-field stimuli. Conscious representation depends on stimuli being attended. Even without attention, however, well-learned stimuli (such as letters) may still contact stored knowledge; for instance, in the present procedure, distractor letters appear to activate their stored representations. This pre-activation facilitates subsequent matching when distractors are re-presented as targets.

In contrast to the evidence for facilitatory priming from "extinguished" left-field stimuli, we failed to find reliable interference effects from distractors on DW's matching and identification performance (in Experiment 2, and in the *what* task in Experiment 4). This indicates that DW was successful in selecting targets, using either colour or location information. The present finding of no reliable interference, along with positive priming from distractors, confirms that interference and priming are caused by separate processes (Driver & Tipper, 1989; Fuentes et al., submitted; see also Experiment 3, where single distractor letters were used with normal subjects).

Two other findings are of interest, in that they support the contention that inhibition of distractors operates at the level of processing required for selection in the task (cf. Tipper et al., 1994). The first is that, for normal subjects in Experiment 1a, negative priming was confined to a condition in which distractors were identical to targets on "different" trials. Fuentes et al. (submitted) found negative priming in the different-distractor condition, relative to the neutral condition, when subjects matched on the basis of whether targets in prime and probe displays were both letters (or both digits). This indicates that, in category matching, inhibition may be applied across a category (i.e. to all letters, not just those repeated in prime and probe displays). Here, matching was based on physical identity, and inhibition was applied only to the distractors in probe displays.

The second finding was that, for DW, right-field distractors differing in case to targets were not inhibited (in Experiment 2b). This contrasted with when distractors and targets were in the same case (Experiment 2a). Here again, inhibition seemed to be applied only to stimuli coded at a level appropriate for the goals of the task. These results support the proposal advanced by Tipper et al. (1994) that inhibition is a rather flexible mechanism. That is, inhibition is associated with distractor properties that

compete with the target for the control of action. Upper-case distractors but not lower-case distractors were inhibited in a task requiring physical matching of upper-case targets.

Overall, the data indicate that there can be processing of "extinguished" stimuli to a relatively high level by neglect patients, that such stimulus representations nevertheless fail to be inhibited, and that inhibition is applied to the level of coding required for the goals of a task.

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