

Activating Response Codes by Stimuli in the Neglected Visual Field

Asher Cohen
Hebrew University

Robert D. Rafal
University of California, Davis, and
Veterans Affairs Medical Center, Martinez

Richard B. Ivry
University of California, Berkeley

Carolyn Kohn
University of California, Berkeley

The ability of 2 patients with a clinical deficit of extinction to process stimuli presented contralaterally to their lesions was tested with 2 variants of the flanker task. The patients saw 2 colored stimuli, 1 of which appeared in the center of the visual field and the other either on the ipsi- or contralateral side. In the peripheral report task, the patients had to report the color of the peripheral stimulus. In the center report task, the patients had to report the color of the central stimulus. The patients were much slower in the peripheral report task when the target was presented contralaterally to their lesion. By contrast, the responses in the center report task were equally influenced by ipsi- and contralateral flankers. The findings indicate that the patients were not impaired in the perceptual processing or the activation of response codes for contralateral stimuli. Their impairment is related to processes needed for generation of overt responses.

Lesions of the posterior association cortex often produce the clinical sign of extinction. Although stimuli contralateral to the lesion may be detected when presented alone, the patient fails to report it if a simultaneous stimulus is presented ipsilesionally and will deny awareness of it. Extinction is one component of the neglect syndrome in which there is an associated failure to explore contralesional space or respond to objects there.

Extinction has been interpreted as an attentional deficit by assuming that attention is drawn more easily to the ipsilesional side (for reviews, see Baylis, Driver, & Rafal, 1993; Heilman, Watson, & Valenstein, 1985; Robertson, 1991). Thus, when stimuli are presented bilaterally, the ipsilateral stimulus will capture attention and the contralateral stimulus will be ignored. The current study examines the extent to which extinguished stimuli are processed. Assuming that extinction is due to an attentional deficit, the answer to this question is related to two important questions in the research on visual attention. First, what is the role of attention in the stream of processes that ends with a response to a visual stimulus? Second, what is the degree to which stimuli outside the focus of attention are processed by the visual system? Behavioral research on these questions in normal participants has led to ambiguous results (see Keele & Neill, 1977; for an overview of this controversy, see Kahneman & Treisman, 1984; Shiffrin, 1988).

Asher Cohen, Department of Psychology, Hebrew University, Jerusalem, Israel; Richard B. Ivry and Carolyn Kohn, Department of Psychology, University of California, Berkeley; Robert D. Rafal, Department of Neurology, University of California, Davis, and Veterans Affairs Medical Center, Martinez, California.

This research was supported by National Science Foundation Grant BNS 90-12471 and Public Health Service Grants MH41544 and AG0256.

Correspondence concerning this article should be addressed to Asher Cohen, Department of Psychology, Hebrew University, Mount Scopus, Jerusalem, Israel. Electronic mail may be sent to msasher@pluto.mscc.huji.ac.il.

Several studies have previously examined this question with patients. An article by Volpe, LeDoux, and Gazzaniga (1979) showed a striking dissociation in performance for extinction patients on naming and matching tasks. Two stimuli were presented on each trial, one in each hemifield. The participants had to judge whether the stimuli were the same or different and identify the stimuli (reporting only one stimulus following same judgments). All of the patients performed quite well on the same-different task even though they were unable to name the contralesional stimulus. This dissociation led Volpe et al. (1979) to conclude that it "...becomes difficult to assert that the so-called extinguished stimulus is extinguished at all. Rather, this disturbance seems to involve a selective breakdown in a mechanism through which information ... reaches some level which allows for verbal description, if not conscious awareness." (p. 724) However, Farah, Monheh, and Wallace (1991) found a similar dissociation between matching and naming with normal participants with degraded stimuli. They concluded that the argument for normal perception in extinction may be premature. The extent of perceptual analysis needed for matching may be more elementary than that needed for naming.

More recently, there has been a flurry of articles reporting extensive processing of contralesional information in patients with attention disorders. Berti et al. (1992) tested a patient with extinction on a variety of matching tasks. In accord with the findings of Volpe et al. (1979), the patient performed quite well when matching ipsi- and contralesional stimuli. More impressive, the patient was significantly better than chance when the task required affirmative responses to bilateral stimuli that were different exemplars from the same category (e.g., two different pictures of cameras). These data suggest that the extinguished stimulus is processed at least to a semantic level of representation.

It remains possible, however, that the semantic matches were based on physical similarities. It is quite likely that

different exemplars from the same category were more physically similar than exemplars from different categories. A more general problem with the matching task is that it requires that the participant process both stimuli. As a result, it is often not possible in this method to determine the extent of processing that is required for a correct response. In addition, it is not clear where the participants focus their attention. They could process both stimuli in parallel or shift sequentially from one stimulus to the next. Another complication is that it is difficult to compare the Berti et al. (1992) study with the study of Volpe et al. (1979) because the former examined a patient with a temporal lobectomy instead of patients with parietal lesions. Nevertheless, the matching studies indicate that some processing of extinguished stimuli may take place.

Two recent studies provide more convincing evidence that neglected information achieves a semantic level of representation. Berti and Rizzolatti (1992) had patients with neglect judge whether a stimulus presented in the ipsilesional hemifield was a picture of a fruit or vegetable. The target was preceded by a contralesional prime that was either identical to the target, unrelated to the target, or a different exemplar from the same category. Significant categorical priming was obtained even though most participants denied ever having seen the primes in the contralesional hemifield. Similar results were obtained by McGlinchey-Berroth, Milberg, Verfaellie, Alexander, and Kilduff (1993) with a lexical decision task following a presentation of a line drawing prime. Moreover, in this study, the target was presented foveally, and the prime was presented in either the ipsi- or contralesional hemifield. The magnitude of priming was comparable for the two hemifields, indicating that the perceptual analysis of the neglected prime was as extensive as for the non-neglected prime. McGlinchey-Berroth et al. (1993) also included an important control experiment in which the patients were required to match a prime that was presented peripherally to a target that was presented centrally after the offset of the prime. The performance of the patients in this task was much worse when the prime was presented in the contralesional side than when it was presented ipsilesionally. However, the target in this control experiment consisted of a picture rather than a string of letters; thus it is different from the experimental lexical decision task.

This body of evidence strongly supports the hypothesis that the deficit in extinction is not in perceiving contralesional stimuli *per se*, but rather in postperceptual processes that occur after the initial recognition of the stimulus. Furthermore, the study of McGlinchey-Berroth et al. (1993) also highlighted the importance of distinguishing between tasks in which the patients have to respond explicitly to the contralesional stimulus and in which patients are impaired (as in the control task) and tasks in which no explicit response to the contralesional stimulus is required (as in the experimental task) in which processing is observed.

Nonetheless, the methods used in the studies reviewed above have several limitations. In both of the priming studies, the prime preceded the target by a substantial amount of time (400 ms in Berti & Rizzolatti, 1992; 600 ms in McGlinchey-Berroth et al., 1993). Because the prime was first presented by itself and extinction patients may be able to process a single contralesional stimulus, it is possible that the patients first

focused their attention on the contralesional prime and then shifted their attention to the ipsilesional target. Thus, in all these studies it is not entirely clear where the patients' attention was focused and to what extent they could report the contralesional stimuli at the time in which it was presented. Even more importantly, although it is clear that some semantic processing of the contralesional stimulus took place, it is not clear what is the extent of this processing. The studies indicate that this processing is sufficient to facilitate the response to the target, but the extent of semantic facilitation that is needed for such priming is not known.

The main goal of our study was to characterize the extent of processing of stimuli in the extinguished field. In particular, we tested whether patients with extinction not only process contralesional stimuli but also activate response codes that are associated with these stimuli. Furthermore, our hypothesis held that this processing of contralesional stimuli occurs even when they are presented simultaneously with foveally presented targets. To these ends, a modified version of the flanker task was used (e.g., Eriksen & Eriksen, 1974; Eriksen & Schultz, 1979).

In the basic form of the flanker task, one of two possible targets (e.g., X or O) is presented at a known location on each trial. Participants are instructed to respond by pressing one key for one of the targets and a different key for the other target. The target letter is flanked by two or more other stimuli in this task, and the key question is whether these flanking stimuli influence the ability to perceive or to respond to the target. The critical manipulation is the relation between the target and the flankers. The flankers may be either neutral (e.g., the letter F), compatible (e.g., both target and flankers are O or both are X), or incompatible (e.g., the target is X and the flankers are O or vice versa). Even though the target occurs at a known location, compatible flankers tend to reduce response latencies to the target and incompatible flankers tend to increase response latencies (e.g., Eriksen & Eriksen, 1974; Miller, 1991).

It is important to keep in mind that the interference from incompatible flankers is primarily due to their association with particular responses. In the example given above, participants are slower to respond to a Target X flanked by Os than to X flanked by neutral letters (e.g., Fs). This happens because O is associated with the alternative response, whereas F is not associated with any response. Thus, the flanker effect can be obtained only if the flankers are fully identified and their response association is activated. Indeed, a common interpretation of these results (e.g., Eriksen & Schultz, 1979) is that the interference caused by incompatible flankers occurs because these flankers compete with the target for attentional resources needed in response selection which leads to a slower response. The facilitation of compatible flankers is the result of increased activation of the response code associated with the target.

In our modified task, a target located in the center of the display was flanked by a single irrelevant stimulus located in either the ipsi- or contralesional hemifield. In the main experimental task, the participants had to focus on the central target and respond to it only while ignoring the peripheral flanker. The critical comparison in this paradigm is between

effects of the ipsilesional flanker and the effects of the contralateral flanker. If the patients are able to process contralateral stimuli and activate their response code, we should find a flanker effect from extinguished stimuli. Because we know that patients with extinction suffer from an attentional deficit to contralateral stimuli, this result would also indicate that stimuli can be identified and their response code activated even when attention is focused elsewhere.

In the current experiment, participants judged whether a centrally presented target was red or green. This target was flanked by a second stimulus that was red, green, or blue. The task imposes no need for processing of the peripheral flanker because the color of this object provides no information as to the color of the target object. Moreover, the central target and peripheral flanker can be presented simultaneously. In this manner, a comparison of the magnitude of the flanker effect can be made between the ipsi- and contralateral conditions. Because the onset of the flanker is simultaneous with that of the target and not preceding it, as was the case in the priming studies summarized earlier, there was no opportunity for attention to be drawn to a contralateral flanker before the target appeared. Thus, we could be more confident that any effect of the contralateral flanker is not attributable to some allocation of attention to it before the target appeared.

Another important addition in our study is the inclusion of a control task to examine the extent of extinction with the same stimuli. We showed the participants the same stimuli as in the experimental task but asked them this time to ignore the center stimulus and instead report the color of the peripheral stimulus. Thus, the positions of the target and flanker were reversed. The peripheral target could either be presented in the ipsi- or contralateral hemifield. Both of our patients had neglect, as measured by conventional clinical tests, and reliable extinction on conventional tests where two stimuli are presented and the patient is required to attempt to report both of them. In addition, typical examination of extinction involves a brief presentation of the stimuli, whereas the stimuli in our task were presented until the participant responded. When not required to report the central target and encouraged to ignore it and presenting the stimuli until the onset of response, both were able to do this task. Nevertheless, as will be shown, the central stimulus in the control task did strongly compromise responses to contralateral targets; and this provided a measure similar to the one referred to by Posner, Walker, Friedrich, and Rafal (1984) as an "extinction-like reaction time pattern." This confirmed the fact that the patients were more impaired in responding overtly to contralateral stimuli and provided a measure of the severity of this impairment. Inclusion of this control peripheral report task provided two benefits. First, a quantitative assessment of extinction was obtained, which not only supplemented the clinical assessment of extinction and neglect, but also provided a quantitative measure of extinction with the identical stimuli used in the experimental task. Second, by assessing visual field differences in the experimental and control tasks, we compared the extent of implicit processing of extinguished stimuli (in the experimental task) with deficits observed when patients were required to make an overt response to extinguished stimuli (in the control task).

Method

Participants

Two patients were tested on multiple sessions. Lesion reconstruction produced from MRI scans are shown in Figure 1 for the 2 patients. Six years prior to testing, Patient E.H. had a stroke affecting the left hemisphere resulting in right hemiparesis and persistent right hemineglect. Minor word-finding difficulties were the only signs of aphasia. MRI revealed bilateral periventricular lucencies and two discrete infarctions in the left hemisphere. The anterior focus was in the frontal corona radiata and operculum, involving the dorsolateral prefrontal cortex including the frontal eye fields. The posterior focus was in the lateral occipital and parieto-occipital junction involving the inferior parietal lobule, but not the superior parietal lobule or the temporo-parietal junction (see Figure 1). Patient C.R., 12 years prior to testing, had a stroke that affected almost the entire right middle cerebral artery territory. The lesion involved the inferior and superior parietal lobules, the temporo-parietal junction, the frontal and parietal operculae, the insula, the basal ganglia and internal capsule, and much of the dorsolateral prefrontal cortex including motor and premotor cortex area 45 and 46 and the frontal eye fields (see Figure 1). Although alert and vigorous, he has a dense left hemiplegia and hemianesthesia and left visual extinction with intact visual fields.

Stimuli and Procedure

The stimuli and basic procedure were identical for both control and experimental tasks. The patients sat in front of a computer screen and saw two colored stimuli on each trial. One of the stimuli was presented at the center of the screen, and the other stimulus was presented to either the left or right of the central stimulus. The stimuli were always identical in shape (the letter O) and were presented in one of two sizes. From a viewing distance of 100 cm, the center stimulus subtended a visual angle of approximately 0.35 degree of arc in height and 0.28 degree in width. The peripheral stimulus was larger and subtended a visual angle of approximately 0.57 degree in height and 0.52 degree in width. The horizontal edge-to-edge distance between the center and peripheral stimuli was 0.63 degree of arc. The stimuli were arranged so that the vertical midline of the center and peripheral O's was identical.

In both the control and experimental conditions, the participants' task was to name the color of the target stimulus. In the control condition, the peripheral report task, the peripheral stimulus was the target and the center stimulus was the distractor. In the experimental condition, the center report task, the center stimulus was the target and the peripheral stimulus was the flanker. The color of the target was either green or red, and the patient was required to report this color. Because E.H. had difficulty using a response board,¹ he made his responses orally, and an experimenter entered the responses on the response board. The experimenter was positioned out of sight of the monitor and was unaware of the correct response for each trial. Thus, the reaction time (RT) data for E.H. overestimates his actual RTs by a constant (estimated to be about 500 ms). C.R. made his responses on the response board directly, with the middle finger of his right hand to indicate that the target was green and the index finger of his right hand to indicate that the target was red (the same mapping was used for the experimenter entering E.H.'s responses). The color of the flanker stimulus was green, red, or blue. When it was green or red, it was either

¹ E.H. has a history of word difficulties as well. However, he did not have any difficulty in expressing the two words (*green* and *red*) required in this task.

E.H.

C.R.

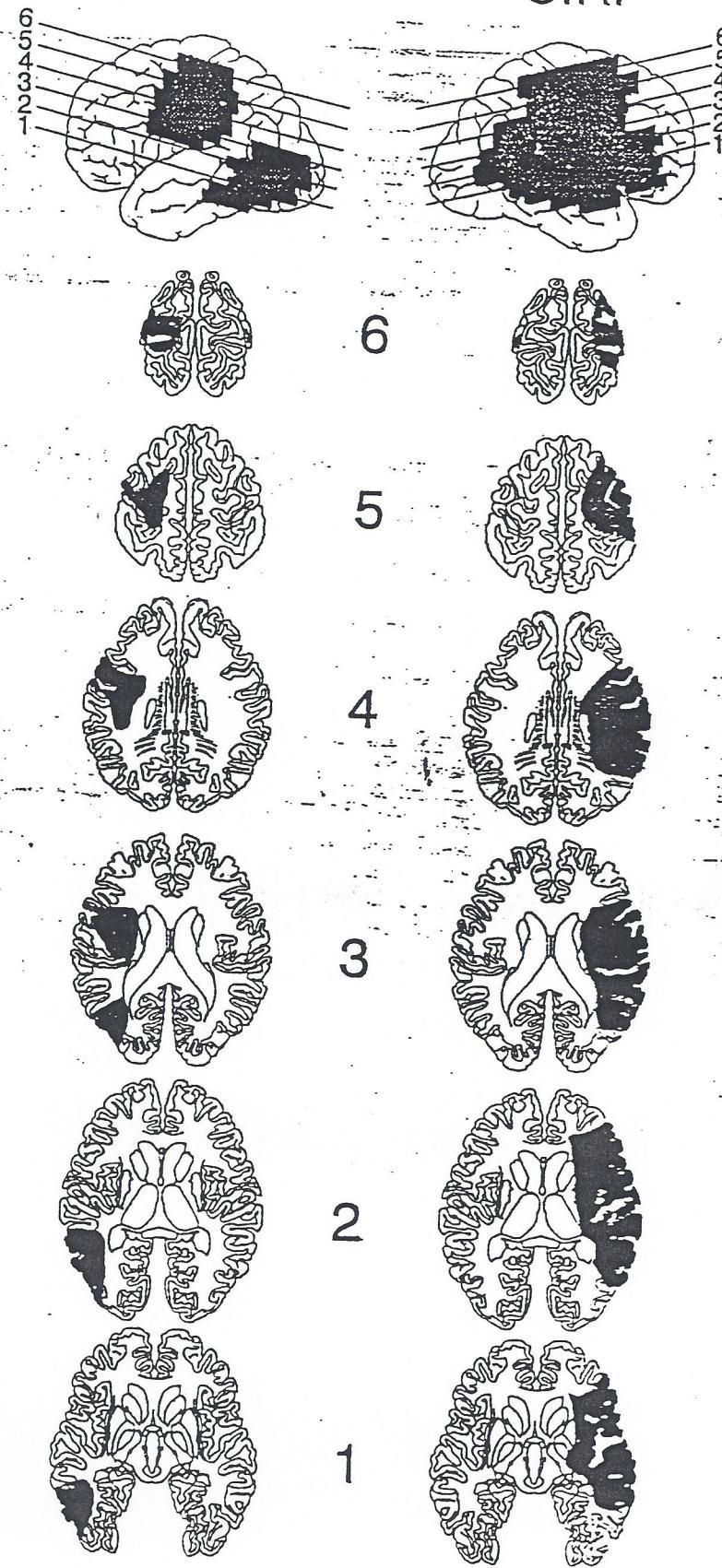


Figure 1. Neuroimage reconstructions for Patient E.H. (left) and Patient C.R. (right).

compatible or incompatible with the target color. Blue flankers served as a neutral baseline condition.

Each trial began with the presentation of three horizontal bars (0.35 in length) indicating the possible positions of the two stimuli. One second later, an asterisk appeared above the bar in the center location. This served as a fixation marker as well as an alerting signal. After 1 s, the asterisk was erased. Five hundred milliseconds later, the stimulus display of the two colored Os was presented. One of these stimuli was always positioned above the bar in the center location. A second stimulus was positioned above the bar located to the right or left of the center position. The display remained visible until the participant responded. The patients were instructed to ignore the flanker stimulus (center stimulus in the control condition and peripheral stimulus in the experimental condition) and report only the color of the target letter as quickly as possible. The horizontal bars and difference in size between the two stimuli were included to eliminate the possibility that the participant would not know which stimulus was the target. Erroneous responses were followed by feedback.

Overall, there were 24 different trial types: 2 Tasks (peripheral

report and center report) \times 3 Flanker Types (compatible, neutral, and incompatible) \times 2 Sides (peripheral report task: left and right targets; center report task: left and right flankers) \times 2 Target Colors (green and red). On half of the trials, the target color was green, and on the other half the target color was red. The three flanker types were each presented on one third of the trials. The side of presentation, flanker type, and target color were randomized within blocks of 96 trials each. To minimize the possibility that the participants could become confused as to which stimulus to respond to only one task was performed during a given test session. Each participant completed eight test sessions, four during which they responded to the center stimulus and four to the peripheral stimulus. The sessions alternated between the two tasks with a minimum of 1 week between each test session. Each session consisted of one practice block of 48 trials and four test blocks of 96 trials. Participants were given a break of approximately 3 min between blocks.

Results and Discussion

E.H. has a left hemisphere lesion and C.R. a right hemisphere lesion.² To the extent that they suffer from extinction, it was expected that E.H. would be slower in the peripheral report task when the target was located in the right peripheral location and C.R. would be slower in the peripheral report task when the target was located to the left of center. The difference in RT between the right and left side stimuli would give us a quantitative estimate of the severity of the patient's attention deficit. The central question was the relative influence of ipsi- and contralesional flankers in the central task.

Because the results of the four sessions were similar, the data were averaged across sessions. Figure 2 presents the main data averaged across target color (green and red). The top shows results for E.H. and the bottom shows results for C.R. Within each task, separate results are shown for the three flanker types for each side.

The data from the peripheral report task were analyzed in a repeated measures analysis of variance (ANOVA) with the 2 patients as a between-subjects variable and the sessions as the repeating measure.³ As expected, latencies to the contra-

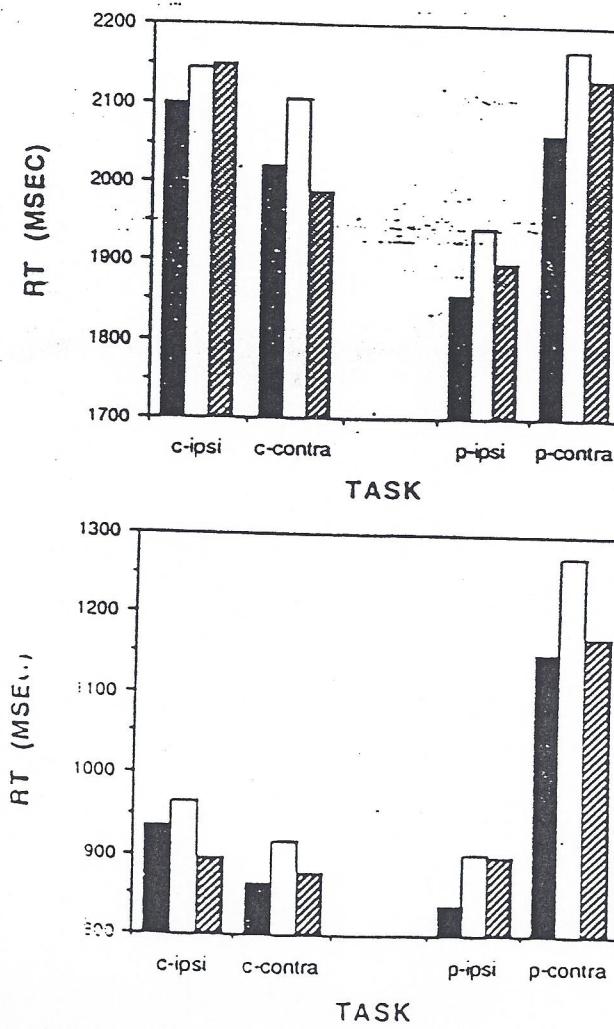


Figure 2. Mean reaction times (RTs) for Patients E.H. and C.R. Central (c) report conditions (left) and peripheral (p) report conditions (right). For each task, the congruent (solid bars), neutral (hatched bars), and incongruent (open bars) conditions are shown for the ipsi- and contralesional sides. For E.H., the right visual field is contralateral; for C.R., the left visual field is contralateral.

²The current center task is different from the typical flanker experiment in that there was just a single flanker on each trial. The peripheral report task had never been used before. Therefore, we first tested normal college students on both tasks. Results in both tasks were similar: Participants were fastest in the congruent conditions, slowest in the incongruent conditions, and intermediate in the neutral condition. In addition in both tasks, there was no difference between results obtained with the right peripheral stimulus and the left peripheral stimulus. The important point for our purposes is that the to-be-ignored stimulus was processed by the participants and influenced their reaction times. That is, both the center report and peripheral report task yielded results similar to that obtained in studies using the standard flanker task (e.g., Eriksen & Eriksen, 1974).

³The pattern of results from the individual analyses essentially mirrored that obtained in the combined analyses with minor differences. As can be expected from Figure 2, in all of the analyses, the latencies for E.H. were significantly slower than those for C.R. An interaction involving the subject variable was obtained in one case: On the center report task, there was a Subject \times Side interaction, $F(1, 6) = 6.12, p < .05$, because the side effect was larger for C.R. However, as confirmed in separate analyses for each participant, the side factor was significant for both patients.

sional stimuli were much slower than responses to ipsilesional stimuli, $F(1, 6) = 78.66, p < .001$. For E.H., RTs to ipsilesional stimuli were 222 ms faster than for contralateral stimuli. For C.R., ipsilesional stimuli were responded to 333 ms faster than contralateral stimuli. In addition, a significant effect of flanker type was also obtained, $F(2, 12) = 15.19, p < .001$. The interaction of Side \times Flanker Type was not significant, $F(2, 12) < 1.0$. Pairwise comparisons indicated that responses on incongruent trials were significantly slower than responses on congruent trials, $F(1, 6) = 22.98, p < .01$, and neutral trials, $F(1, 6) = 10.56, p < .02$.⁴

The error data were in agreement with the latency data. E.H. responded incorrectly on 19.0% of the trials when the target was contralateral in comparison to an error rate of 9.4% for ipsilesional trials. Moreover, responses on 24.2% of incongruent contralateral trials were incorrect, a value almost twice as large as that observed for congruent contralateral trials (12.8%). For the most part, C.R. showed the same pattern but was more accurate, averaging 3.7% and 10.0% errors for ipsi- and contralateral targets, respectively. The only condition for which his error rate was higher than 5.0% was for incongruent contralateral trials. Here, C.R. made errors on 22.5% of the trials.

In summary, the peripheral report task verifies that the patients suffer from extinction. Responses to contralateral stimuli were slower than responses to ipsilesional stimuli. However, for both sides, the color of the center O influenced processing as indicated by the difference between the RTs for the congruent and incongruent conditions.⁵

The results for the center report task are shown in Figure 2 where a significant effect of side was obtained, $F(1, 6) = 73.78, p < .001$. Unlike the peripheral report task, both participants were slower in responding when the peripheral flanker was on the ipsilesional side. E.H. was 92 ms slower when the flanker appeared on the left ipsilesional side and C.R. was slower by 46 ms overall when the center target was flanked by a peripheral stimulus on the ipsilesional right side. Although this result may at first appear somewhat counterintuitive, it actually provides another demonstration of the patients' extinction. Although the patients knew that the target would appear in the center and could focus on this location in advance, the appearance of another stimulus more ipsilesional than the target caused interference.

More interestingly, latencies to identify the color of the center target were affected by the color of the peripheral flankers. A main effect of flanker type was obtained, $F(2, 12) = 16.30, p < .001$, and pairwise comparisons indicated that responses on incongruent trials were slower than responses on congruent trials, $F(1, 6) = 21.08, p < .01$, and neutral trials, $F(1, 6) = 18.25, p < .01$. Most interestingly, the Side \times Flanker type interaction was not significant, $F(2, 12) < 1.0$. For E.H., the difference between the incongruent and congruent mean RTs was 43 ms for ipsilesional flankers and 87 ms for contralateral flankers. Comparable figures for C.R. were 29 ms and 54 ms for the ipsi- and contralateral flankers, respectively. If anything for both participants, the trend was for the congruency effect to be larger for contralateral flankers than for ipsilesional flankers.⁶

Interestingly, there is a consistent difference between the

incongruent condition and the neutral condition indicating interference when incongruent flankers appear with the target. Similarly, there is a consistent difference between the incongruent condition and the congruent condition. However, the

⁴We also examined possible differences between the two color targets. The pattern of results for both patients was similar for both targets in the peripheral report task. For C.R., the difference between the ipsi- and contralateral sides was 246 ms in the congruent condition, 319 ms in the incongruent condition, and 193 ms in the neutral condition when the target was red. The difference between the ipsi- and contralateral sides was 376 ms in the congruent condition, 425 ms in the incongruent condition, and 351 ms in the neutral condition when the target was green. The difference between incongruent and congruent condition was 85 ms in the ipsilesional side and 158 ms in the contralateral side when the target was red. The difference between incongruent and congruent condition was 42 ms in the ipsilesional side and 91 ms in the contralateral side when the target was green.

For E.H., the difference between the ipsi- and contralateral sides was 189 ms in the congruent condition, 208 ms in the incongruent condition, and 121 ms in the neutral condition when the target was red. The difference between the ipsi- and contralateral sides was 224 ms in the congruent condition, 246 ms in the incongruent condition, and 352 ms in the neutral condition when the target was green. The difference between incongruent and congruent condition was 87 ms in the ipsilesional side and 106 ms in the contralateral side when the target was red. The difference between incongruent and congruent condition was 83 ms in the ipsilesional side and 105 ms in the contralateral side when the target was green.

⁵Our primary measure of extinction in this study was the difference in latencies in the peripheral task. The typical clinical measurement of extinction is construed as a lack of awareness of contralateral stimuli in the presence of more ipsilesional stimuli. As mentioned earlier, this test requires the patient to report both ipsi- and contralateral stimuli and involves a brief presentation of the stimuli. Both C.R. and E.H. show extinction as determined by this test. To relate our study more directly to the clinical phenomenon, we tested C.R. on a modified version of the peripheral report test. The stimuli in this modified peripheral report task were identical to those of the original task. The only difference was that the stimuli appeared on the screen for a limited duration and then disappeared. Similar to the original task, C.R. had to report the peripheral stimulus. In this task, however, the independent variable was accuracy rather than latency.

Because C.R.'s mean latency to contralateral stimuli on the peripheral report task was 1,211 ms, we expected him to perform reasonably well on the modified task with an exposure duration of 1,000 ms (assuming some time for response execution). Surprisingly, when the stimuli were presented for 1,000 ms, C.R. did not report the color of the contralateral targets. He claimed not to see anything on these trials and was very reluctant to guess. In a later session, the exposure duration was increased to 2,140 ms over four blocks of 24 trials each, 12 per side. C.R. failed to identify the color of the ipsilesional target on only 1 trial out of 48. In contrast, C.R. was correct on only 17 of the 48 trials with contralateral targets, with the alternative color selected on 13 trials, and no response made on the remaining 18 trials. We were not able to resolve the discrepancy between C.R.'s difficulty on this task and his high level of accuracy in the main study on the peripheral task because C.R. found the limited exposure experiment frustrating and unpleasant. It is possible that not seeing the target on a significant portion of the trials affected C.R.'s willingness to concentrate. Nonetheless, the limited exposure experiment provides additional evidence that C.R. shows extinction.

⁶We also looked at possible differences between the two color targets in the center report task. There was no hint of such a difference for

difference between the neutral condition and the congruent condition is not entirely consistent in this study. This is not unique to the present study and is, in fact, common in the flanker literature with normal study participants (e.g., Grice & Gwynne, 1985). Although interference is found consistently, the finding of facilitation by congruent flankers is much less consistent. The reason for this phenomenon is in dispute. This phenomenon, however, is not related to the main conclusions of our study. The important finding in our study is that there is a similar difference between the incongruent condition and the neutral condition in both hemifields and that the only difference between the two conditions is the degree of congruency of the responses. That is, in both incongruent and neutral conditions the target and flankers are different. However, in the incongruent condition, the flanker is assigned to a different response from the target, whereas in the neutral condition the flanker is not assigned to a different response.

As in the peripheral report task, the error data revealed a similar pattern of results as was found for the latency data. For both participants, more errors were made when the flanker was in the ipsilesional visual field (center target in contralateral direction to the flanker), the difference being 3.6% (14.9% vs. 11.3%) for E.H. and 2.3% (6.0% vs. 3.7%) for C.R. The highest error rates were found for the incongruent ipsilesional conditions (E.H.: 17.9%; C.R.: 8.4%).

Overall, the findings from the center report task clearly indicate that visual features from contralateral stimuli are processed, even when the response only requires the participant to attend to a centrally located target. This finding supports the hypothesis that extinction patients perceive stimuli located in the contralateral visual field and that these percepts affect response selection processes.

General Discussion

The results of the present study have important implications for understanding the nature of extinction. A longstanding debate in neuropsychology concerns the source of the extinction deficit. As found in other patients with extinction (e.g., Posner et al., 1984), E.H. and C.R. could respond to contra-

C.R. The difference between congruent and incongruent condition was 32 ms when the flanker was ipsilesional and 61 ms when the target was contralateral for the red target. The difference between congruent and incongruent conditions was 25 ms when the flanker was ipsilesional and 48 ms when the target was contralateral for the green target. These differences were observed in all sessions.

The pattern of results for E.H. was different, however, for the two colors. The difference between incongruent and congruent conditions was observed for all sessions when the target was green and was on the average 170 ms for the ipsilesional flanker and 219 for the contralateral flanker. The results for the red target were not as consistent. When the flanker was contralateral the reaction times (RTs) to the congruent condition were faster in two of the sessions, the RTs for the incongruent condition were faster in one session, and equal in a fourth session. When the flanker was ipsilesional, the RTs to the congruent condition were faster in just one session, and the RTs for the incongruent condition were faster in the other three sessions. Nevertheless, across both targets the RTs for the congruent condition were faster than the RTs in the incongruent condition in all sessions.

sional stimuli under some conditions. Although both had extinction with brief bilateral presentation, they were able to report a contralateral stimulus in the presence of a central distractor when the center stimulus did not require action and the peripheral target remained visible until a response was made. Even under these conditions, both patients were considerably slower to respond to contralateral targets in the peripheral report task. These findings suggest that at the very least there was considerably more extinction in the contralateral field than in the ipsilesional field. Some theorists (e.g., Bender, 1952) have attributed extinction to low level sensory problems, suggesting that there is impaired perceptual processing of the contralateral signal. The finding of the peripheral report task would be consistent with this account. However, a flanker at the same location on the center report task produced a comparable amount of interference as an ipsilesional flanker despite the stronger extinction in the contralateral field. Thus, these results suggest a deficit in postperceptual processes, a conclusion that is in accord with a growing body of evidence on the nature of extinction (e.g., Berti & Rizzolatti, 1992; McGlinchey-Berroth et al., 1993; Volpe et al., 1979).

Our findings provide new insights into the locus of postperceptual processing at which extinction occurs. The basic paradox to be explained is why the processing of contralateral stimuli appears to differ depending on whether this processing is assessed directly (as in the peripheral report task) or indirectly (as in the center report task). One possibility is that contralateral stimuli are at a disadvantage in activating response codes in comparison to ipsilesional stimuli. The present results are not consistent with a deficit at this stage of processing. As discussed earlier, the congruency effect is attributed to the activation of response codes by the flanking stimuli. Facilitation on congruent trials is assumed to reflect the activation of a common response code by both the target and flanker. Interference on incongruent trials is assumed to reflect the activation of competing response codes by the target and flanker. Thus, a deficit in activating response codes associated with contralateral stimuli should predict that the congruency effects would be diminished when the flanker is presented in the contralateral hemifield. This prediction was not supported by the data. Similar congruency effects were found for ipsi- and contralateral flankers, suggesting that contralateral stimuli activate response codes in a manner similar to ipsilesional stimuli.

A second hypothesis is that extinction reflects a specific deficit in generating overt responses to contralateral stimuli. This hypothesis can account for the direct-indirect dissociation seen in the current results as well as previous findings. For example, McGlinchey-Berroth et al. (1993) found that patients were clearly impaired in explicitly reporting contralateral stimuli even though these stimuli produced normal priming effects on a central target. As in our study, one difference between the priming task and the control task in the study of McGlinchey-Berroth et al. (1993) was the need to generate an overt response in the control task. By this account, response codes were activated in a normal manner by contralateral stimuli, but selection of an overt response code linked to a contralateral stimulus is impaired.

With a very different paradigm, Baylis et al. (1993) have reported evidence for an impairment related to overt response selection in extinction patients. They presented colored letters to extinction patients, one object to each hemifield. The patients were asked to report what they saw on each side. In one condition, the patients were asked to report only the letters and in another condition they were asked to report only the colors. When the patient had to report the letters, they had difficulty in reporting a contralesional stimulus in the bilateral condition when that stimulus was identical in shape to the ipsilesional stimulus. When the two letters were different, the patients were able to report both letters on a significantly greater number of trials. Importantly, the color of the letters had no effect on the patients' response. A similar result was obtained on the color report task. Again, the patients were most impaired in reporting the color of the contralesional stimulus when the ipsilesional stimulus was of the same color. The identity of the letters did not influence their responses. As in our study, these results indicate that the contralesional stimuli are processed and the extinction deficit is due to postperceptual processes at a stage of overt response selection.

Although our study suggests that the problem of extinction lies in generating overt responses, other interpretations are possible as well. It is possible that other as-yet-unknown processes involved in response selection are impaired and that these impairments lead to the extinction present in the peripheral report task. Future studies are needed to address this issue.

Given the evidence (see Heilman et al., 1985; Robertson, 1991) that the deficits of extinction patients are due to an attentional impairment, we suggest that stimuli can be processed without attention. It has been argued that one role of attention is to communicate percepts to a system involved in the generation of overt responses. For example, based on PET studies, Posner, Petersen, Fox, and Raichle (1988) argued that, whereas posterior regions of the cortex play a dominant role in perceptual processing, overt response selection is done by systems located in the anterior part of the brain. It is possible that patients with extinction are impaired in the ability to communicate information from posterior perceptual systems to anterior overt response selection systems, normally done by attentional mechanisms. However, our study had just 2 patients and thus did not provide any evidence concerning the anatomy of extinction.

In the present study, patients with extinction processed ipsi- and contralesional color information in a similar manner up to some level below that needed for making overt responses. However, this does not mean that the same result would hold for all visual stimuli. Psychological, neuroanatomical, and neurophysiological evidence indicates that the visual scene is first parsed into features, such as color, line orientation, and direction of motion (reviewed in DeYoe & Van Essen, 1988; Livingstone & Hubel, 1987; Treisman, 1986). Objects consisting of a particular conjunction of features are analyzed by the visual system at a later stage (e.g., Cohen, 1993; Cohen & Ivry, 1989, 1991; Ivry & Prinzmetal, 1991; Prinzmetal, Presti, & Posner, 1986; Treisman & Schmidt, 1982). The task of the patients in our study was to identify colors. Thus, it is possible that single features, such as color and line orientations, can be

analyzed in a normal manner even if overt responses to those features are impaired (as was demonstrated in this study). By contrast, identification of conjunction of features may require attentional mechanisms. Cohen and Rafal (1991) reported a case study of a patient with a posterior parietal lobe damage who showed no clinical evidence of extinction. This patient was impaired in her ability to correctly combine color and shape information for stimuli presented in the contralesional hemifield, despite normal performance in identifying the simple features. Importantly, the deficit of this patient in feature-integration appeared to be directly related to her deficit in orienting attention. Taken together, the results of the current study and Cohen and Rafal (1991) suggest dissociable attentional deficits. One deficit is characterized as a problem in binding simple visual features into objects. This deficit can arise without a concurrent deficit in making overt responses (at least to simple features), as shown by Cohen and Rafal (1991). The second deficit is characterized as a problem in generating overt responses to objects and, as shown by the current study, this mechanism is impaired in patients with extinction. It remains to be seen whether these patients are also impaired in perceiving conjunctions of features presented in the contralesional hemifield.

Finally, an interesting parallel may be drawn between the pattern of findings obtained with patients who have attentional deficit, such as patients with extinction and neglect, and the pattern of findings for patients with memory deficits (for recent reviews, see Schacter, 1992; Squire, 1992). The deficits observed in these two groups of patients are very different. Yet, in both domains, the deficit of the patients is primarily manifested when the patients are asked to respond overtly to stimuli. Although it is possible that these similar behavioral symptoms are coincidental, they may also reflect a fundamental property of the cognitive architecture. For example, the impaired ability to make overt responses in the face of relatively normal processing as assessed by indirect measures may reflect the greater sensitivity of processes associated with consciousness to neural damage. Perhaps these processes reflect more recent adaptations and as such are more susceptible to brain injury. The special status of tasks requiring overt responses across task domains is in need of direct investigation.

References

- Baylis, G. C., Driver, J., & Rafal, R. D. (1993). Visual extinction and stimulus repetition. *Journal of Cognitive Neuroscience*, 5, 453-466.
- Bender, M. B. (1952). *Disorders in perception*. Springfield, IL: Thomas.
- Berti, A., Allport, A., Driver, J., Denies, Z., Oxbury, J., & Oxbury, S. (1992). Levels of processing for visual stimuli in an "extinguished" field. *Neuropsychologia*, 30, 403-415.
- Berti, A., & Rizzolatti, G. (1992). Visual processing without awareness: Evidence from unilateral neglect. *Journal of Cognitive Neuroscience*, 4, 345-351.
- Cohen, A. (1993). Asymmetries in visual search for conjunctive targets. *Journal of Experimental Psychology: Human Perception and Performance*, 19, 775-797.
- Cohen, A., & Ivry, R. (1989). Illusory conjunction inside and outside the focus of attention. *Journal of Experimental Psychology: Human Perception and Performance*, 15, 650-663.

- Cohen, A., & Ivry, R. (1991). Density effects in conjunction search: Evidence for a coarse location mechanism of feature integration. *Journal of Experimental Psychology: Human Perception and Performance*, 17, 891-901.
- Cohen, A., & Rafal, R. D. (1991). Attention and feature integration: Illusory conjunctions in a patient with a parietal lobe lesion. *Psychological Science*, 2, 106-109.
- De Yoe, E. A., & Van Essen, D. C. (1988). Concurrent processing streams in monkey visual cortex. *Trends in Neurosciences*, 11, 219-226.
- Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception and Psychophysics*, 16, 143-149.
- Eriksen, C. W., & Schultz, D. W. (1979). Information processing in visual search: A continuous flow conception and experimental results. *Perception and Psychophysics*, 25, 249-263.
- Farah, M. J., Monheh, M. A., & Wallace, M. A. (1991). Unconscious perception of "extinguished" visual stimuli: Reassessing the evidence. *Neuropsychologia*, 29, 949-958.
- Grice, R. G., & Gwynne, J. W. (1985). Temporal characteristics of noise conditions producing facilitation and interference. *Perception and Psychophysics*, 37, 495-501.
- Heilman, K. M., Watson, R. T., & Valenstein, E. (1985). Neglect and related disorders. In K. M. Heilman & E. Valenstein (Eds.), *Clinical neuropsychology* (2nd ed., pp. 243-293). New York: Oxford University Press.
- Ivry, R. B., & Prinzmetal, W. (1991). Effect of feature similarity on illusory conjunctions. *Perception and Psychophysics*, 49, 105-116.
- Kahneman, D., & Treisman, A. M. (1984). Changing views of attention and automaticity. In R. Parasuraman & D. R. Davies (Eds.), *Varieties of attention* (pp. 29-61). Orlando, FL: Academic Press.
- Keele, S. W., & Neill, W. L. (1977). Mechanisms of attention. In E. C. Carterette & M. P. Friedman (Eds.), *Handbook of perception* (Vol. 9, pp. 3-47). New York: Academic Press.
- Livingstone, M. S., & Hubel, D. H. (1987). Psychophysical evidence for separate channels for the perception of form, color, movement, and depth. *Journal of Neuroscience*, 7, 3416-3468.
- McClinchy-Berroth, R., Milberg, W. P., Verfaellie, M., Alexander, M., & Kilduff, P. T. (1993). Semantic processing in the neglected visual field: Evidence from a lexical decision task. *Cognitive Neuropsychology*, 10, 79-108.
- Miller, J. (1991). The flanker compatibility effect as a function of visual angle, attentional focus, visual transients, and perceptual load: A search for boundary conditions. *Perception and Psychophysics*, 49, 270-288.
- Posner, M. I., Petersen, S. E., Fox, P. T., & Raichle, M. E. (1988). Localization of cognitive operations in the human brain. *Science*, 240, 1627-1631.
- Posner, M. I., Walker, J. A., Friedrich, F. J., & Rafal, R. D. (1984). Effects of parietal lobe injury on covert orienting of visual attention. *Journal of Neuroscience*, 4, 1863-1874.
- Prinzmetal, W., Presti, D. E., & Posner, M. I. (1986). Does attention affect visual feature integration? *Journal of Experimental Psychology: Human Perception and Performance*, 12, 361-369.
- Robertson, L. C. (1991). Perceptual organization and attentional search in cognitive deficits. In D. Margolin (Ed.), *Cognitive neuropsychology in clinical practice* (pp. 96-113). New York: Oxford University Press.
- Schacter, D. L. (1992). Understanding implicit memory: A cognitive neuroscience approach. *American Psychologist*, 47, 559-569.
- Shiffrin, R. M. (1988). Attention. In R. C. Atkinson, R. J. Herrnstein, G. Lindzay, & R. D. Luce (Eds.), *Stevens's handbook of experimental psychology: Vol. 2 Learning and cognition* (pp. 739-811). New York: Wiley.
- Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review*, 99, 195-231.
- Treisman, A. M. (1986). Properties, parts and objects. In K. Boff, L. Kaufman, & J. Thomas (Eds.), *Handbook of perception and human performance* (pp. 1-70). New York: Wiley.
- Treisman, A. M., & Schmidt, H. (1982). Illusory conjunctions in the perception of objects. *Cognitive Psychology*, 14, 107-141.
- Volpe, B. T., LeDoux, J. E., & Gazzaniga, M. S. (1979). Information processing of visual stimuli in an "extinguished" field. *Nature*, 282, 722-724.

Received October 15, 1993

Revision received July 5, 1994

Accepted November 4, 1994 ■