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WHEN DOES "NO" REALLY MEAN "YES"? A CASE STUDY IN UNILATERAL VISUAL NEGLECT

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Abstract—A patient with unilateral visual neglect indicated whether a dot was or was not present in a display. When present, the dot appeared equally often in the left and right visual fields. Although he typically denied having seen dots in his left visual field, he was able to make this judgment much more quickly than when no dot was in fact present. The mean response times when the dot was present (1135 and 1004 msec, for left and right) were almost twice as fast as the response times when no dot was present (2025 msec). This result suggests that the patient searched the visual fields individually, and in fact generated a "No" response based on detecting the dot in his neglected field. Thus, the mechanisms used to detect stimuli apparently are not rigidly linked to those used to classify them or to produce a response.

INTRODUCTION

THE unilateral neglect syndrome is normally diagnosed by a patient's failure to report or respond to contralesional stimuli [6, 7] as well as by a denial of deficit [2]. However, several studies have demonstrated that neglected (contralesional) stimuli are processed to some extent. We know, for instance, that contralesional stimuli can cause skin conductance changes [15] and normal somatosensory or visual evoked potentials [16], and that they can facilitate detection of targets presented in the intact field, provided that the prime and target are identical or, more interestingly, belong to the same semantic category [1]. We also know that neglect patients have better access to contralesional stimulus information if asked about it indirectly. For example, VOLPE *et al.* [17] found that patients who explicitly deny the presence or identity of contralesional stimuli were still able to judge whether two stimuli simultaneously presented to the left and right hemifield are the same or different, and MARSHALL and HALLIGAN [10] described a case of a woman who stated a preference for an intact versus a burning house drawing while claiming that the two drawings were identical (the fire was drawn in the neglected hemifield).

The fact that performance and judgment can be affected by stimuli that do not reach awareness is not in itself special to neglect patients (e.g. Refs [13], [18] and [19]). What is striking in neglect patients is the tolerance for logical confusion and inconsistency that such residual processing provokes. Such inconsistency, from a commonsensical perspective, is revealed by the patient of MARSHALL and HALLIGAN [10], who should have been perplexed by her own statement of preference between "identical" houses. However, because the inconsistency is manifest only across two judgments, namely, the same/different judgment

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and the preference judgment, we cannot, strictly speaking, ascribe to her an inconsistency within a single judgment, on a single occasion.

The case study described here demonstrates that a stimulus can be simultaneously detected and labeled as absent. More specifically, in our experimental procedure, one aspect of the patient's response, the response time, indicates stimulus detection, whereas another aspect, the verbal content, simultaneously denies it. The task is simple yes/no detection, and the target appeared in left or right hemispace or was absent altogether. For our patient, the processing of denied targets is betrayed by the fact that the latency distribution for *denied* contralesional targets matches the latency distribution for *detected* ipsilesional targets, rather than the slower distribution produced by true target absence. The first two distributions were virtually disjoint from the third, plainly indicating that the denied stimulus was processed up to the "stop further search" command.

METHOD

Patient history

F.C., a 65-year-old right handed man, was admitted to the neurology ward after a sudden onset of left-side weakness. The patient was alert and cooperative. A neurological examination showed that he was anosognosic, ignored left-sided space, and was hemiplegic in the left arm and leg. His memory, language comprehension, and repetition were normal but his speech was slurred. His praxis was intact. He was unable to move his eyes leftward across the midline. His construction was poor, featuring severe neglect of left hemispace. He was unaware of painful stimulation on the left lower extremity but did appear to perceive pain in the right groin when painful stimulation was applied to his left side. He extinguished to left auditory stimuli on double simultaneous presentation. CT at admission revealed a right middle cerebral artery territory infarction. As illustrated in Fig. 1, MRI performed 3 days later showed a middle cerebral artery infarction involving the superior temporal gyrus, the frontal operculum and posterior-lateral part of the frontal-orbital region, the parietal operculum, and the insular region of the right cerebral hemisphere. This diagnosis was supported by an MR angiogram which showed a right internal carotid occlusion. Ten days later F.C. was transferred to a rehabilitation hospital where his condition continued to improve. He began to show increased awareness of left hemispace; he was able to move his eyes across midline to the left even though his head was still turned to the right, and would state that he had a stroke but could not yet specify that his left side was weak.

The study described here took place 1 month after F.C.'s stroke, while he was still undergoing intensive occupational and neuropsychological training. In an assessment two days prior to the experiment, he exhibited severe neglect on line cancellation (18/40 line). At the time of testing, his line cancellation performance had improved to 35/40. In the clock drawing task, he placed numerals on both sides of clock face, although his planning was poor. He did not show left-sided hemianopia on confrontation testing and was sensitive to pinprick and light touch on both sides, but he demonstrated persistent extinction to double simultaneous visual, auditory and tactile stimulation.

Stimuli and apparatus

The experiment made use of one of six tasks initially designed for a larger study of categorical and coordinate spatial relations encoding [8]. It was carried on a Macintosh Powerbook 140 laptop computer with a built-in microphone, running a modified version of the MacLab program [5]. As illustrated in Fig. 2, the stimulus consisted of a background figure and a target; the figure was made up of four shaded squares (2 cm × 2 cm) and one open square (4 cm × 4 cm) superimposed on two crosshairs (10 cm each). The target was a black dot (1 mm × 1 mm). On half of the trials the dot was present, and on half it did not appear on the screen. When the dot was present, it appeared to the left of the central vertical crosshair on half of the trials and to the right of the central vertical crosshair on the other half of the trials.

Procedure

The subject was tested in a quiet, private room. F.C. sat in his wheelchair in front of the computer, which was centered at the midsaggital plane with respect to his body. The task consisted of 32 experimental trials, preceded by 8 practice trials (which were themselves preceded by 12 response training trials). The purpose of the response training was to accustom the patient to speaking into the microphone. The word "YES" or "NO" appeared in the center of the screen, and he simply read it aloud into the microphone. The experimental trials were presented in a quasi-random order (i.e. random with the constraint that no more than three consecutive responses of the same type were demanded).

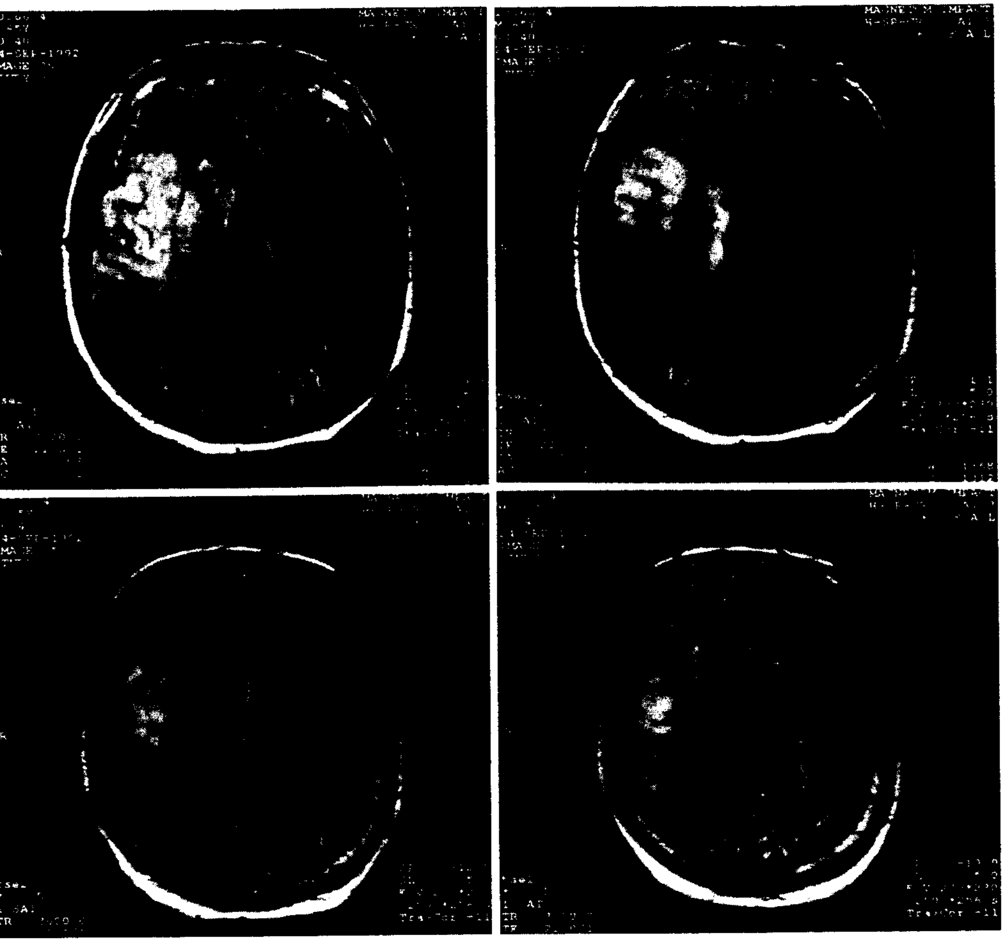

Fig. 1. MRI of patient F.C. showing an infarction involving the right middle cerebral artery territory.

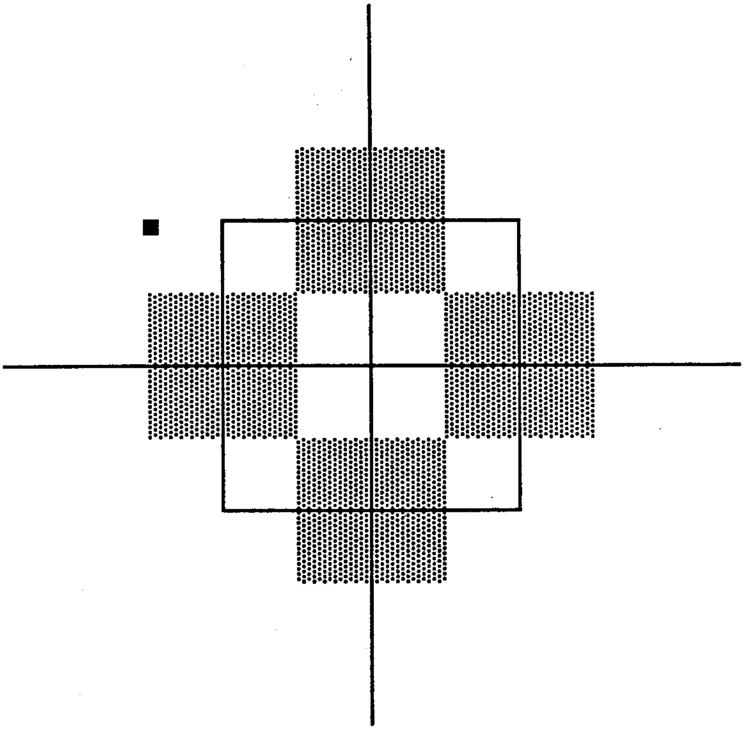

Fig. 2. Stimulus pattern with target on the left (a "yes" trial); in the "no" trials the background pattern was present and the dot was absent.

In each trial a centered exclamation point (1.2 cm × 2 cm) announced the appearance of the stimulus figure and was terminated by the experimenter's keypress. The screen was then blank for 500 msec. After that, the stimulus appeared and remained on the screen until the patient responded by speaking into the microphone. F.C. was instructed to say "yes" into the microphone if the dot was on the sceen and "no" if it was not, in either case as quickly and accurately as possible. He was told that the computer would record the time it took him to respond and that what he said would be recorded by the experimenter.

RESULTS

Error rates and response times were analyzed separately. As expected given his neglect, F.C. correctly detected the left-side dot less often (1 time out of the 8 trials) than the right-side dot (6 times out of the 8 trials), χ^2 (1) = 6.35, $P < 0.02$. There were no false alarms; that is, F.C. never responded "yes" when the dot was not present.

Figure 3 displays the response time distributions in box-plot format [14] for the 16 correct "no" responses (middle box plot), 7 incorrect "no" responses to left-sided dots (left box plot), and 6 correct "yes" responses to right-sided dots (right box plot). The mean response times with dot present (1135 and 1004 msec, for left and right) are almost twice as fast as the response times on null (no dot) trials (2025 msec). The null trial response time distribution has a significantly higher mean that either the left-side distribution [t (21) = 2.61, $P < 0.05$, two-tailed, separate variance] or the right-side distribution [t (20) = 2.87, $P < 0.01$]. The distributions are also different according to the nonparametric Mann–Whitney U test ($P < 0.05$ for each comparison). The response times to left and right dot presentations are not significantly different ($t < 1$).

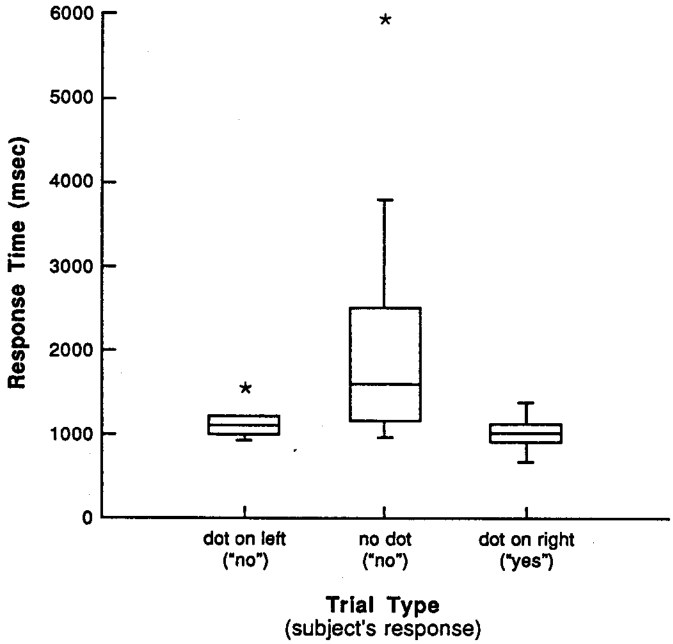

Fig. 3. Response time distributions from F.C. for the three types of trials, in box-plot format. The top and bottom sides of each box mark the interquartile range, the horizontal line inside each box marks the median, and asterisks denote outliers (for more details, see Ref. [14]).

Additionally, to make the distributions more normal and to diminish the influence of outlying data points, we performed a logarithmic transformation on the response times and repeated the analysis [t (21) = 3.07, $P < 0.01$ for left vs null, t (20) = 3.49, $P < 0.005$ for right vs null]. The log response times to left and right dot presentations are not significantly different ($t < 1$).

DISCUSSION

Ignoring the response labels, "yes" and "no", the response time data show that target presence yields quick judgments and target absence slow ones. Given this overall pattern, one could interpret a speedy response time as indicating detection of target on that trial, and a slow one as indicating a failure to detect it. Yet such an inference is rendered problematic by the semantic content ("no") of the responses to left-sided targets.

This apparent inconsistency between performance and awareness exhibited by F.C. raises similar problems of interpretation as do the findings of BISIACH *et al.* [4] and of TEGNÉR and LEVANDER [12]. In the BISIACH *et al.* study [4], subjects were required to respond to green or red diodes in either visual hemifield by pressing the response key of matching color, which would be red in one hemispace and green in the other. One of their patients (F.S.) exhibited a startling pattern to stimuli in the ipsilesional hemifield (right): When the color indicated a rightward response, performance was excellent; when the color indicated a leftward response, the patient would often deny the stimulus altogether. In a similar result, TEGNÉR and LEVANDER [12] found that in a mirror reversed line cancellation task, some of their patients denied the presence of lines present in their intact visual field when cancellation required contralesional hand movements.

Commenting on the behavior of F.S., Bisiach says that "given his correct performance on trials with right hand stimuli requiring responses to the right side of the panel, it is plausible to assert that he had been phenomenally aware of those stimuli, at least for a brief interval, also when he denied the occurrence of some of them in trials requiring responses to the left side. What is not possible to say is whether any trace of phenomenal experience persisted at the moment when he uttered his denial. Perhaps, all conscious memory of the stimulus had been suppressed by inhibitory processes caused by not having found the appropriate response-key on the preferred side" [2, p. 121]. A similar type of suppression would, according to BISIACH [2], explain the denial in TEGNÉR and LEVANDER's [12] patients. The common element in both tasks is the required contralesional hand movement.

In our task, no hand movement was required. To explain denial within the theoretical framework of BISIACH [2, 3], one would need to entertain the possibility of a functional equivalence between verbal acknowledgment of left-side targets and required leftward movement, which produced denial in the studies cited above. The role of verbal responses in gating access to consciousness has also been demonstrated by MARCEL [9], who found that requiring a verbal response rather than a blink or a button press, lowered detection accuracy both in blindsight patient G.Y. and in normal subjects operating near the visual threshold (see also Ref. [20]).

To the extent that processing can be inferred from response time distributions, we can conclude that the denied targets and the detected targets were processed in the same way by our patient F.C., and that both engendered different processing from trials without targets. The detection of a target should normally produce two commands, one to stop searching further and one to say "yes". In the case of F.C., the first of these two commands is processed efficiently, but the second one apparently is not initiated or is rerouted into "no". It is possible that detection up to the point of the "stop search" command is processed by intact low-level mechanisms, whereas awareness is gated by higher ones, which have been asymmetrically damaged. These higher mechanisms would be engaged in executing movement, as well as verbally acknowledging stimuli.

The other anomalous aspect of F.C.'s performance, the longer response times when targets are absent than when they are present, is not unusual in neglect patients who *acknowledge* targets on *both* sides of space. The experimental evidence is reported and discussed in greater detail by MIJOVIĆ *et al.* [11]. In the case of F.C., the increase in response time would be consistent with serial search, a checking for target absence first in one hemispace and then in the other. Indeed, F.C. required about twice as much time to report that a stimulus was absent when it was not present as to process stimuli that were present. Moreover, anyone watching F.C. perform the task would have noted the difference between his assured manner when denying the targets on the left and doubtful tone when indicating true absence. By his manner, F.C. acknowledged that he was at some level "aware" of his unawareness.

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