



Fast responses to neglected targets in visual search reflect pre-attentive processes: an exploration of response times in visual neglect

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Abstract

AE is a patient who suffered a right hemisphere stroke resulting in visual neglect symptoms. In the first experiment, AE neglected a single visual target that was present in half of the trials and appeared in variable and unpredictable positions on the computer screen. The contrast of the target to the screen's background was also varied. AE demonstrated severe neglect for left-sided targets, and yet his RTs to targets reported incorrectly as absent were faster than correct rejections and even right-sided hits. AEs fast "neglect" responses seem to indicate that the target was detected but that he remained unaware of its presence. Counter intuitively, his fast misses got faster as the discriminability of the target decreased. The possibility that fast responses to neglected targets reflected a guessing strategy, used proportionally to the degree of uncertainty of a target presence, was examined. AEs fast misses were indeed faster at lower level of contrast of the stimulus, but his error rate did not tend to approach the chance level as the guessing model would predict. In a second experiment, AE searched for the letter Z, present on half of the trials, among variable sets of distractor letters. In one condition the distractors were all O's and therefore differed from the target by an elementary feature. In the other condition, the distractors were various letters that differed from the target by combinations of features. The key finding was that fast responses to neglected targets occurred only in the simple feature search task and not in the complex features (conjunction) task. We interpret these findings as indicating that AEs pre-attentive processing can detect pop-out targets on the left-hand side, but that the attentional search is faulty and is aborted early. Hence, the patient's attentional system has an "early start" when "pop-out" forms are present, but can also fail to "grab" the detected target; consequently, by not attending to a stimulus, the patient remains unaware of its presence and will quickly respond "no" to present targets. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Visual neglect is most often seen after damage to the right hemisphere and one of its main features is defective exploration of the left side of space, or more generally of space contralateral to the lesion [70,86,87]. When patients with neglect are tested in a typical visual search task in which a previously defined target can appear unpredictably in several locations of the field of vision, such patients often wrongly report left-sided targets as absent. In addition, even when left targets are correctly reported as present, these patients may show significantly slower response times (RTs) to left targets than to targets that occupy right-sided locations. When the visual field is cluttered with visual distractors, and particularly when these appear on the right side, a further decrease in these patients' search efficiency to a left-sided target is also observed [7]. In general, neglect has been interpreted as reflecting the damage to attentional

mechanisms. The "spotlight/zoom" account of attention posits that spatial attention normally selects an area of space and enhances its content [44]. Brain lesions could damage this mechanism so that the attention window could become unable to disengage or unlock from right-sided information [38,64–66,69]. In those occasions in which damaged attention mechanisms actually succeed in disengaging and shifting, the attention window may do so at an abnormally slow rate and/or be directed onto a wrong location of the search field (e.g. it may undershoot the target's location, cf. [7,53]).

Some studies have also observed that the speed of response tends to be rather variable in these neglect patients [2,5,60]. One interesting phenomenon is that, despite the fact that a patient's response is generally slow, one occasionally observes rather fast RTs to left-sided targets. This may not be surprising if we do not simply view the damage to attention as an all-or-none phenomenon, so that the actual probability of a left target of capturing attention is never zero [2,5]. Indeed, it is now clear that spatial attention is modulated by other more general attentional factors, such

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as arousal or alertness [74–76, 80]. In other words, on some occasions, a left target can capture the patient's attention and result in a normal shift towards the target.

What seems paradoxical in light of the above considerations is that neglect patients have also been reported to provide fast "absent" RTs to present left targets. This contrasts with the case in which the left target had been detected and the patient acknowledged its presence; such correct detection would seem to reflect the occasional normal processing discussed above. However, in the case of a fast "neglect" response the patient's response seems to indicate that the target was detected but the patient remained unaware of its presence. This phenomenon was observed in a study of Mijović-Prelec et al. [60], where a neglect patient searched for a simple standard figure that was equally likely to appear on the computer screen or to be absent. The patient's task was simply to search for the target and say "yes" to its presence and "no" to its absence. The findings revealed that the patient's "neglect" responses (i.e. "no" to a present target) were as fast as his right-sided hits ("yes" to a present target), whereas when correctly reporting the absence of a target, his RTs were significantly slower than his incorrect "no" to left targets as well as his correct "yes" responses. Mijović-Prelec et al. suggested that the patient had been detecting the neglected target at the normal speed and that the patient's "no" responses (absence instead of presence) indicated that he failed to become aware of having actually detected a target. This unimpaired detection process would terminate the search but, since its content was suppressed from consciousness, the answer would be a "no" to the target presence. In the authors' words, the patient's "no" really means "yes", albeit in an implicit manner.

In the present study we examined in detail a case of left-sided neglect (AE), who also showed paradoxical fast responses to neglected targets. Our main goal was to clarify the cognitive mechanism that specifically underlies this phenomenon of rapid rejections of a present target. In our view, a patient's cognitive impairment, in this case unawareness for an object, could be argued to be the result of the dysfunction of a variety of different cognitive mechanisms (cf. [54]). In the first experiment, we examine the possibility that changes in RT performance could reflect a compensatory strategy that the patient utilizes to cope with diminished attention to the left and the resulting reduction in the ability to perceptually discriminate a left-sided figure from its background.

2. Experiment 1

A patient with severe neglect, AE, was examined in a visual search task where the target was a single gray diamond shape of variable contrast that appeared over a light green background on a computer screen. There were no distractors. The patient's task was to press a key marked 'yes' as quickly and accurately as possible when detecting the target shape

and a key marked 'no' when seeing no target (the actual likelihood was 50%).

Our first goal was to replicate the phenomenon of fast misses of left targets in visual neglect. Secondly, we put to the test an alternative to Mijović-Prelec et al.'s "implicit detection" account that quick misses in perceptual tasks reflect correct detections followed by a lack of awareness for fast misses in visual neglect. A simple alternative view is that the phenomenon originates as a compensatory strategy assumed (by normal subjects as well) under conditions of "perceptual uncertainty". For some patients even simple tasks would give rise to perceptual uncertainty and so the compensatory strategy would be triggered in situations that would not pose a problem for normal subjects. Specifically, we based our account on Luce's [55] review of animal and human studies of two-choice perceptual discriminations. This research has shown that RTs tend to become shorter with increasing levels of discrimination difficulty within the task. According to Luce's model of reaction time performance, a dual mechanism could fully account for the gradual shortening of RTs in increasingly difficult two-choice perceptual discriminations. Normally, RTs reflect the amount of sampling necessary for determining the presence of a target in a directly proportional manner; hence, when the signal-to-noise ratio of target to the background is high, the perceptual sampling is completed rapidly, and when the signal-to-noise ratio of target to background is low, the RTs are lengthened, since more sampling is necessary. However, both humans and animals (e.g. pigeons [13]) show a tendency to give occasional very fast responses (indeed, faster than most RTs to strong signals). According to Luce, another strategy is introduced in these cases, and this strategy is non-perceptual: subjects are simply "guessing" the presence of the target. These "guess" responses are fast, because they require by definition no perceptual sampling but only a random response selection (in tasks where there are only two possibilities and their probability is 50%, this would amount to a simple mental "flip of a coin").

Neglect can be conceived of as a situation in which there is an increased degree of uncertainty of a target's presence. For example, if neglect results from a pathological reduction in the numbers of cells representing particular lateral positions in space [67,68], the resulting distortion of the spatial frames of reference would bias, along a horizontal gradient, the control of spatial attention so as to increase the uncertainty about a target's presence. Interestingly, in a group study of neglect patients, Mijović-Prelec et al. [61] observed that right parietal patients showed abnormally longer RTs to the absence of a target than its presence. They suggested that these neglect patients might have been adopting a double-checking strategy due to lowered perceptual confidence.

If the "fast-guessing" account of neglect is correct, by varying the discriminability levels of a target from its background we should observe that at lower levels of discriminability the patient will produce more guessing responses. In addition, if the level of discriminability affects guessing

linearly, we should also be able to observe a positive regression between discriminability levels and RTs. Similarly, if discriminability of a target affects the guessing rate in a non-linear fashion, decreasing contrast manipulations should result in graded decreases in the average speed of responses. Specifically, we can predict that in a present/absent search task where the target probability is 50% and the patient neglects left targets, decreasing discriminability should result in “guess responses” predominating. Hence, if the patient’s hit rate was originally above chance, performance should get worse with lower target contrasts and tend towards the limit of 50% chance level; if the patient’s performance was below chance, then performance should paradoxically “improve” towards the same limit of 50% correct responses.

2.1. Method

2.1.1. Case history

AE was a 64 years old male who worked in the fishing industry for 32 years until his retirement in 1990, and who suffered a CVA in 1997 which affected the occipital and parietal areas of the right hemisphere as well as the thalamus on the same side (according to a CT scan performed at the Regional Hospital in Tromsø, northern Norway). As a result of his stroke, AE showed a left homonymous hemianopia (according to visual perimetry assessments) as well as left-sided neglect in standard neurological tasks (e.g. line bisection, cancellation tasks, search of target shapes among distracters, clock drawing). In addition, AE showed left hemiparesis and was confined to a wheelchair. His neglect and hemiparesis made it impossible for him to live independently, and he became a resident at a rehabilitation nursing home in Tromsø, where he received both physical therapy (for his hemiplegia) and occupational therapy. On neuropsychological testing in February 1998, AE was oriented in time and space and had normal short- and long-term memory for word pairs. AE had normal visual acuity (no need of eyeglasses or lenses). Moreover, the neurological exam at the hospital showed no evidence of abnormality in AEs eye movements. His performance on a test of word definitions and verbal associations was in the normal range but his number span was below average for his age. On tests of attention he showed very severe left-sided neglect. For instance, on letter and star cancellation tasks he crossed only the rightmost targets. Line bisection was markedly poor, cutting lines on average in the ratio 7:1 (i.e. a severe displacement of the perceived center of the line towards the right end). The patient died in the spring of 2000.

2.1.2. Stimuli and apparatus

Experiment 1 was run on a 166 MHz PC with a color monitor. The software package used was ERTS from Berisoft. Tim Brennen wrote the experimental script. The patient responded by use of a response pad directly connected to the hard drive, accurate to within 1 ms [10]. Targets were presented at three different distances from the fixation cross

(3, 9 and 15 cm), and eight different radial positions (evenly spaced with one at 22.5°), giving a total of 24 target positions. The target was luminance varied across four different levels, from light gray to dark gray, whereas the background was green and its luminance was kept constant. For each luminance condition there was a trial with a target at each position and 50% of the trials had no target, giving (four luminance levels \times 24 target positions \times 2 present/absent) 192 trials. All conditions were mixed randomly and AE was tested in six sessions of 192 trials each, on separate occasions, for a total of 1152 trials. Ten control subjects (age range 50–80 years old; mean age = 66.6, S.D. = 5.3) also performed one session of the task ($N = 192$ trials).

2.1.3. Procedure

On each trial a gray fixation cross was presented in the middle of the screen for 500 ms. On half the trials a 5 mm \times 5 mm diamond target was presented on screen as the fixation cross disappeared; on the other half, no target was presented. The patient’s task was to press a key marked “Ja” as quickly and accurately as possible when detecting the target and a key marked “Nei” when detecting no target. For both keys, AE used his right hand to respond.

2.2. Results

2.2.1. Control subjects

The 10 control subjects made no errors; therefore their responses consisted of true positives and true negatives exclusively. Overall, the control subjects showed longer RTs to absent target trials (mean RT = 1389, S.E. = 54) than to present targets. A repeated-measures ANOVA with target (absent, LHS, RHS) as the within subjects factor and RTs as the dependent variable confirmed a significant effect, $F(2, 20) = 22.2$, $P < 0.0001$; t -tests also confirmed that RTs to absent trials were slower than LHS and RHS trials ($4.8 < t < 6.4$, $0.0001 < P < 0.0003$) and the latter two did not significantly differ from each other, $t = 1.5$. Table 1 summarizes the control subjects’ performance in these conditions.

A separate ANOVA with level of discriminability (L1: low; L2, L3 and L4: high) as the within-subject factor and RTs as the dependent variable showed no significant effect of this variable on the normal subjects’ performance (L1: mean RT = 1176, S.E. = 43; L2: mean RT = 1171, S.E. = 30; L3: mean RT = 1153, S.E. = 53; and L4: mean RT = 1135, S.E. = 34), $F(3, 27) = 0.4$. Finally, an ANOVA with the lateral position (–3: farthest left; –2, –1, +1, +2 and +3: farthest right) of present targets as the within-subject factor and RTs as the dependent variable showed no significant effect of this variable, $F(6, 30) = 0.3$.

2.2.2. AE

The patient showed strong left-sided neglect, performing the task with an overall 40.2% error rate on LHS trials and 2% errors on RHS trials. AE committed no false positive

Table 1
Averaged performance of ten age-matched control subjects' performance on trials where the target was present^a

Target present						Target absent		
Left hemisphere			Right hemisphere			Percentage	RT	S.E.
Percentage (raw count)	RT	S.E.	Percentage (raw count)	RT	S.E.			
True positives						True negatives		
100	1118	13	100	1184	47	100	1389	54
False negatives						False positives		
–	–	–	–	–	–	0	–	–

^a Trials with RTs more than 3 S.D. from the subject's mean for each condition were discarded. There were neither false negatives (omissions) nor false positives (false alarms).

errors or false alarms. Thus, of the possible four types of responses, the patient made only the other three types: (1) true negatives, i.e. 'no' answers in trials where the target was absent; (2) true positives, i.e. 'yes' answers in trials where the target was present; and (3) false negatives, i.e. 'no' answers in trials where a target was actually present.

First of all, it was of particular interest to compare AEs RTs in the three types of responses: false negative RTs were faster (mean RT = 991, S.E. = 66) than true negative RTs (mean RT = 1506, S.E. = 55) and true positives RTs (mean RT = 1462, S.E. = 65). A repeated-measures ANOVA with response type (false negatives, true negatives, true positives) as the within-subject factor and RTs as the dependent variable showed that this difference was statistically reliable, $F(2, 737) = 10.7, P < 0.0001$. Scheffe's comparisons confirmed that false negative RTs differed from both true negatives ($P < 0.001$) and true positives ($P < 0.03$) RTs. These findings replicate the existence of fast false negative responses in neglect, as described by Mijović-Prelec et al. [60]. However, the present findings also differ in an important way, since Mijović-Prelec et al. found that false negative responses were as fast as the true positive responses. Table 2 summarizes AEs performance for target-present trials in each hemisphere and for absent target trials.

A repeated-measures ANOVA with target position (–3: farthest left; –2, –1: closest to the mid-line) as the within-subject factor and only RTs to neglected targets (i.e. in LHS) as the dependent variable, showed that AEs RTs

were slower to the leftmost targets (mean RT = 1162, S.E. = 43), and increasingly faster for positions closer to the mid-line (–2: mean RT = 1001, S.E. = 65; –1: mean RT = 814, S.E. = 45), $F(2, 119) = 43.8, P < 0.0001$. Scheffe's tests confirmed that RTs for each position differed significantly from the other positions, $0.0001 < t < 0.006$.

Importantly, RTs of false negative responses were positively correlated to increasing levels of discriminability of the stimulus (i.e. greater contrast of the dot to the background); slope = 113, intercept = 126; $F(1, 107) = 5.8, P < 0.017, R = 0.23$. In other words, the patient's responses became increasingly faster the more difficult it was to detect the stimulus (see Table 3). An ANOVA with level of discriminability (L1: low; L2, L3 and L4: high) as the within-subject factors and RTs in LHS trials (where all false negative responses occurred) as the dependent variable confirmed a significant effect of levels of discriminability, $F(3, 237) = 11.4, P < 0.0001$. In contrast, an ANOVA

Table 3
AEs RTs and associated % error rates or false negatives in the left hemisphere, at each level of discriminability

Discriminability	RT	% Error
1 (low)	844	43
2	857	52
3	1065	32
4 (high)	1197	37

Table 2
AEs performance in experiment 1^a

Target present						Target absent		
Left hemisphere			Right hemisphere			Percentage	RT	S.E.
Percentage (raw count)	RT	S.E.	Percentage (raw count)	RT	S.E.			
True positives						True negatives		
43.4 (125)	1462	65	80.6 (235)	1260	33	100 (541)	1506	55
False negatives						False positives		
40.2 (116)	991	66	–	–	–	0	–	–

^a Trials with RTs more than 3 S.D. from the patient's mean for each condition were discarded as outliers (left hemisphere = 16.4%; right hemisphere = 6.4%). No error data are reported for the right hemisphere condition since there were only six misses (2% of trials). There were also no false positives or false alarms.

with level of discriminability (L1: low; L2, L3 and L4: high) as the within-subject factors and RTs in RHS trials (where no false negative responses occurred) as the dependent variable did not reveal a significant effect of levels of discriminability, $F(3, 237) = 0.7$. Clearly, the effects of target contrast were confined to the neglected hemifield and in the non-neglected, right-sided, field, AE behaved similarly to the normal controls.

The next question was whether such fast neglect responses truly reflected guessing strategies. If so, AE's error rate should also increase (towards the chance level limit) concomitantly to his decrease in RTs. Thus, we performed a linear regression analysis with RTs in the LHS as the regressor and percent errors in LHS as the dependent variable. It turned out that errors in the four discriminability conditions did not correlate with RTs; slope = -10.4 , $F(1, 2) = 2.4$, $P < 0.3$. However, we cannot assume linearity in the relation between these two functions; hence, we additionally performed an ANOVA with level of discriminability (L1: low; L2, L3 and L4: high) as the within-subject factors and percent error rate as the dependent variable. This analysis showed no reliable difference on error rates for different levels of discriminability, $F(3, 365) = 1.7$. Table 3 summarizes RTs and percent error rates for each level of target contrast. In conclusion, despite the presence of effects of target contrast on RTs, there was no evidence for an associated change in error rate, as the "guessing strategy" hypothesis would predict.

2.3. Discussion

When AE responded "no" incorrectly to a present stimulus, his RTs were faster than when responding "no" correctly to absent targets as well as responding "yes" correctly to present targets. Thus, AE's case confirms the existence of fast responses to neglected stimuli. However, the fact that AE's false negatives were actually faster than his true positive RTs additionally implies that different processes or mechanisms operated in conditions where the stimulus was detected and those where its presence went undetected. One possibility that we examined was that fast false negatives could reflect the patient's compensatory strategy when perceptual discriminability was low. In other words, the patient would "take a guess" about the target's presence or absence and more often so the more the target was hard to discriminate. Indeed, AE's false negative RTs were positively correlated to increasing levels of discriminability of the stimulus (i.e. greater contrast of the target to the background) or, in other words, the patient's responses became increasingly faster the more difficult it was to detect the stimulus. This performance would indeed be predicted by a fast-guess model of RT performance (e.g. [55]). However, such a model would also predict that errors in the decreasing discriminability conditions would correlate positively with RTs. In fact, there was no evidence for a concomitant increase in AE's error rate, or a gradual approach, to the 50%

chance level with increasingly faster RTs. In sum, because a key prediction of the "guessing strategy" was not supported, we cannot conclude that AE's increasingly fast RTs reflect such a fast-guess strategy. Nevertheless, we cannot exclude the possibility that other neglect patients may show increasing amounts of fast-guess responses in difficult perceptual situations and that, when levels of contrast of stimuli appearing in the neglected field decrease, the patients' performance could even "paradoxically" improve and gradually approach the chance error rate; but AE's pattern of performance in experiment 1 requires another explanation.

Interestingly, Chun and Wolfe [15] raised the question of how and when a normal subject decides to terminate a search in tasks where a target (among distractors) can be absent. They propose that the subject could either (1) search through all the distractors that have a certain likelihood of being a target; or (2) use an "educated guess" strategy. The latter strategy would be based on an internal "timing" model according to which, during the task, the subject could develop some estimate of how long it takes to find a target; the subject would terminate a trial when the duration of the trial exceeds some duration threshold. We note that a same subject may use both Luce's, and Chun and Wolfe's "guessing strategies" during the same task. However, according to Luce, the former strategy of "fast guessing" would be used in conditions of low discriminability (e.g. reduced contrast of the target or increased similarity between target and distractors), whereas according to Chun and Wolfe, the "educated guessing" strategy would take place in absent trials, in a typical search task (where error rates are low), and such a strategy would yield not fast but slow responses. Future studies with several neglect patients may reveal whether a patient opts for these guessing strategies in a task. In our case, AE's fast "no" responses to present targets cannot be completely accounted by a "fast-guess" model. Nevertheless, we cannot exclude that he terminated some trials where he could not find a target (either correctly or wrongly) because the estimated time had actually exceeded a self-imposed limit.

AE appeared to differ from the case examined by Mijović-Prelec et al. [60] in several respects. Most importantly, their patient's false negative RTs were as fast as the true positive RTs. This fact led these authors to entertain the possibility that fast false negatives could reflect a "denial" of the stimulus after the patient's implicit detection of the stimulus. According to Bisiach [11], "denial" is an inhibitory process of all conscious memory; that is, the patient suppresses an implicitly represented target and reroutes the response to a negation of the target's presence. Always according to Bisiach, the patient may even be phenomenally aware for a fleeting moment of the stimulus at the time that a denial response is generated. Such an additional hypothetical mechanism that denies access to consciousness to a stimulus clearly differs from other current explanations, where neglect implies a loss or "subtraction" of a previously normal mechanism. If such an additional processing stage were involved after the stimulus was detected, then we would expect that

“denial” would result in RTs that are never faster than the RTs to acknowledged stimuli. Indeed, we would expect that the RTs to “denied” stimuli should be actually longer than RTs for non-denied stimuli. In contrast, if we believe that neglect consists of the absence of some underlying processing, then faster RTs to neglected stimuli than to the acknowledged stimuli would be consistent with this account. Indeed, if a mechanism is “subtracted” from the normal sequence of processing then the resulting performance should be incomplete, interrupted, or aborted. In conclusion, the present findings do not support the presence of a “denial” mechanism, since AE’s false negatives were faster than his true positive RTs. Moreover, the patient’s responses became increasingly faster the more difficult it was to detect the stimulus. If the patient were denying an implicitly “perceived” stimulus we would have expected the opposite relation. The easier it is to discriminate the stimulus, the faster it would be to reject it from consciousness and to generate a ‘no’ response.

Finally, one complicating factor in this study was that AE suffered not only from visual neglect but, additionally, from hemianopia. There is growing recognition that hemianopia may be an important factor in influencing the misrepresentation of space in patients with visual neglect (e.g. [18,29]). Thus, the question arises whether a patient’s fast neglect responses may be related to the hemianopia in any way. Interestingly, Mijović-Prelec et al.’s patient, who showed fast neglect responses, had no hemianopia [60]. Moreover, it may be unclear how AE’s pre-attentive mechanism could process left-sided stimuli that, typically, fell in the hemianopic field. It seems unlikely that AE’s pre-attentive vision could detect visual stimuli in the blind field (i.e. as a form of “blindsight”, cf. [92]), unless there were “islands” of preserved vision (cf. [28,81]) within AE’s scotoma that went undetected during the visual perimetry test. Nevertheless, AE’s RTs to left-sided field were rather slow (more than 1 s on average), and crucially, they increased systematically with further displacement towards the left side. These findings are not consistent with the idea that a fast neglect response depends on hemianopia; rather, they are consistent with another, straightforward, account of AE’s pre-attentive vision. The patient moved his eyes towards the left in order to include the display within his spared field of vision; hence, the items just to the left of the mid-line would be detected more quickly than items further to the left, because they are closer to the spared field of vision.

3. Experiment 2

Several studies have shown that patients who neglect or fail to report lateral stimuli can still show considerable processing of such neglected stimuli. Patients who “extinguish” a left-sided stimulus in the presence of a competing right-sided stimulus can show some unconscious residual processing of the neglected stimulus (e.g. [89]). This is clearly exemplified in a study by Marzi et al. [58],

where neglect patients were actually faster in pressing a key to bilateral visual stimuli than to unilateral right stimuli, despite the fact that the patients’ verbal reports showed that they were not aware of the difference between bilateral and unilateral conditions and they often reported only seeing the right-sided stimulus. As pointed out by several researchers (e.g. [19,21]) such unconscious processing corresponds well with that considered to take place “pre-attentively” in the normal visual system. Indeed, there is evidence that pre-attentive processes, like grouping, can be operative in patients who show extinction, and in some instances these can virtually abolish this form of neglect [20,32,36,91]. Mattingley et al. [59] used Kanisza illusory figures in an extinction study. Their patient extinguished most left-sided circles in bilateral trials when these did not allow modal surface completion or the formation of a connecting “subjective” surface. However, extinction was abolished and normal performance restored when the circles were partially drawn and arranged so as to suggest occlusion from a single subjective object. Similarly, in normal vision, the limitation in attending to multiple current targets can be reduced if these are linked together in a higher order unit or group [6,22,23]. A few visual search studies on patients with unilateral visual neglect have shown that pre-attentive visual search can also be affected in neglect patients (e.g. [26]); however, a few studies [3,25,33] have also provided clear evidence for the existence of a dissociation; that is, pre-attentive processes can guide these patients’ visual searches despite their pathological spatial bias. Moreover, Laeng et al. [54] have shown the opposite dissociation in their analysis of a single patient; namely, a loss of the pre-attentive mechanism’s “spatial indexing” ability, so that parsed regions of the visual field failed to guide bottom-up attention (cf. [88]), whereas top-down executive control of attention shifts were spared.

According to recent models of attention and visual search (e.g. [24,47,52,93,96,97]), pre-attentive or “bottom-up” processes are complemented by “top-down” control or executive mechanisms that, while holding a template (or “object file”) of the sought information in working memory, direct attention to the location of the stimulus detected by the pre-attentive mechanism. By focusing attention on the stimulus’ location, the activated target’s features can be actively compared with the features contained within the attention window and, consequently, action can be directed to the stimulus [1,14,23,50,72]. On this view, in normal circumstances where a stimulus “pops out”, search functions should not differ when varying the numbers of simultaneously present distractors. Once pre-attentive mechanisms have detected the target, the executive component invariably applies a single shift of attention. Hence, the matching of the stored template to the location indexed pre-attentively can be achieved with equal levels of efficiency regardless of the distractors’ set size. However, the key point is that attention is still required in “pop-out” conditions for becoming conscious of the presence of a pop-out element

[93]. Indeed, Joseph et al. [45] have shown that the detection of differences in a simple feature task (i.e. one line oriented differently from other lines) is severely impaired in normal subjects by additionally imposing an attentionally demanding task (i.e. letter identification in a rapid serial visual presentation task). Hence, several lines of research indicate that attention (either as a “resource” or a “selective window”) is critical even for the perception of so-called “pre-attentive” features (see also [63,82]). Moreover, several current theories identify attention as a necessary operation for any perceptual content to be consciously represented (e.g. [34,56]). On some views, awareness of any perceptual attribute would seem to require not only the activation of a representation of that attribute (the “type”), but also the individuation, via attentional mechanisms, of that perceptual information as a distinct event (the “token”) or a discrete object appearing in a particular place in space and time [46,48,49,77].

The above considerations, that (1) “pre-attentive” mechanisms can function despite the patient’s pathological spatial bias to right-sided stimuli; and that (2) once attention has enveloped the pre-attentively detected stimulus, conscious perception of the stimulus’ identity is achieved, suggest to us a specific account of AE’s fast absent responses to present stimuli. Specifically, we hypothesize that AE could pre-attentively detect some stimuli (e.g. a single left-sided stimulus, as in experiment 1, that differs from the uniform background in contrast and color). Thus, the pre-attentive mechanism could signal the presence and location of a candidate stimulus. However, for AE to perceive and become aware of such stimulus as the target (or something else than the target), his attentional resources need to be employed. In other words, normally, the serial stage of attention can take advantage of a preceding parallel stage that is able to parse the array into distractors and candidate targets (cf. [96]). While the pre-attentive signal would, also normally, initiate the process of shifting and sampling from within the attention window, brain damage may have compromised AE’s ability to use such information to effectively guide the attention window towards the correct location. Consequently, several outcomes can result. The attention window may not move away from a currently attended location [53] or a shift could be quickly aborted or be guided by incomplete, weakened, or biased spatial information so as to undershoot the target’s position (cf. [8,40,41]). Because we assume that a present target is acknowledged as such only when the attributes stored in the target template’s representation and the content of the attention window match, all of the above forms of impairment would result in AE giving fast responses to present targets while at the same time not acknowledging their presence. In essence, our proposal is that the patient has impaired awareness of a target, despite detecting it, because the patient’s attention window attempts to match prematurely a target’s features to an area of space where the target is indeed absent (either empty or including a distractor). Logically, if we can only be aware of what we perceive

and we perceive what we attend to [56], then such a patient will have no choice other than report a target’s absence.

In the following experiment, we put to test the idea that AE’s fast absent responses depend on the efficient engagement of pre-attentive mechanisms. Specifically, we used the classic visual search paradigm [9,83,94,95], according to which the encoding of elementary visual features (e.g. straight versus curved lines) is performed pre-attentively, with no constraints posed on the efficiency of searches by the number of distractors. In contrast, when a target shares several features with its distractors (e.g. combinations of straight and curved lines), the number of distractors present slows search performance proportionately.

We asked AE and 10 age-matched control subjects to search for the letter Z among variable numbers of distractor letters. In one condition all the distractors were the vowel O, thus differing by a simple visual feature (curvature) from the target. This condition is expected to produce “parallel” search functions for both AE and normal subjects when RTs are plotted against distractor’s set size [98]. In other trials, that were randomly intermixed with the above described “simple” trials, the target letter Z appears among the same numbers of distractor letters but these were all randomly picked letters (e.g. N, A, K). We predicted that AE’s fast neglect responses would occur only in the “simple” search condition (Z versus O) but not in the “complex” search conditions (Z versus various letters), since according to current cognitive models pre-attentive mechanisms can be relied on as the basis of accurate performance in the former but are ineffectual in the latter.

3.1. Method

3.1.1. Stimuli and apparatus

The stimuli consisted of letters of the alphabet (Geneva, size 28) presented on a white background with constant luminance. The target item was always a “Z” which could appear in one of twelve possible positions on the screen, six in each hemispace, each position regularly spaced in two columns. On half of the trials the target was present, on the other half it was absent. The distractors were other letters of the alphabet: “O” in the simple feature search condition and different letters (e.g. T, N, E, W, B, F, Y, etc.) in the complex, conjunction, search task (see Fig. 1, for example of the stimuli used in the two conditions). The experiment was carried out on a Macintosh Powerbook 1400cs and each experimental event was controlled by MacLab software.

3.1.2. Procedure

AE sat comfortably on a sofa in the living room of his nursing home apartment. The computer was positioned in front of him on a coffee table, centered on his body’s mid-line, under the room’s natural lighting conditions. He was first instructed that a letter “Z” could appear on either side of the computer screen and that his task was to respond as quickly, but also as accurately as possible, by pressing a

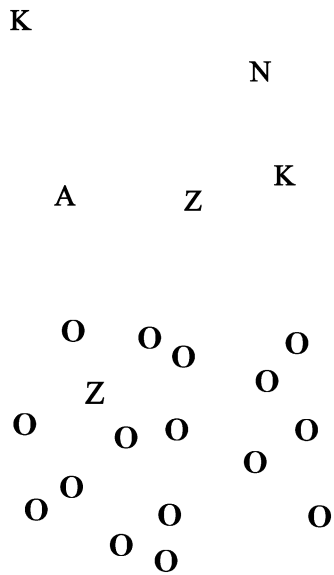


Fig. 1. Examples of a complex search present trial (top) and a simple search present trial (bottom).

key labeled “Ja” (i.e. the B key on the QWERTY keyboard) when the target was seen and a key labeled “Nei” (the N key) when the target was not seen. The computer stored RTs from stimulus onset to the time of a key press as well as the key’s name. Each trial would begin with a press on the space bar. Immediately after, a display of letters would appear on the screen. In each trial, there could be 4, 8, 16 or 32 distractors appearing in randomly scattered positions over the screen’s space. Each of the target positions was combined with an equal number of trials including a specific set of distractors. There were 96 trials for the target present condition and a same amount of trials for the target absent condition, for a total of 192 trials in the task. Ten age-matched control subjects (mean age = 66, S.D. = 5.1) performed the same computerized task once, whereas AE repeated the whole task in a separate session, on a different day, for a total of 384 trials.

3.2. Results

We first calculated descriptive statistics for each participant, obtaining a mean RT and percent error rate for each combination of the variables of task (simple versus complex), target (present versus absent), distractors (4, 8, 16 and 32), and hemispace (LHS versus RHS). Separate ANOVAs were performed on the data of the control subjects and of AE. The control subjects’ error rates were remarkably low, ranging from 0 to 1.2%. However, for both controls and AE, RTs from trials on which errors occurred were excluded from analyses of the RTs, and trials with RTs longer than three standard deviations from each individual’s mean RT for that cell were treated as outliers and excluded from all subsequent analyses.

3.2.1. Control subjects’ RTs

A repeated-measures ANOVA was performed on the 10 age-matched control subjects with task (simple versus complex), target (present versus absent), distractors (4, 8, 16 and 32) as the within-subject factors, and RTs as the dependent variable. The analysis revealed that RTs were shorter in the simple task (mean RT = 1384, S.E. = 36) than in the complex task (mean RT = 2583, S.E. = 128), $F(1, 27) = 264$, $P < 0.0001$. There was also a significant effect of distractors, $F(3, 27) = 109$, $P < 0.0001$; RTs increased with number of distractors. RTs were also significantly faster for present target trials than for absent target trials, $F(1, 9) = 44$, $P < 0.0001$. As expected, the factor of distractors interacted with task, $F(3, 27) = 78$, $P < 0.0001$. Specifically, in the complex task, RTs increased with increasing numbers of distractors; whereas, in the simple task, there was no increase of RTs with increasing number of distractors. Fig. 2 illustrates this interactive effect.

A separate repeated-measures ANOVA with condition (target absent, LHS, RHS) as the within-subject factors and RTs as the dependent variable showed that absent target trials were responded the slowest (absent: mean RT = 2290, S.E. = 65), $F(2, 14) = 22$, $P < 0.0001$, whereas there was no difference between the LHS (mean RT = 1636, S.E. = 36) and RHS (mean RT = 1720, S.E. = 36), as confirmed by *t*-tests. Another repeated-measures ANOVA with target position (−1, −2: leftmost; +1, +2: rightmost) as the within-subject factors and RTs to present target trials only as the dependent variable revealed no effect of this factor on the normal subjects’ performance, $F(3, 27) = 0.2$.

3.2.2. AEs error rates

The patient showed strong left-sided neglect, performing the tasks with an overall 62.5% error rate on LHS trials and only 1.2% errors on RHS trials. A repeated-measures ANOVA was performed on AE’s percent error rate, with task (simple versus complex), distractors (4, 8, 16 and 32), and hemispace (LHS versus RHS) as the within-subject factors. This analysis revealed that more errors were committed when the stimuli were presented in LHS (mean percent error 62.5, S.E. = 4.9) than in RHS (mean percent error 1.2, S.E. = 1.1), $F(1, 176) = 204.8$, $P < 0.0001$. This analysis revealed also a statistically reliable effect of the task factor (simple versus complex), $F(1, 176) = 36.8$, $P < 0.0001$; AE committed more errors in the complex (mean percent error 44.8, S.E. = 5.1) than in the simple search task (mean percent error 18.8, S.E. = 4.0). The interactive effect of task and hemispace was also significant, $F(1, 176) = 42.8$, $P < 0.0001$; specifically, while virtually no errors were committed by AE in both tasks in RHS trials (simple: 0%, complex: 2.1%, S.E. = 2), he committed more errors in LHS trials in the complex than in the simple task (simple: 35.4%, S.E. = 6.9; complex: 89.5%, S.E. = 4.5). Finally, there was a tendency for error rates to increase with number of distractors in the complex task (for 4, 8, 16 and 32% errors rate were 37.5, 41.7, 50 and 50%, respectively), and

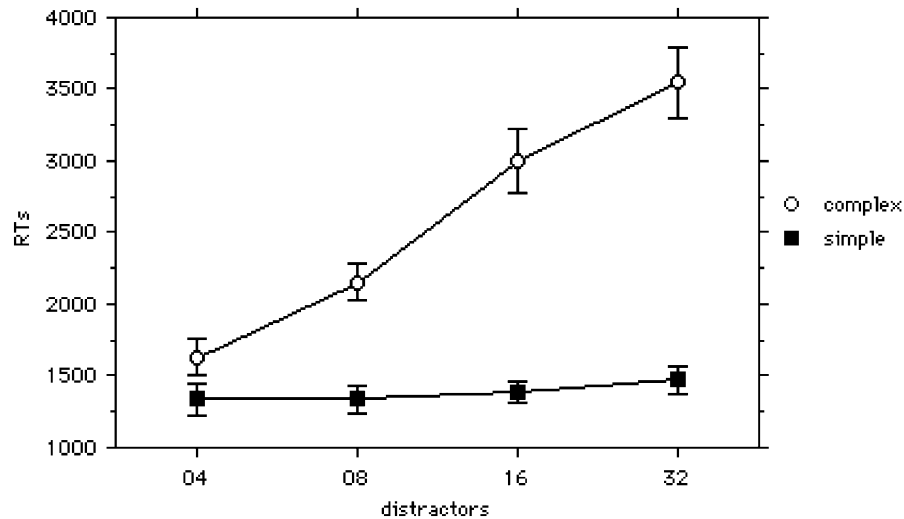


Fig. 2. Means and standard errors of the 10 age-matched control subjects' RTs in the complex and simple search for the letter "Z" plotted over increasing numbers of letter distractors.

decrease with number of distractors in the simple task (for 4, 8, 16 and 32% errors rate were 25, 20.8, 16.7 and 12.5%, respectively); but this interactive effect failed to achieve significance, $F(3, 176) = 1.8$, $P < 0.15$. None of the other main or interactive effects were statistically reliable.

3.2.3. AE: response times

Firstly, a repeated-measures analysis of variance was performed on AE's RTs to "target present" trials, with task (simple versus complex), distractors (4, 8, 16 and 32), and hemispace (LHS, RHS) as the within-subject factors. This analysis revealed that RTs were overall shorter in the simple task (mean RT = 1768, S.E. = 51) than in the complex task (mean RT = 2418, S.E. = 84), $F(1, 155) = 44.8$, $P < 0.0001$. As expected, there was a significant effect of hemispace, $F(1, 155) = 13.9$, $P < 0.0003$; AE's RTs were

significantly slower in LHS (mean RT = 2267, S.E. = 92) than in RHS (mean RT = 1894, S.E. = 68). The main effect of the distractors factor approached significance, $F(3, 155) = 2.1$, $P < 0.09$; namely, there was a tendency for RTs to increase with number of distractors. Most importantly, the factor of distractors interacted with task, $F(3, 155) = 9.3$, $P < 0.001$. Specifically, in the complex task, RTs increased with increasing numbers of distractors; whereas in the simple task, RTs decreased with increasing number of distractors. A decrease of RTs with increasing distractors may seem paradoxical but it is a well-known effect in search tasks where the distractors are all homogenous (e.g. [3]); indeed, the more homogenous the display looks the more this can be taken as a signal that a target is absent or, in present trials, to segregate it from the background. Fig. 3 illustrates this interactive effect. Not

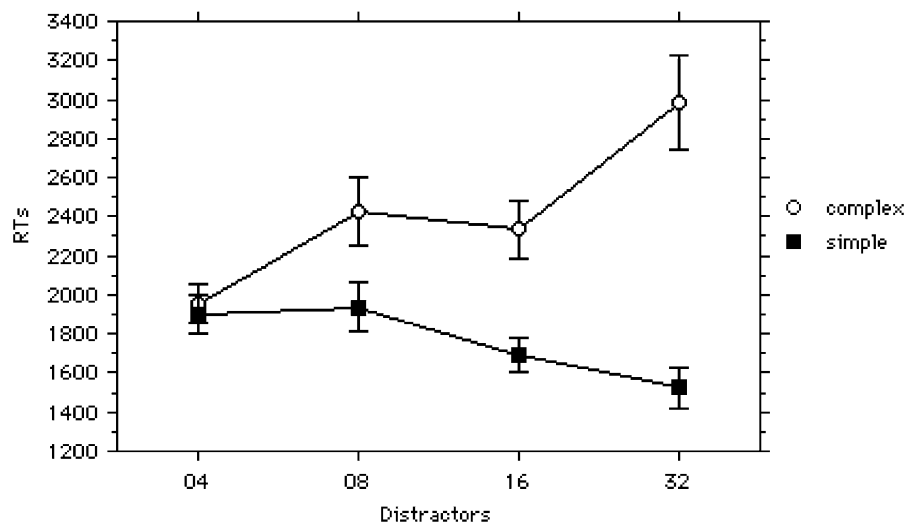


Fig. 3. Means and standard errors of AE's RTs in the complex and simple search for the letter "Z" plotted over increasing numbers of letter distractors (that is, various letters in the complex condition and just "O" letters in the simple condition).

surprisingly, given the patient's unilateral neglect, the factors of distractors and task interacted also with that of hemispace, $F(3, 155) = 2.7$, $P < 0.04$. None of the other main or interactive effects were statistically reliable.

3.2.4. AE's RTs according to type of response

Because we have predicted that fast RTs to neglected targets occur in conditions where pre-attentive processes can guide attention (i.e. in the simple search of a Z among O's) but not in conditions where these processes are ineffectual (i.e. in the complex search of the same Z among variable letters), it was of particular interest to compare the RTs in the three types of responses: (2) false negatives; (2) true negatives; and (3) true positives. Therefore, we performed a separate analysis on AE's RTs, with task (simple versus complex) and response (false negatives, true negatives, and true positives) as the fixed factors. Note that AE's false negative responses occurred virtually only in LHS trials for both tasks (simple: 35.4%; complex: 89.5%), in contrast true positive responses reflect performance in both hemispaces (but also note that AE responded correctly to a present target in 98.9% of the RHS trials).

The analysis confirmed the previously seen main effect of task, $F(1, 337) = 37.5$, $P < 0.0001$. There was also a main effect of the response factor, $F(2, 337) = 14.5$, $P < 0.0001$, but most importantly, this factor interacted significantly with that of task, $F(2, 337) = 5.4$, $P < 0.005$. Specifically, as confirmed with individual t -tests. In the simple task, false negative RTs (mean RT = 1784, S.E. = 87; $t = 1.9$, $P < 0.04$) and true positive RTs (mean RT = 1753, S.E. = 68; $t = 2.3$, $P < 0.03$) were both faster than true negative RTs (mean RT = 2082, S.E. = 111), and did not differ significantly from each other ($t = 0.2$, $P < 0.85$); in contrast,

in the complex task, true negative RTs (mean RT = 2752, S.E. = 86; $t = 5.1$, $P < 0.0001$) and false negative RTs (mean RT = 2704, S.E. = 117; $t = 4.5$, $P < 0.0001$) were both slower than true positive RTs (mean RT = 1965, S.E. = 91) and did not differ significantly from each other ($t = 0.4$, $P < 0.73$). This interaction is illustrated in Fig. 4.

A separate ANOVA was also performed with target position (-1, -2: leftmost; +1, +2: rightmost), task (simple versus complex), as the within-subject factors and RTs in true positive trials only as the dependent variable. There was one significant effect on AE's performance, consisting of the main effect of target position, $F(3, 70) = 13.2$, $P < 0.0001$. Correct present responses to present targets were slowest in the leftmost position (-2: mean RT = 2779, S.E. = 198) and fastest in the rightmost position (+2: mean RT = 1537, S.E. = 79), the other two positions yielding intermediate speed of responses (-1: mean RT = 2226, S.E. = 144; +1: mean RT = 1775, S.E. = 71). Another separate ANOVA was performed with target position (-1, -2: leftmost; +1, +2: rightmost), task (simple versus complex), as the within-subject factors and RTs in false negative trials only as the dependent variable. This analysis revealed not only the already described effect of task, $F(1, 94) = 26.3$, $P < 0.0001$, but also the effect of target position on AE's performance, $F(3, 94) = 4.9$, $P < 0.003$. It is interesting to note that also the false negative responses were slowest in the leftmost position (-2: mean RT = 2479, S.E. = 134) and fastest in the rightmost position (+2: mean RT = 1487, S.E. = 335), the other two positions yielding intermediate speed of responses (-1: mean RT = 2127, S.E. = 101; +1: mean RT = 2127, S.E. = 101). This behavior would seem consistent with the patient shifting the eyes into left-sided hemisphere to bring the display within his spared field of

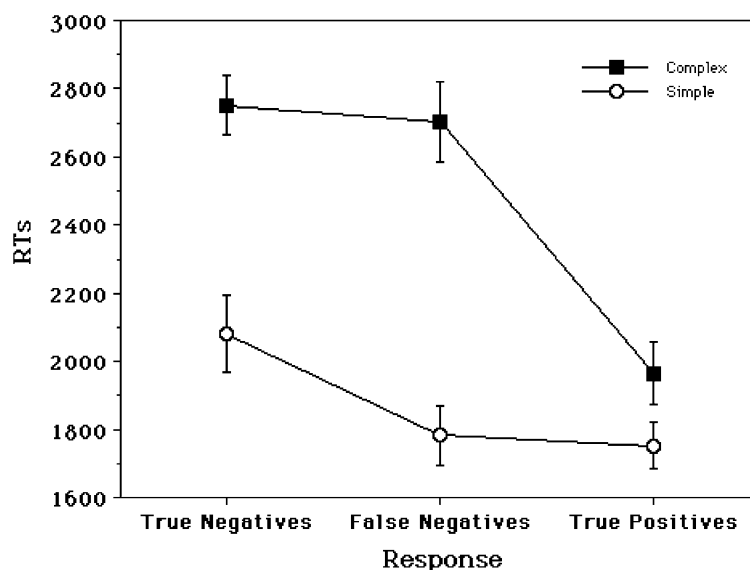


Fig. 4. Means and standard errors of AE's RTs in the complex and simple search for the letter "Z" plotted over response type: true negatives is equal to target absent, AE answers 'no' correctly; false negatives is equal to target present, AE answers 'no' incorrectly; true positives is equal to target present, AE answers 'yes' correctly.

vision. Hence, targets further displaced to the left would take longer to be detected.

3.3. Discussion

On the basis of (1) the well-established phenomenon that a pre-attentive system can quickly engage the attentive system by detecting pop-out targets; and (2) the fact that AE is able to detect such targets pre-attentively but that this information fails to spatially guide the attention window, we predicted fast but incorrectly negative responses in some trials of a simple search (pop-out) task. According to the same logic, we expected that in a task where targets do not pop-out and where the attentive system would normally engage in a serial, item-by-item, search, AE should not show fast and incorrect negative responses to left-sided targets. These predictions were confirmed in a search task where a letter (Z) appeared in one condition where it was mixed with O distractors (so that the Z would pop-out) and another conditions in which the distractors would consist of other letters composed of straight lines (thus, no pop-out). Indeed, AE's target misses were significantly faster than correct rejections in the simple search condition, whereas there was no difference between misses and correct rejections in the complex search condition. In addition, whereas AE's search function in the simple, pop-out, condition demonstrated that searches were not influenced by distractors' set size, in the complex, non-pop-out, condition the RTs increased as the distracter set size increased. This pattern of performance is usually interpreted as reflecting a self-terminating serial search strategy [83]. In general, a serial search is thought to reflect the (normal) inability of the pre-attentive system to detect any candidate targets (e.g. any "odd-man-out" or "proto-object"). Consequently, the attentional window examines the search field on an item-by-item analysis and search is terminated once the target is identified or all the items have been examined (in absent trials).

AE showed a serial search in the complex task and a nearly "flat" search in the simple task, just like the normal subjects. The difference between AE and the control subjects' performance was that AE neglected left-sided targets in both tasks, although to a lesser extent in the "pop-out" task. Similar benefits of tasks where processing depends on pre-attentive mechanisms has been observed in several previous studies (e.g. [59]). Moreover, visual search paradigms similar to the one used here have also been used in a few studies with neglect patients and these have also shown benefits from pre-attentive processes, despite the fact that the control of focal attention was compromised in these patients [3,25,27,33].

Some current models of visual search do not make a qualitative or modular distinction between pre-attentive and attentive mechanisms (e.g. [24]). According to these models, it is the difficulty of the visual discrimination between the target and the distractors that determines whether a search will be efficient (e.g. parallel) or inefficient (serial).

Nevertheless, predictions of models based on target/distractors similarity can also be met by the classic models and, especially, recent guided-search models (e.g. [94]), where a modular distinction is explicitly maintained between a pre-attentive visual stage and an attentive process that is guided by the former; thus, qualitatively different types of representations distinguish the two types of vision [96]. However, it is of interest to examine a possible extension of the claim that the difficulty of the visual discrimination between the target and the distractors determines the speed (intercept) and function (slope) of visual searches. Specifically, according to models based on target/distractors similarity, reducing the difference between a target and its distractors should result in the same function as when target discriminability decreases. Therefore, a plausible prediction in the light of such models is that the complex features or serial search task, used in experiment 2, should increase the number of "fast guesses" compared to the other simple, parallel, search task. However, what was found was the opposite of such a prediction. Thus, both experiments 1 and 2 fail to support an interpretation of fast neglect RTs as consisting of fast guesses due to the difficulty of visual discriminations.

4. General discussion

The phenomenology of neglect is heterogeneous and it has become increasingly clear that its symptoms could originate from damage to several cognitive mechanisms and neural circuits [70]. Moreover, it is likely that part of the phenomenology of neglect reflects attempts from the patients' to cope with a loss of perceptual or attentional abilities. In this study, we specifically investigated the possibility that a paradoxical phenomenon associated with neglect, i.e. fast incorrect "absent" responses to present stimuli, could reflect a compensatory strategy (also used in special cases by normal humans and animals; see Luce [55]) that consists of the emission of guessing responses in situations of perceptual uncertainty. In a simple detection task, we observed that AE did indeed show progressively faster RTs with decreasing contrast between the target and the background; however, in this same experiment, we failed to reveal another of the landmarks that should be associated with a guessing strategy: namely, the tendency of error rates to approach the limit of chance accuracy.

In a separate experiment based on another visual search task, we found that AEs fast RTs to neglected targets occurred only in a task, where the target would normally "pop-out" or be detected pre-attentively, but not in a task where the same target does not "pop-out", and normally, subjects would engage in serial searches. These effects occurred in the presence, for both AE and control subjects, of increasingly longer searches in the non-pop-out task versus no effects of number distractors in the pop-out task. These latter findings support a view that pre-attentive mechanisms were able to engage an early and parallel search also in our

patient. However, AEs fast “absent” responses to present targets indicate that a mismatch must have occurred between the expected pattern and information gathered by his search. We surmise, mainly on the basis that RTs to neglected stimuli were actually faster than those to acknowledged stimuli, that these pre-attentively guided visual searches were incomplete or aborted early, resulting in premature sampling of a region of space where the target was indeed not present.

Our proposal is that pre-attentive mechanisms provide a spatial index of a certain strength that signals the location of a candidate target to the neural mechanisms controlling attention. Psychophysical investigations of normal subjects, with visual presentations of just a few milliseconds followed by a mask, indicate that it is possible to report “where”, coarsely, a form differing from a simple feature from the other elements occurred (e.g. a line oriented differently among several lines of the same orientation), but it is not possible to indicate its identity until the form is brought under focal attention [4,78,79]. We surmise that the strength of this pre-attentively registered spatial information could decrease with decreasing discriminability or contrast of the stimulus. In other words, low contrast stimuli would be able to engage the attentional system and initiate an early search, or give the “start” signal, but they could provide only a weak signal about the location of the stimulus. Moreover, there is other evidence that spatial information can be impaired selectively from information about the simple “presence” of forms. For example, when enumerating a few ($N = 4$) elements (or “subitizing” [57]) some patients with spatial attention and perception problems can subitize without being able to say where the items correctly counted had appeared (e.g. [17,90]). The above evidence suggests that a pre-attentive stage of processing can extract a few forms in parallel across the visual field; but once extracted, these forms must also be *indexed* spatially so as to guide the attention window to the location of the “odd-man-out” form for further processing, e.g. matching to the target’s template for identity and the encoding of explicit spatial relations (cf. [51,54,85]).

Based on the above considerations, we surmise that when AE viewed simple features with decreasing contrast (as in experiment 1), he was able to detect the target shape at all contrasts, as demonstrated by the fast responses of true positive and false negative trials; but at the same time, his ability to use the spatial indexes of the targets’ location was proportionally reduced. Hence, increasingly noisy or biased spatial information resulted in attention shifts that were either aborted early or carried out incompletely, so as to land in a region of space close to the original point of fixation that does not contain the expected target [8,53]. The outcome would then necessarily be a premature conclusion about the absence of the target. This account seems to us highly consistent with well-known aspects of the phenomenology of neglect, like the presence of ineffective attentional and ocular shifts or “hypodirectionality” of movement [8,12,40–43,71] or the inability to “disengage” from a previous stimulus that is right-sided in relation to a left-sided target [65,66]. In the

former case, searches may be based on incorrect information or in the latter cases simply aborted. Moreover, the account would also seem consistent with current knowledge about the specialization of function of neural areas controlling the active exploration of the visual environment and saccadic scanning movements. Findlay and Walker [30] have recently reviewed the neurophysiological evidence on the oculomotor system and concluded that two separate pathways are concerned with the spatial and the temporal programming of the movement (“where” versus “when” to look). In this view, while some brain areas are responsible for the voluntary or automated programs to move or fixate, other brain areas are responsible for the spatial and search decisions. Considering that several current theories of attention (e.g. [16,39,43,62,73]) have stressed the intimate coupling of neural mechanisms supporting oculomotor programming and spatial attention, the above considerations strongly suggest that similar dissociations between the “where” and “when” of attentional shifts should be observable in neglect patients.

Interestingly, some studies with normal subjects have shown that responses to absent targets can, in some circumstances, be faster than those to present targets. Such a phenomenon has been observed exclusively in classic visual search tasks where a pop-out target item is searched for among a variable number of distractors. Specifically, Humphreys et al. [37] saw that searching for an inverted T among upright T’s, which could either be arranged regularly (i.e. along an imaginary circle) or irregularly (i.e. in random locations within the search field), led to an advantage for absent trials in the regular pattern condition. Moreover, the effect disappeared, even with regular patterns, when the distractors were made heterogeneous. In another study, Hübner and Malinowski [35] found that neither grouping distractors by regularity nor by similarity results per se in an absent trials’ advantage; instead, the presence of the effect depends on whether the different conditions (pattern regularity versus irregularity, homogenous vs. heterogeneous distractors) are blocked or whether the trials are mixed together. Hübner and Malinowski have proposed a revised guided-search model, based on the homonymous model by Wolfe [94]. Namely, they suggested that a guided search only starts when the activation threshold is passed within a certain limit of time. In guided-search models, items produce activation on an internal activation map. An item’s activation level depends not only on its features but also on the feature differences and on the spatial distance to its neighboring items [93,94]. Items are then checked according to their activation strength, starting with the highest. According to Hübner and Malinowski [35], if a pattern produces only low activations that do not reach the threshold before a specified deadline, an absent response can be triggered relatively early. Moreover, with blocked patterns a subject tends to adjust the thresholds individually for each type, so that no appreciable absent-advantage occurs; however, when different types are mixed, the same subject would tend to adjust the thresholds to cope with these types simultaneously. They conclude

that decisional processes instead of perceptual processes are crucial for the occurrence of an absent advantage effect.

It is then relevant to note that, in our experiment 1, normal subjects did not show an absent-advantage; indeed, no previous study has shown such effects in tasks where there are no distractors. However, in experiment 2, there were both homogenous and heterogeneous distractors (in the pop-out task or simple search task trials for the former and in the complex features tasks for the latter) and, indeed, these two conditions were randomly mixed in the task. In these circumstances, according to the above model, normal subject could show an absent advantage effect. We, however, did not observe this; instead, every normal control subject showed slower RTs to absent trials than to present trials. Nevertheless, we can speculate whether Hübner and Malinowski's model could be useful in interpreting AE's performance or that of other patients with neglect. Such an alternative account could interpret neglect as a reduction in the activation level of present targets in left hemispace and different optimal thresholds' adjustments for each hemispace. Thus, if this interpretation is correct, in any pop-out task where present trials for targets in left (neglected) hemispace and in right hemispace are mixed, a patient with neglect may simultaneously adjust searches in the good and bad field to a specific "no"-threshold criterion. Then, the chosen criterion, reflecting searching items in parts of the visual field which differ in activation levels, would cause searches being initiated only when activations are above such "no"-threshold (i.e. most likely when the target is in right hemispace), whereas when activations are below the "no"-threshold (i.e. most likely when the target is in left hemispace) a search will not be initiated. Moreover, we would assume that diminutions in contrast or discriminability of the item would increase the likelihood that activations remain below the "no"-threshold. In essence, this account would predict the same outcome that our original account based on a problem with spatial indexing would predict. Attentional shifts or guided searches are simply not initiated and trials are terminated early. Future studies with neglect cases could help disentangling the relative contribution of (a) shifts in criterion; and (b) changes in perceptual processing or indexing; for example, by testing visual search in blocked hemispace conditions.

Finally, a "denial" account of RTs in neglect, advanced by Mijović-Prelec et al. [60], was revealed to be implausible. Denial would seem by definition a post-perceptual process. If it is necessary to have a perceptual content in order to subsequently deny it, then RTs for omissions should typically be longer and never shorter than RTs for hits. However, AE showed exactly this latter, counter-intuitive pattern. Moreover, Mijović-Prelec et al. based their observation on a very small number of trials and the suspicion remains that at a more careful look (e.g. more trials and/or low contrast stimuli), the same pattern of performance would have been observed in their patient as well.

Several current views point to an intimate relation between spatial attention and conscious perception (e.g.

[34,56]). A post-attentional feature binding could ultimately be responsible for our conscious apprehension of what sorts of objects are present "out there" [31,84]. In neural terms, this may imply interactions between parietal areas relevant for spatial encoding and other (temporal) areas that represent basic features. Damage to the parietal lobe could result in inadequate spatial maps, which would seem a necessary condition for the control of shift attention from one location to another [67,68]. To summarize our interpretation, the patient responded "no" wrongly, because "conscious awareness" does not have direct access to pre-attentively detected information and an intervention of focal attention is needed to achieve awareness. On this view, the patient's attentional system could have an "early start" when "pop-out" forms were present, but could also fail to "grab" the detected target; consequently, by not attending to a stimulus, the patient remained unaware of its presence.

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