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ORIGINAL ARTICLE

Inhibitory and facilitatory location priming in patients with left-sided visual hemi-neglect

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Abstract In visual search for pop-out targets, reaction times are facilitated when the target on the current trial appears at a previous target location, and inhibited when it appears at a previous distractor location, relative to when it appears at a previously empty (neutral) location (Maljkovic and Nakayama, Perception and Psychophysics 58:977–991, 1996). However, while normal subjects are able to positively/negatively tag selected target/rejected distractor locations to guide search on the next trial, patients with visual hemi-neglect may have a (uni- or bilateral) deficit in these functions that may contribute to their disturbed visual scanning behavior. To examine this, using a pop-out search task, the present study assessed cross-trial facilitatory and inhibitory priming in 14 patients with left-sided visual hemi-neglect and in 14 age-, education-, and IQ-matched control subjects. The group of neglect patients did show significant facilitatory and inhibitory priming. However, while control subjects exhibited balanced effects of facilitation and inhibition, inhibition was relatively reduced in magnitude in neglect patients. In particular, inhibition was virtually absent in two patients with lesions affecting superior regions of the frontal cortex, putatively encroaching on the frontal eye field of the right hemisphere. These findings provide neuropsychological evidence that facilitatory and inhibitory priming effects are based on dissociable mechanisms, consistent with Geyer et al. (Journal of Experimental Psychology: Human Perception and Performance 33:788–797, 2007).

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Introduction

Patients with visual hemi-neglect because of, predominantly, right-sided temporo-parietal brain damage is unable to detect or respond to stimuli in the left, contra-lesional, hemi-field (Karnath, Milner & Vallar, 2002; Kerkhoff, 2001; Mort et al. 2003). This failure to acknowledge objects on the left is due to attentional unawareness, rather than primary visual deficits such as hemianopia, and can occur even when visual fields are completely preserved.

Although patients with visual hemi-neglect are impaired in reacting to stimuli presented in their left field, there is a growing amount of evidence that they can process considerably more left-field information than previously thought. Relevant studies have typically used ‘implicit’ measures that do not require the patients to explicitly report the stimuli presented, but rather indirectly reveal the stimuli’s influence on the patients’ subsequent performance. Using such measures it has been revealed that even objects that escape awareness can strikingly affect neglect patients’ forthcoming responses. One of the first reports of this was provided by Marshall and Halligan (1988), who used a semantic-priming task. They found that a neglect patient was unable to discriminate between two line drawings of a house that were presented simultaneously to the left and the right, one house with flames on its left side and the other without flames. However, when forced to decide in which house she would prefer to live, on almost all trials the patient chose the house that was not on fire. Since then, implicit processing in neglect patients has been investigated extensively. For example, McGlinchey-Berroth, Milberg, Verfaellie, Alexander, and Kilduff (1993) induced left-sided visual extinction by presenting meaningful objects in the left field accompanied by scrambled patterns in the right field. Afterwards, the patients were unable to decide which one of two choice objects had been shown. However, when presented with words that were semantically related to the 'extinguished' stimuli, they were faster to respond in a word/nonword discrimination task than when presented with words that were semantically unrelated.

Such effects of semantic priming induced by object information can be explained by the notion of dual visual processing routes (Ungerleider & Mishkin, 1982), with a ventral and a dorsal pathway (see Driver & Mattingley, 1998, for a similar argument). While the dorsal pathway, which supports spatial perception and goal-directed behavior, is typically affected in neglect patients, the ventral pathway, which is critical for object recognition, may remain relatively intact. Therefore, implicit processing of object identity might arise from object information provided by the ventral stream.

However, recent evidence suggests that *spatial* (i.e., dorsal-route) information within the neglected field might also affect performance in neglect patients. This evidence is based on positional cross-trial priming in visual pop-out search tasks, first demonstrated by Maljkovic and Nakayama (1996). In their paradigm, normal subjects were presented with three colored diamonds (e.g., one red and two green), and they had to decide as rapidly as possible on which side the odd-colored diamond was cut off (left vs. right). Thus, this task is a so-called 'compound-search' task, in that the attention-relevant feature (color) is varied independently of the response-relevant feature (orientation). Maljkovic and Nakayama (1996) found that subjects responded faster when the current target was presented at a position that was also occupied by a target on the preceding trial (facilitation) and slower when it was presented at the position of a distractor on the preceding trial (inhibition), compared to a target presented at a previously neutral (i.e., neither target nor distractor) position, respectively. On the basis of these findings, Maljkovic and Nakayama (2000) surmised that visual search is aided by an (implicit) short-term memory system for target and distractor positions.

Using a very similar paradigm, Kristjánsson, Vuilleumier, Malhotra, Husain, and Driver (2005) reported evidence for intact positional priming even in neglect patients. Specifically, two patients with unilateral left-sided neglect (following right-sided parietal lesions) exhibited response facilitation when the target on the current search trial n appeared at the location of the target on the previous trial $n - 1$. Importantly, the neglect patients' performance was facilitated in the left (affected) visual hemi-field to the same degree as in the right hemi-field. Furthermore, the size of the facilitatory effect was comparable to that found for normal observers. Constant priming effects, however, were found only with unlimited displays. With brief displays, where the neglect patients sometimes missed targets in their neglected hemifield, position priming required awareness of the preceding target. Thus, based on a task requiring implicit processing of target position, it is possible to conclude that at least facilitatory priming of target locations is preserved in neglect patients when they have unlimited time to view the display. However, given that Kristjánsson et al. (2005) did not examine the inhibitory effect resulting from the presentation of the trial n target at a trial $n - 1$ distractor location, the question remains whether neglect patients would also show a preserved ability to inhibit distractor locations.

This issue is theoretically interesting because Geyer and colleagues (Geyer, Müller, & Krummenacher, 2007; Geyer & Müller, 2008) have recently shown that the cross-trial memory of distractor and target locations involves separable mechanisms. In more detail, Geyer et al. (2007) found that only inhibitory (but not facilitatory) priming was affected by the arrangement of the stimuli. That is inhibition turned out to be absent with irregular and non-predictive stimulus arrangements (i.e., when the distances between the singleton target and two distractors could randomly vary across trials), but was present with regular and predictive stimulus arrangements (i.e., when the distances between the three search items were constant across trials). Moreover, Geyer and Müller (2008) showed that only inhibitory priming was affected by the number of distractor stimuli in the search display (effectively, there was no inhibition with more than two distractors). By contrast, facilitatory priming was obtained regardless of the number of the stimuli. Thus, while the more robust facilitatory priming may be preserved in neglect patients, inhibitory priming—which draws on more complex processes, in particular, relational coding of the distractor relative to the target location—might turn out to be specifically affected. Note that normal facilitation combined with impaired inhibition could contribute to the inefficient visual search behaviour displayed by neglect patients, which is characterized by repeated re-examinations of already scanned ('old') items and misjudgements of these as 'new' (Behrmann, Watt, Black, & Barton, 1997; Mannan et al. 2005; Malhotra, Mannan, Driver, & Husain, 2004).

To examine the hypothesis that facilitation and inhibition might be differentially affected in neglect patients, we tested a group of neglect patients and compared their performance with that of a group of matched control subjects. Based on the findings of Kristjánsson et al. (2005), we expected facilitation of reaction times when the *n* target appeared at a trial $n-1$ target location. The prediction regarding distractor inhibition was twofold, based on the findings of Geyer and colleagues (Geyer et al. 2007; Geyer & Müller, 2008), with regular target-distractor arrangements (as used in the present experiment), reaction times may be slowed when the trial *n* target is presented at a trial $n-1$ distractor location, even in neglect patients. Alternatively, neglect patients may fail to inhibit distractor locations on trial $n-1$, perhaps because they are unable to apply inhibitory tags based on a 'top–down', spatial reference frame centered on the target location. In the latter case, no or (relative to a neutral baseline) reduced reaction time costs were expected for neglect patients, compared to control subjects, when the trial *n* target appears at a trial $n-1$ distractor location.

Method

Subjects

Fourteen stroke patients (11 male, 3 female) with the diagnosis of mild to moderate left-sided visual hemi-neglect after right-hemisphere damage were recruited from the Neurological Clinic Bad Aibling, Germany, and were tested within 3–500 (*Mdn* = 10.29) weeks post injury. The diagnosis was based on neurological examination as well as neuropsychological assessment using established conventional neglect tests. Although the specific tests differed between patients, they were tested comprehensively with cancellation or visual search tasks, line bisection, figure copying, and representational drawing. All patients showed the typical symptoms of left-sided visual hemi-neglect on neurological confrontation testing as well as in the more comprehensive and standardized neuropsychological examination.

One patient (KF) was left-handed. Due to a left-sided hemiparesis, he responded with the non-dominant right hand. Whereas, he responded well within the range of the other patients with regard to response speed his accuracy was somewhat lower than in the other patients.

Since it has a special focus on therapy of visuo-spatial disturbances, a relatively large number of neglect patients are in therapy in the neurological clinic Bad Aibling. Although many of them were not able to participate in reaction-time based computerized experiments, e.g., due to an inability to maintain a constant trunk and head position, we were able to select a number of neglect patients according to the following criteria: all patients included were able to attend to a task for at least 30 min, to sit on a normal chair and to maintain a fixed trunk and head position with the aid of a head and chin rest. Mostly, these patients suffered from relatively mild neglect or had already undergone several weeks of therapy. Furthermore, patients with visual-field deficits interfering with task performance were excluded from the study. Mean age of the 14 patients taking part in the study was 57.4 years (SD = 15.6; range = 37–78 years), mean duration of education was 11.1 school years (SD = 1.8; range = 8–13 years), and mean IQ as estimated by a vocabulary test (MWT-B; Lehrl, Triebig, & Fischer, 1995) was 107.1 (SD = 13.62; range = 91–136). Informed consent according to the Declaration of Helsinki II was obtained from all participants. All of them had normal or corrected-to-normal visual acuity. Relevant biographical and clinical data of each patient are summarized in Table 1.

Lesion data are presented in Fig. 1. As can be seen, in accordance with the literature on the anatomical basis of

Table 1 Clinical and demographic data of neglect patients

Patient	Sex	Hand	Age	Education (years)	IQ	Injury type	Lesion location	TSI (weeks)
CH	m	r	42	13	104	infarction	F, P	17
RL	m	r	42	10	94	Infarction	F, P	31
KW	m	r	51	13	136	Infarction	F, P	500
KF	m	l	78	8	92	Infarction	P	11
LH-L	f	r	39	10	91	Infarction	T, P + Ins	6
ML	m	r	74	10	104	Hemorrhage	P	4
GS	m	r	45	13	112	Infarction	F, T, P	25
K-KL	m	r	65	13	107	Infarction	F, T, P	10
HA	m	r	77	13	124	Infarction	SC	4
VS	f	r	37	13	124	Infarction	SC	18
MM	m	r	64	10	112	Infarction	T	3
OB	f	r	60	9	NA	Infarction	T, P	9
MP1	m	r	46	9	91	Infarction	F, T, P	20
MP2	m	r	72	10	104	Hemorrhage	SC	9

TSI time since injury, *m* male, *f* female, *r* right-handed, *l* left-handed, *P* parietal, *F* frontal, *T* temporal, *INS* insular, *SC* subcortical

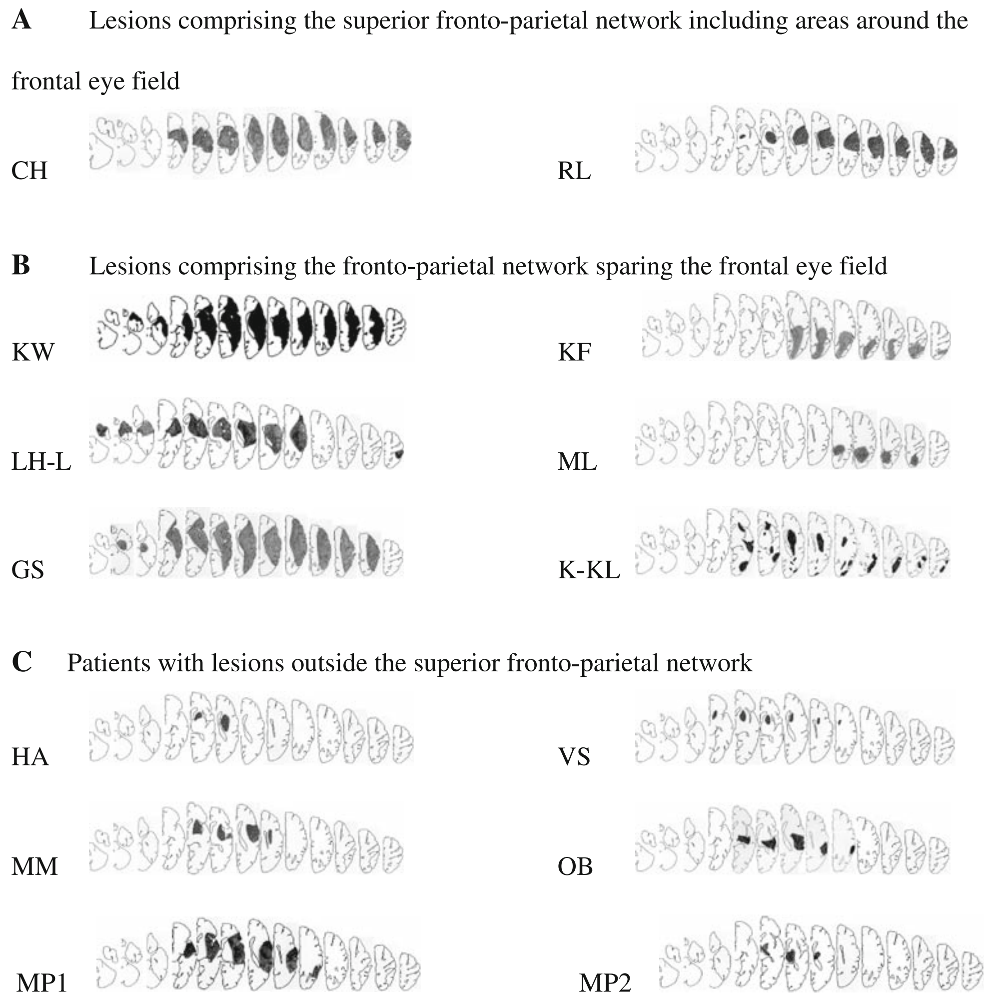


Fig. 1 Lesion reconstructions of the 14 neglect patients. Lesions have been drawn onto standard slices of the Damasio template system (Damasio & Damasio, 1989). Only the right (affected) hemisphere is depicted. **a** Lesions affecting the superior fronto-parietal network and comprising the frontopolar area, **b** lesion affecting the superior fronto-parietal network sparing frontopolar areas, **c** lesions outside the superior fronto-parietal network

neglect (Karnath, Milner, & Vallar, 2002; Mort et al., 2003), lesions are mainly located in the inferior parietal, temporo-parietal, and superior temporal areas.

An age- and education-matched healthy control group of 14 subjects (7 male, 7 female) was also tested. None of the subjects reported any history of neurological or psychiatric disease. All subjects had normal or corrected-to-normal vision. Mean age was 53.6 years (SD = 13.0; range = 34–78 years), mean duration of education was 11.7 school years (SD = 1.6; range = 9–13 years), and mean IQ was 116.1 (SD = 15.9; range = 97–136). The group of control subjects did not differ significantly from that of the neglect patients with respect to age [$t(26) = 0.58$, $P > 0.65$], duration of education [$t(26) = -77$, $P > 0.40$], and IQ [$t(26) = 1.61$, $P > 0.10$].

Priming paradigm

Stimuli

A search display (see example in Fig. 2) consisted of three stimuli, one red target and two green distractors. The stimuli, presented on a black background (0.5 cd/m^2 in luminance), were near-equiluminant (red: 7.7 cd/m^2; green: 8.0 cd/m^2) and diamond-shaped (size: 1.2° of visual angle). All stimuli had a (response-relevant) cut-off section (size: 0.3°) at either the top or the bottom. The cut-off sections were determined randomly and independently for each target and distractor stimulus. The search elements were arranged on a near-circular 'ellipse', with horizontal and vertical axes of 17.5° and, respectively, 14.0°, around a white fixation cross (size: 0.5° × 0.5°; luminance: 13.7 cd/m^2). The singleton color target could appear at one of a total of six possible locations on the circumference of the ellipse. The distractors were then positioned such that the distances between adjacent stimuli on the circumference (target-distractor and distractor-distractor distances) were equal (i.e., the separation between adjacent locations was 6/3 = 2, with one intervening location). No stimuli occurred on the imaginary vertical midline, permitting reaction times and errors to be determined separately for the right and the left visual field. The target appeared either on one side and the two distractors on the other side or the target appeared together with a distractor on one side and the other distractor on the other

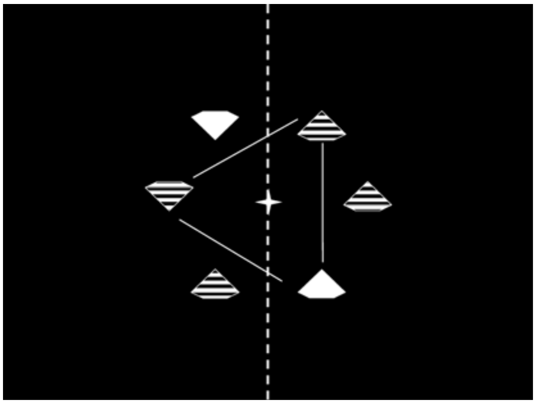


Fig. 2 Illustration of the search displays used in the present experiment. The singleton target (*open diamond*) appeared together with two distractors (*striped diamonds*) in either the left or right visual field. One possible search display is indicated by the connecting *lines* between the stimuli, another display is shown without connecting *lines*. No stimuli appeared on the imaginary vertical midline (illustrated by the *dashed line*)

side. With respect to the previous trial $n-1$, targets on trial n appeared at one of three types of position: at the same position as the target on the previous trial, at the position of a distractor on the previous trial, or at a position that was empty on the previous trial (neutral baseline).

Stimulus presentation and response registration were controlled by a standard computer. The experimental control software was purpose-written in C++. Subjects responded with a standard two-button mouse connected to the computer via the serial port. The mouse was fixed on the table in front of the subject, rotated by 90° such that the 'left' mouse button could be used as the 'upper' (top section cut off) and the 'right' button as the 'lower' (bottom section cut off) response key. Observers viewed the monitor from a distance of approximately 55 cm, with head position maintained by the use of a head and chin rest.

Procedure

At the beginning of each trial, a blank screen with just the fixation cross in the center of the monitor was presented. The fixation cross remained on all the time. After 1,000 ms, the search display was presented and remained visible until the subject responded (see Fig. 3).

The task was to press the upper/lower response key as fast and as accurately as possible according to position (top/bottom) of the cut-off target section. Each display remained visible until subjects responded. Reaction times (RTs) and errors were recorded. Error feedback was not provided. Subjects were instructed verbally and tested individually. The experiment consisted of 384 experimental trials, presented in 4 blocks of 96 trials each, with a minimum 10-s break after each block. If necessary, break duration was

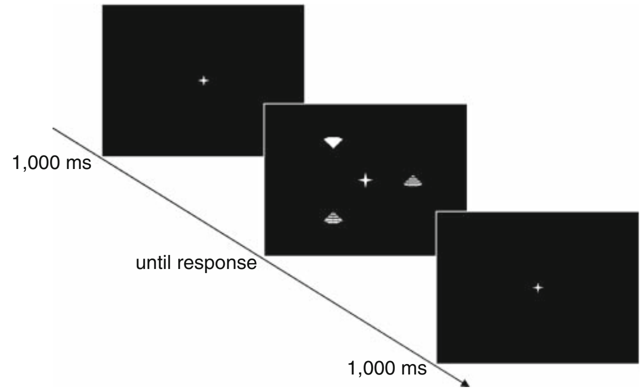


Fig. 3 At the beginning of each trial, a blank display with a central fixation cross was presented for 1,000 ms, followed by the visual search display. After the subject's response, the next trial followed

adjusted to the patient's individual requirements. The experimental session was preceded by a practice block of 96 trials (data not recorded). The whole experiment lasted about 30 min.

Results

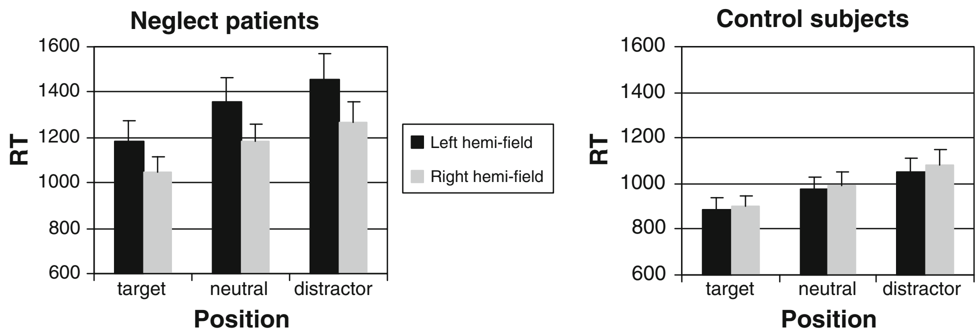
The dependent variables RT (excluding error trials and trials following an error trial) and accuracy (error rate) were examined in separate ANOVAs with the between-subject factor Group (neglect patients, control subjects) and the within-subject factors Side (target in left, in right hemifield), and Position (target at previous target location, at previous distractor location, at previously empty location). Level of significance was 5%.

Reaction times

Mean RT for neglect patients and control subjects are shown in Fig. 4. The ANOVA of the RTs revealed all main effects to be significant: Group [$F(1, 26) = 6.89$, $P < 0.05$], Side [$F(1, 26) = 9.52$, $P < 0.01$], and Position [$F(2, 25) = 89.59$, $P < 0.01$]. As of particular interest, the Group × Side interaction was also significant [$F(1, 26) = 15.52$, $P < 0.01$]. While normal subjects showed a tendency for faster responses to left- compared to right-side targets [$t(13) = -2.01$; $P < 0.07$], neglect patients responded slower to left-side stimuli [$t(13) = 3.60$; $P < 0.01$]; the latter result was, of course, expected based on the patients' diagnosis. Compared to control subjects, neglect patients' RTs were significantly slower for left-side targets [$t(26) = 3.20$; $P < 0.01$]; while their RTs only tended to be slower for right-side targets [$t(26) = 1.81$; $P < 0.09$].

Furthermore, the Group × Position interaction was significant [$F(2, 25) = 4.36$, $P < 0.05$]. Separate ANOVAs with the factor Position for the two groups revealed a significant

Fig. 4 Mean RTs (in ms) of neglect patients (*left side*) and control subjects (*right side*), separately for both hemi-fields and for the different target positions (at previous target location, at previously empty = neutral location, at previous distractor location)



main effect in both healthy control subjects [$F(2, 12) = 57.70$, $P < 0.01$] and neglect patients [$F(2, 12) = 42.46$, $P < 0.01$]. Furthermore, both groups showed significant facilitatory cross-trial priming [neglect patients: $t(13) = 7.17$; $P < 0.01$; healthy subjects: $t(13) = 7.76$; $P < 0.01$] as well as inhibitory priming [neglect patients: $t(13) = 6.74$, $P < 0.01$; healthy subjects: $t(13) = 7.93$, $P < 0.01$]. However, relative to facilitatory priming, the inhibitory priming was less pronounced within the group of neglect patients (92 vs. 154 ms; healthy control subjects: 89 vs. 84 ms). For each of these patients we calculated the facilitation and inhibition effects relative to the overall RTs (in percent). Comparisons between the respective relative facilitation and relative inhibition effects *within* the two different groups revealed inhibitory priming to be significantly weaker than facilitatory priming only in the neglect group [$t(13) = 4.00$; $P < 0.01$; control group: $t(12) = 0.13$; $P > 0.85$].

The target Side × Position interaction [$F(2, 25) = 0.21$, $P > 0.80$] was non-significant, as was the Group × Side × Condition interaction [$F(2, 25) = 0.46$, $P > 0.45$]. The non-significant Group × Side × Condition interaction means that neglect patients exhibited no evidence of a specific deficit in location priming in their contra-lesional hemi-field.

In neglect patients, there might be differences in priming depending on whether there were two items on the left or right. Therefore, in a further ANOVA only for the neglect patients' group, using the factors Two Stimuli Side (left, right) and Position (target at previous target location, at previous distractor location, at previously empty location). It revealed only the described main effect of Position to be significant. The main effect of Two Stimuli Side was non-significant [$F(1, 13) = 0.94$; $P > 0.30$], as was the interaction [$F(2, 12) = 2.27$; $P > 0.10$].

Accuracy

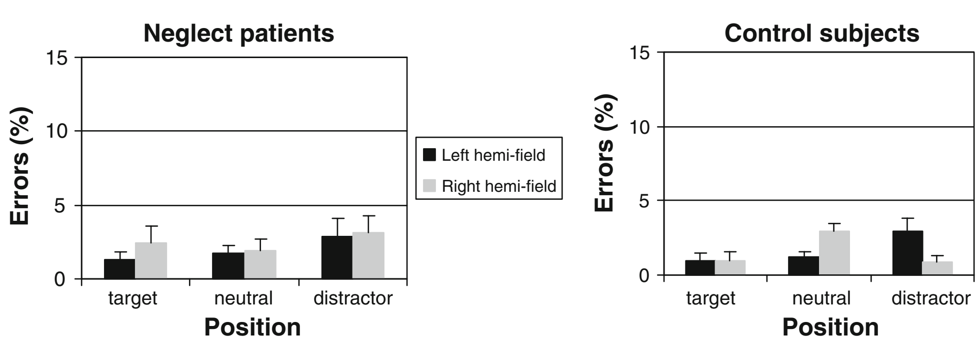
Accuracy was generally very high in both groups and across the different hemi-fields and target locations (see Fig. 5). An ANOVA with the factors Group, target Side, and target Position revealed no significant main effects or interactions (all $P > 0.10$).

Priming effects and lesion location

The only significant difference in priming effects between the neglect patients and the control subjects was that, relative to facilitatory priming, inhibitory priming was less pronounced in neglect patients. Therefore, notwithstanding the fact that priming seemed to be relatively preserved in neglect patients at the group level, we examined the possibility that circumscribed lesions might have specific effects on the magnitude of inhibitory positional priming.

To this end, we focused on a subgroup of (eight) patients with lesions affecting the superior fronto-parietal network, which has been shown to be critically involved in the control of spatial attention (Mesulam, 1999; Kastner & Ungerleider, 2001; Corbetta & Shulman 2002) and in location priming as assessed by means of fMRI (Kristjánsson, Vuilleumier, Schwartz, Macaluso, & Driver, 2007). The lesions exhibited by this subgroup of patients are depicted

Fig. 5 Error rates of neglect patients (*left side*) and control subjects (*right side*), separately for both hemi-fields and for the different target positions (at previous target location, at previously empty = neutral location, at previous distractor location)



in Fig. 1a, b. For each of these patients we compared the relative facilitation and inhibition effects to the range of values in the control group. Using the boundaries of the normal controls' range as cut-off points, we found two patients, CH and RL, who fell outside this range with respect to inhibition: they showed almost no slowing of RTs when the current target was presented at a previous distractor location. For patient RL, there was no inhibition in either the left or the right hemi-field. For patient CH, there was slight inhibition in the left hemi-field, but no inhibition in the right hemi-field (see Fig. 6). In contrast, reliable RT facilitation was found for both patients (and both target sides).

As depicted in Fig. 1, patients CH and RL (Fig. 1a) differed from all the other (six) patients (Fig. 1b) with respect to lesion site: their lesions involved the anterior portion of the uppermost horizontal slice and encroached the superior frontal sulcus in the region of the right frontal eye field and neighbouring areas. In contrast, patients CH and RL (as well as the other six patients) were well within the normal controls' range with respect to relative facilitation. As can be seen from Fig. 1, most of these patients had lesions within the inferior parietal lobe, as was the case for the patients assessed by Kristjánsson et al. (2005), who showed preserved facilitation.

Discussion

Using a priming of pop-out paradigm, the present study investigated whether location priming would be observed in patients with left-sided visual hemi-neglect. More specifically, the goal was to examine whether there would be a reduction of inhibition for pop-out targets presented at positions previously occupied by a distractor. This special focus on inhibition was motivated by prior studies on neglect patients (e.g., Kristjánsson et al. 2005) that had been concerned with positional facilitation, but were not informative about positional inhibition—leaving the possibility that inhibitory priming is differentially affected in neglect patients. This was anticipated on the basis of recent findings (Geyer et al., 2007; Geyer & Müller, 2008) which had suggested positional facilitation and inhibition to originate from separable processing mechanisms. In particular, the evidence suggested that inhibition involves relational coding of distractor locations anchored on the target location, based on regular display geometry. Consequently, inhibitory priming might be selectively impaired in the presence of intact facilitatory priming.

We tested 14 subjects with relatively mild visual hemi-neglect. The results were that, although re-presentation of the target at a previous target location led to RT benefits for both normal observers and neglect patients, the presentation of the target at a former distractor location led to RT costs that were less pronounced for neglect patients than for normal observers. That is, in the control group, inhibitory positional priming was comparable in size to the facilitatory priming; in contrast, in the patient group, the magnitude of the inhibitory effect was reduced relative to the facilitatory effect. There was no interaction between side and position of the target, suggesting that the pattern of positional priming effects is comparable between the 'affected' contra- and the 'preserved' ipsi-lesional field of the neglect patients. Furthermore, the distribution of items on the screen, i.e., whether two of the three items were placed on the right and only one on the neglected side or vice versa, did not influence the positional priming effects. Thus, although in conditions with the majority of stimuli placed on the right side the pathological attentional bias might have been even enhanced, facilitatory and inhibitory priming occurred to the same degree as in conditions with the majority of stimuli on the left, in which the imbalance of attentional weights might have been temporarily ameliorated.

Overall, this pattern of results is consistent with the assumption that positional priming enhances overall search efficiency (Maljkovic & Nakayama, 1996), but that patients with neglect have a particular deficit in inhibiting distractor locations. This would contribute to the striking tendency of neglect patients to re-visit already searched locations, misjudging them as novel (e.g., Malhotra et al., 2004; Mannan et al., 2005). As a consequence of the 'unbalanced' interplay between facilitatory and inhibitory priming in neglect

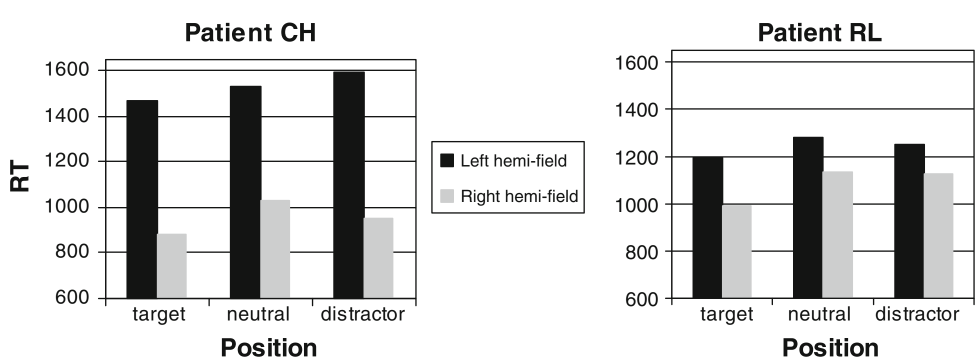


Fig. 6 RT performance (in ms) of patients CH (*left side*) and RL (*right side*), separately for the left (*black bars*) and right (*grey bars*) visual hemi-fields and for the different target positions (at target location, at neutral location, at distractor location). Both patients showed intact facilitation at previous target locations, but impaired inhibition at previous distractor locations

patients, predominant facilitation might actually exacerbate search inefficiency by boosting the patients' tendency to iteratively examine target positions that had already been inspected. In more severe cases than those assessed here, i.e., in patients with acute or severe chronic neglect, this pathological pattern might be even exaggerated compared.

Moreover, these results agree with the assumption put forward by Geyer et al. (2007) that facilitatory and inhibitory priming arise from different processing mechanisms and might thus be differentially affected following brain damage. Geyer et al. proposed that, while the target's location are encoded absolutely (in terms of the exact *x* and *y* stimulus coordinates), distractor locations may be encoded relative to the target location into visual short-term memory. In other words, target locations would be represented within an egocentric and distractor location within an allocentric frame of reference. Such an allocentric, or object-based, representation might be directly supported by the presentation of three stimuli (one target, two distractors) in a regular triangular constellation on each trial. It is well established that neglect symptoms can dissociate depending on the frame of reference, with egocentric (space-based) and allocentric (object-based) subtypes of neglect occurring in different patients (Vallar, 1998; Walker, 1995), and even within the same patients in different tasks (Baylis, Baylis & Gore, 2004). Consequently, the differential deficit in inhibitory priming exhibited by the patient group assessed in the present study may be regarded as a sign of object-based neglect in these subjects.

These considerations are supplemented by the anatomical information that is (albeit tentative) available from our study. The reduction in inhibitory priming was the most pronounced in two patients with lesions affecting frontal areas within the region of the superior frontal sulcus. In fact, location-based inhibitory priming was almost absent in these patients. One possible account of this deficit is that it arises because of the lesions affecting the frontal eye field. In fact, frontal eye field neuronal activity has been shown to be involved in cross-trial positional priming in monkeys (Bichot & Schall, 2002), and a special role of the right frontal eye field in positional cross-trial priming has also been revealed in humans in a recent fMRI study by Kristjánsson et al. (2007). Moreover, the frontal eye field has been suggested to be involved in extracting regularities from visual scenes and in learning visual context information for guiding eye movements (Bichot, Shall, & Thompson et al., 1996; Passingham, 1993). Recently, Saevarsson et al. (2008) have found intact contextual priming in neglect patients with lesions sparing frontal eye fields. Thus, frontal eye field lesions may degrade the ability to build up a stable representation of a global stimulus arrangement and of the regularity of the stimulus configuration across trials. According to Geyer et al. (2007), this ability is a pre-requisite for inhibitory tagging of distractor information, tentatively assumed to operate in an allocentric frame of reference.

An alternative explanation might be that reduced inhibitory priming results from an impairment of spatial working memory. Such an impairment has been documented repeatedly in neglect patients (Malhotra et al., 2004; Mannan et al., 2005; Wojciulik, Rorden, Clarke, Husain & Driver, 2004) and is, in fact, considered as a core feature of spatially non-lateralized deficits that contribute to the neglect symptomatology (Husain & Rorden, 2003). Evidence from functional-imaging studies points to a region immediately adjacent to the right frontal eye field that is critically involved in spatial working memory storage (Haxby, Petit, Ungerleider & Courtney, 2000). Accordingly, damage to superior frontal regions would interfere with the ability to reliably encode and/or maintain the distractor positions in spatial working memory, due to a reduction in storage capacity. Consequently, inhibitory tagging would be rendered less effective (if at all possible) due to an impaired working memory representation of the spatial array composed of the target and distractor stimuli.

In accordance with the results of Kristjánsson et al. (2005), we found no evidence for priming of pop-out being affected by parietal lesions. Given that the integrity of parietal areas is critical for efficient spatial remapping (Heide & Kömpf, 1998; Pisella & Mattingley, 2004), it would be interesting to test whether patients with parietal lesions would show preserved inhibition and facilitation effects in the presence of remapping requirements. That is, can positional priming effects also be observed across two subsequent trials when saccadic or spatial attention shifts are induced in-between? Our results of widely preserved priming effects under conditions without remapping demands suggest that the priming of pop-out paradigm can serve as a valuable tool to examine this question.

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