AWARE AND UNAWARE PERCEPTION IN HEMISPATIAL NEGLECT: EVIDENCE FROM A STEM COMPLETION PRIMING TASK

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Abstract

The current study used the process dissociation procedure in conjunction with a stem-completion priming task to disentangle the influences of aware and unaware perception in patients with hemispatial neglect. One lateralized picture prime was presented simultaneously with a filler picture followed by a centrally presented word stem. In the inclusion condition participants were asked to complete the word stem with the previously presented picture name; in the exclusion task they were asked to complete the stem with the name of a picture other than the one previously presented. Findings indicated that neglect patients had reduced unaware perception of pictures presented in the left visual field and an absence of awareness for those same pictures. In addition, patients had reduced awareness for right visual field pictures, but unaware perception remained intact. These findings suggest that observations of preserved information processing in neglect are due to residual unaware perception and not due to residual awareness of information in the neglected hemispace.

Key words: consciousness, attention, process dissociation

Introduction

Hemispatial neglect refers to a common neurobehavioral syndrome in which patients fail to report or orient to information presented in the contralateral side of space (Heilman et al., 1993). Most frequently seen following lesions of the right hemisphere, the disorder may affect not only the ability to process incoming information on the contralateral side, but also the ability to respond or act upon stimuli on that side of space. Although there is general agreement that these deficits reflect lateralized impairments of attention, possibly at different functional levels, the exact nature of these impairments remains controversial. For instance, whereas some have emphasized the inability to direct attention contralaterally (Kinsbourne, 1987; Heilman et al., 1993), others have emphasized the excessive capture of information on the ipsilateral side (Mark et al., 1988; Marshall and Halligan, 1989).

Recent studies of preserved information processing in neglect have demonstrated that considerable visual processing can occur in the neglected space, even in the face of severe attentional limitations. Although neglect patients are unable to name or otherwise identify contralateral stimuli, they are quite accurate at making same/different judgments involving these stimuli (Volpe et al., 1979; Verfaellie et al., 1995; Berti et al., 1992), a finding suggesting that some contralateral visual information is processed. Moreover, processing of contralateral stimuli does not appear to be limited simply to the processing of early visual features that may allow such same/different judgments. A number of semantic priming studies (McGlinchey-Berroth et al., 1993, 1996b; Ládavas et al., 1993; Berti and Rizzolatti, 1992) have demonstrated that neglect patients show intact semantic priming from contralesional primes. These findings suggest that processing of "neglected" information can proceed at least to a semantic level of representation. Finally, two additional studies have demonstrated that activation of perceptual and semantic representations also can give rise to the activation of appropriate response codes, even though the information that gives rise to this response activation is unavailable to awareness (Cohen et al., 1995; Audet et al., 1991).

The dissociation between preserved and impaired processing in neglect has potentially important implications for understanding the nature of the attentional impairment in neglect. Because sensory information processing itself appears to proceed relatively normally, the impairment in neglect must occur at a relatively late stage of processing. Consistent with late selection theories of attention that stress automatic activation of object-level information (e.g., Goldsmith, 1998), the attentional impairment in neglect could be viewed as a disruption in those processes by which perceptual and semantic representations reach awareness.

Before accepting this hypothesis, however, a critical assumption underlying these studies must be evaluated. In particular, it is generally accepted that neglect patients are truly unaware of the contralateral information that is processed. However, such claims are controversial and are susceptible to the same criticisms that have been levied against claims of unaware perception in studies of normal individuals (Merikle and Reingold, 1998, 1992). In some studies (Berti et al., 1992; Ládavas et al., 1993) patients were directly asked to report if they were aware of stimuli presented on the contralateral side. Although they reported that they could not see these stimuli, it could still be argued that they perhaps saw some of the stimuli, or parts of the stimuli, but felt insufficiently confident to report their presence. To avoid the difficulties inherent in the use of a subjective criterion, other studies (Ládavas et al., 1993; McGlinchey-Berroth et al., 1993, 1996b; Cohen et al., 1995) have established an objective measure of awareness by directly assessing patients' capacity to perceptually discriminate contralateral stimuli. While more generally accepted, this method is also problematic, since it is often difficult to ensure that the measure of aware processing is equally sensitive to the presence of partial or degraded information as is the measure of unaware processing (Farah et al., 1991). Furthermore, even if concerns regarding task sensitivity can be alleviated, it may not be possible to construct measures of aware and unaware processing that are identical in all critical respects. This is important since small differences in the temporal and spatial requirements of the two tasks can potentially have a significant influence on patients' performance (Verfaellie et al., 1995). For all these reasons, the dissociation between aware and unaware processing in neglect remains open to the criticism that aware processing may have contaminated the measure of unaware perception.

A less often voiced, but nonetheless equally important, concern relates to the possibility that measures of aware processing may be contaminated by unaware influences. For example, using a cross-field matching task with neglect patients, Verfaellie et al. (1995) examined patients' ability to judge whether a contralateral stimulus was identical to an ipsilateral stimulus (matching task). This was compared to their ability to select the contralateral stimulus from two choices presented in midline (forced choice identification task). Some patients performed at chance in the identification task and above chance in the matching task, a pattern consistent with the notion that the matching task was more sensitive to unaware influences. However, other patients performed above chance in both tasks, and their matching performance was equivalent to their identification performance. We hypothesized that this pattern of performance might reflect the fact that both tasks were performed on the basis of partially available, aware information. However, it might also be the case that for these patients, unaware influences contributed to their performance on the discrimination task. Given the available measures, it is impossible to distinguish between these two possibilities.

The current study used an alternative approach to disentangle the influences of aware and unaware processing in neglect based on the process dissociation procedure (Jacoby, 1991). Jacoby made the observation that the problems illustrated above stem from the fact that most studies are designed such that aware and unaware processes have additive effects on performance. Consequently, it is impossible to estimate their respective contributions unless the tasks are process-pure, an assumption which, we just argued, is generally untenable. They demonstrated, however, that by putting the effects of aware and unaware processing in opposition to each other, it might be possible to estimate their separate contribution to performance. This approach was first established to separate aware and unaware influences of memory, but it has been successfully applied to the domain of perception as well. For example, Debner and Jacoby (1994) conducted a study in which words were flashed briefly, followed by the presentation of a to-be-completed stem. In one condition, individuals were asked to complete the stem with any word other than the one that was briefly flashed. This condition was termed an exclusion condition, because individuals were required to exclude the briefly flashed word as a possible response. Any increase in the likelihood of completing the stem with the flashed word could thus be ascribed to unaware influences, since awareness would lead one to provide a word other than the one that was flashed. In another condition, individuals were asked to complete the stem with the flashed word, or if unable to do so, to complete the stem with the first word that came to mind. This condition was termed an inclusion condition because individuals were required to include the flashed word as a response. Under these conditions, an increased likelihood of completing the stem with the flashed word could be due either to aware or unaware influences of perception. Since the effects of unaware perception are identical in the two conditions but those of aware perception are opposite, an estimate of aware perception can be obtained by subtracting performance in the two conditions (Aware Perception = Inclusion – Exclusion).

Once an estimate of aware perception is obtained, an estimate of unaware perception can then be derived by simple algebra (Unaware Perception = Exclusion/1 – Aware Perception). Using this approach, Debner and his colleagues demonstrated that dividing attention drastically reduced the effects of aware perception, but left the effects of unaware perception unchanged.

The current study used a similar paradigm to examine the contribution of aware and unaware perception to the performance of neglect patients. On critical trials, one real picture was briefly flashed to the left (LVF) or right visual field (RVF) together with a filler picture in the opposing visual field, followed by a word stem presented in midline. On baseline trials, a filler picture was presented in both visual fields, followed by a word stem presented in midline. These trials were used to compute the baseline rate of randomly completing a stem with a particular name. Participants were tested in both an inclusion and an exclusion condition. Our hypothesis for the inclusion condition was straightforward: given neglect patients' impairments in awareness of contralesional stimuli, we hypothesized that they would complete a stem with the name of a contralaterally presented stimulus less often than normal individuals. Nonetheless, we hypothesized that the likelihood of a correct completion would exceed that observed in the baseline condition, because unaware as well as aware processes may contribute to performance in this condition. More pertinent are the results of the exclusion condition. Based on previous findings of preserved processing in neglect, we hypothesized that neglect affects unaware perception less than it affects aware perception. If this hypothesis is correct, then neglect patients should experience more difficulty than normal individuals in excluding the names of pictures presented to the contralesional field. Use of the process dissociation procedure also allowed us to compare the magnitude of unaware effects of perception in neglect patients and normal individuals. If unaware perception is entirely preserved in neglect, then estimates of unaware influences on performance should be of a similar magnitude in the neglect patients and normal individuals.

Materials and Methods

Subjects

Ten individuals with hemispatial neglect and fourteen normal age-matched controls participated in this study. The patients were recruited from the Braintree Rehabilitation Hospital and the New England Sinai Hospital and Rehabilitation Center. Damage to the right hemisphere was confirmed in all cases by either CT or MRI. Partial LVF hemianopia was present in four cases (patient J.A., O.C., E.H., and G.S.). Normal control participants were recruited from the Harvard Cooperative Program on Aging. As shown in Table I, neglect resulted from a single right hemisphere stroke in eight patients, from a hemorrhage in one patient, and from an aneurysm in one patient. Inclusion criteria were that patients showed evidence of neglect on at least two tasks included in the Standard Comprehensive Assessment of Neglect (McGlinchey-Berroth et al., 1996a), which includes several copying, reading, cancellation, line bisection and extinction tasks. The clinical characteristics of the patients are provided in Table I.

Normal control participants were matched in age to (M = 69, S.D. = 6.7) the neglect patients (M = 69, S.D. = 8.3). All control participants were free of neurological illness or disease, did not have a history of psychiatric disorder or substance abuse, and were right handed.

TABLE I
Clinical Characteristics of Patients

Patient	Age	Neurological findings	Clinical manifestations
1. JA	63	large right MCA[1] including frontal, temporal, and parietal lobes; basal ganglia; left homonymous hemianopia; dense hemiparesis; left neglect	reading; cross copy; line bisection (mean = 7.33 rightward); cancellation (number of errors): line (left = 11/14; right = 2/14); symbol (L = 7/8; R = 6/8); visual extinction
2. GB	58	large right MCA; left quadrant partial field defect and right gaze preference; left-sided weakness; severe left hemiparesis; left neglect	cross copy; cross recall; line bisection (M = 10.66 mm rightward); cancellation: letter (L = 2/8; R = 0/8); symbol (L = 2/8; R = 0/8); visual extinction
3. FB	73	parietal/occipital hemorrhage with mass effect; neurological report not available	figure copy; cancellation: line (L = 14/14; R = 0/14), letter (L = 3/8; R = 0/8) and symbol (L = 8/8; R = 0/8); line bisection (M = 28.33 mm rightward); visual extinction
4. MB	80	anterior MCA; right-sided weakness; head and eyes deviated to the right; left neglect	reading; cross copy; cancellation: line (L = 14/14; R = 9/14); letter (L = 8/8; R = 6/8); symbol (L = 8/8; R = 5/8); line bisection (M = 66 mm rightward); visual extinction
5. OC	56	large MCA including frontal, temporal and parietal lobes; small left inferior quadrant hemianopsia; right gaze preference; left hemiparesis; left neglect	line bisection (M = 13 mm rightward); visual extinction
6. EH	66	temporal/parietal aneurysm with subsequent craniotomy; left hemianopsia; left hemiplegia; left neglect	reading; cross copy, recall; line bisection (M = 37.5 mm rightward); cancellation: line (L = 8/14; R = 3/14); letter (L = 8/8; R = 1/8); symbol (L = 8/8; R = 0/8); visual extinction
7. JK	71	embolic shower involving parietal lobe; left neglect	cross copy; cross recall; line bisection (M = 31.25 rightward); cancellation: line (L = 14/14; R = 0/14); letter (L = 8/8; R = 3/8); symbol (L = 8/8; R = 3/8)
8. BP	74	posterior parietal lobe; left-sided numbness; left neglect	cancellation: letter (L = 1/8; R = 0/8) and symbol (L = 2/8; R = 0/8); visual extinction
9. DS	73	temporal, parietal lobes; left neglect	cancellation: line (L = 2/14; R = 0/14); letter (L = 2/8; R = 3/8); symbol (L = 6/8; R = 2/8); line bisection (M = 12/83 mm rightward); visual extinction
10. GS	79	frontal and temporal lobes; basal ganglia; left inferior quadrant hemianopsia; left neglect	cross copy; cross recall; cancellation: line (L = 7/14; R = 3/14); letter (L = 4/8; R = 0/8); symbol (L = 5/8; R = 1/8); line bisection (M = 12.83 mm rightward)

[1]MCA = Middle Cerebral Artery.

Stimuli

In this stem completion task line drawings served as the priming stimuli and two-letter word stems served as the targets. The priming stimuli consisted of 96 line drawings, most taken from the Snodgrass and Vanderwort (1980) collection; as well as 192 filler stimuli, created by dividing all of the Snodgrass pictures into small pieces and combining the pieces to form new meaningless fillers.

To generate the stimuli the Snodgrass pictures were sorted alphabetically by picture name and grouped by the initial two letters of the name (the ‘stem’). This resulted in 89 distinct stem groups. The 89 stems were randomized and typed on a sheet of paper and distributed to 33 individuals ranging from 18 to 42 years in age. The individuals were asked to complete each stem with the name of a real, concrete, picturable object. The two most frequently occurring responses for each stem were selected, provided they were contained in the Snodgrass and Vanderwort collection (1980) and were the same or close in the frequency of usage (Francis and Kucera, 1982). This resulted in the selection of 80 pictures, sixteen shy of the 96 needed. The remaining 16 were hand drawn and similar in size and detail to those of Snodgrass and Vanderwort (1980). These new drawings were then scanned into a Macintosh IIsi and converted to MacPaint files using Aldus Superpaint software. This produced the 96 line drawings necessary for two pictures to be matched to each of the 48 stems.

Two test sets were then constructed (one for inclusion, one for exclusion) each containing 48 trials. Three priming conditions, each containing 16 trials, were developed: left, right, & neutral. The left condition consisted of a line drawing presented to the LVF and a filler presented to the RVF. The right condition consisted of a line drawing presented to the RVF and a filler to the LVF. Neutral trials contained two filler stimuli, one in each visual field. The 48 distinct stems and the 2 drawings reserved for each stem were randomly assigned to one of the 3 conditions. Although the neutral condition contained only filler stimuli, assignment to priming condition was counterbalanced across subjects so that each stem and its pictures served in each of the 3 conditions.

Target items consisted of the stem, the initial two letters, followed by a line four spaces in length (i.e., “tr____”). All target stimuli were presented in bold lower case letters in the Geneva 24 font.

Apparatus

Participants were tested on a Macintosh Quadra 610 computer, adjusted so that the center of the monitor and the participant’s head were aligned vertically and horizontally.

Procedure

The onset of each trial was signaled by an asterisk, located at the center of the screen for 500 msec. Following the presentation of the asterisk, the 2 priming stimuli were presented for 200 msec one centered 1.5 degrees to the left and the other 1.5 degrees to the right of center. The prime display was followed by a 400 msec delay. A target stem then appeared in the center of the screen and remained on the screen until the participant’s response. Each participant was tested on the two test lists across two sessions. For one of the test lists, participants were asked to complete the stem with the name of the picture they had just been shown (inclusion set), and for the other test list they were asked to complete the stem with any real object name that was not the name of the picture they had just been shown (exclusion set). Order of inclusion/exclusion sets was counterbalanced across participants. Before the start of experimental trials, participants were administered the sixteen practice trials.

RESULTS

The primary dependent variable was the proportion of word stems completed with the flashed picture. Group means and standard error for all critical conditions are presented in Table II.

Baseline Performance

Baseline performance was estimated by measuring the probability of completing a stem with a critical picture name in the absence of that picture.

TABLE II

Mean (Standard Error) Completion Proportions for Neglect Patients and Control Participants in the Inclusion, Exclusion and Baseline Conditions for Each Visual Field

Group	Inclusion task			Exclusion task		
	LVF	RVF	Baseline	LVF	RVF	Baseline
Neglect patients	.319 (.092)	.750 (.062)	.088 (.023)	.194 (.041)	.163 (.053)	.069 (.020)
Controls	.906 (.020)	.879 (.023)	.098 (.023)	.049 (.025)	.080 (.032)	.085 (.022)

These proportions were subjected to a univariate Analysis of Variance (ANOVA) with Group (neglect patients, control participants) as a between subjects factor, and Task (inclusion, exclusion) and Visual Field (LVF, RVF) as within subjects factors. No main effects or interactions were found to be significant, indicating that both neglect patients (M = 0.078, SE = 0.015) and control participants (M = 0.092, SE = 0.016) were equally likely to complete the stem with the critical picture name in the absence of that picture. This occurred by chance on the same proportion of trials in both the Inclusion task (M = 0.094, SE = 0.016) and the Exclusion task (M = 0.078, SE = 0.015).

Completion Proportions

A univariate ANOVA was conducted on the proportion data for all critical trials with Group, Task, and Visual Field as factors. All main effects were significant [Group: $F(1, 22) = 14.76$, $p < 0.001$; Task: $F(1, 22) = 206.01$, $p < 0.0001$; Visual Field: $F(1, 22) = 14.66$, $p < 0.001$]. Neglect patients (M = 0.356, SE = 0.049) completed less stems with the flashed picture than did control participants (M = 0.479, SE = 0.057). As expected, participants completed more stems with the flashed picture in the Inclusion task (M = 0.743, SE = 0.0415) than the Exclusion task (M = 0.112, SE = 0.020). Participants also completed more stems with the picture when it was flashed in the RVF (M = 0.470, SE = 0.056) than the LVF (M = 0.385, SE = 0.055). Significant two-way interactions were found for Group $\times$ Task, $F(1, 22) = 32.372$, $p < 0.0001$, Task $\times$ Visual Field, $F(1, 22) = 24.066$, $p < 0.0001$, and Group $\times$ Visual Field, $F(1, 22) = 14.225$, $p < 0.01$. The means and standard error for these interactions are reported in Table III.

These two-way interactions were further qualified by a significant three-way interaction, $F(1, 22) = 39.86$, $p < 0.0001$. Means comparisons revealed that in the Inclusion task, when the picture was presented in the LVF, neglect patients completed the stem with the picture on a significantly smaller proportion of trials than control participants, $F(1, 22) = 203.10$, $p < 0.0001$, as well as compared to their own RVF performance, $F(1, 22) = 93.80$, $p < 0.0001$. Neglect patients' RVF performance in the inclusion task was also impaired compared to control participants' RVF performance, $F(1, 22) = 9.86$, $p < 0.01$. Thus, while neglect patients' LVF performance in the Inclusion task was impaired compared to their right visual field performance, their right visual field performance was also impaired when compared to that of control participants, albeit to a lesser

TABLE III

Mean Completion Proportions (Standard Error) for Two-Way Interactions for Group × Task × Visual Field ANOVA

Group × Task	Inclusion task		Exclusion task	
Neglect patients	0.534	(0.073)	0.178	(0.033)
Controls	0.893	(0.015)	0.065	(0.020)
Task × Visual field	**Inclusion task**		**Exclusion task**	
Left Visual field	0.661	(0.072)	0.109	(0.026)
Right Visual field	0.826	(0.031)	0.115	(0.030)
Group × Visual field	**Left visual field**		**Right visual field**	
Neglect patients	0.256	(0.051)	0.456	(0.078)
Controls	0.478	(0.084)	0.480	(0.079)

extent than their LVF performance. A different pattern of performance was seen in the Exclusion task. Recall that in this task, impaired performance is defined by a significantly greater proportion of trials in which the stem is completed with the picture. When the picture was flashed to the LVF, neglect patients' performance was impaired compared to control participants, $F(1, 22) = 12.31$, $p < 0.01$, and when the picture was flashed to the RVF, their performance was marginally impaired compared to control participants' RVF, $F(1, 22) = 3.97$, $p < 0.06$. Importantly, however, neglect patients' LVF and RVF were not significantly different from each other, $F(1, 22) = 0.49$, $p > 0.40$. In sum, in the exclusion task, neglect patients completed the stem with the picture on a greater proportion of trials than did control participants, and their performance did not differ across visual field.

A number of paired t-tests were conducted in order to compare participants' completion proportions in the experimental trials to baseline trials. Tests revealed that, in the inclusion task, both neglect patients and control participants completed the stem with the flashed word on a greater proportion of trials compared to baseline, p's < 0.05. This occurred when the picture was flashed in either visual field, demonstrating that some of the flashed pictures were perceived (either with or without awareness) in both visual fields for all participants. In the exclusion task, control participants' proportions were not significantly lower than baseline, however this was most likely due to a floor effect, since baseline proportions were already quite low ($M = 0.092$). When performing the exclusion task, neglect patients completed the stem with the picture more frequently than baseline in the LVF, $t(9) = 2.30$, $p < 0.05$, but not in the RVF, $t(9) = 1.53$. Thus, even though the ANOVA indicated that there was no significant difference between the LVF and RVF, the t-tests suggest that the proportion of completions in the exclusion task in the RVF were similar to baseline and relatively normal. This strongly suggests unaware processing of those same pictures in the LVF, since aware perception should encourage participants not to complete the stem with the picture.

Aware and Unaware Perception

Aware and unaware perception in each visual field was calculated using the process dissociation approach. As noted above, this approach takes advantage of the fact that in the inclusion task, aware (A) and unaware (U) perception both affect behavior similarly, while in the exclusion task they work in opposition to each other. Specifically, successful completions in the inclusion task reflect the contributions of both aware and unaware perception. Stems would be completed correctly if the flashed picture was perceived with awareness or if the picture was perceived unconsciously, without awareness (U* [1 – A]). Therefore, expressed mathematically, "Inclusion Completions" = A + U* (1 – A). Conversely, in the exclusion task, stems would be completed with the flashed picture *only* if the picture was perceived unconsciously, *without awareness* (U* [1 – A]). Therefore, expressed mathematically, "Exclusion Completions" = U* (1 – A). Using algebra, these simultaneous equations can be solved for A and U, representing the proportion of trials in which the flashed picture was perceived with awareness or without awareness. The resulting calculations reveal that aware perception can be obtained by subtracting completion performance in the exclusion task from the inclusion (A = I – E), since the influence of unaware perception is the same in both tasks. Furthermore, the effects of unaware processing can also be expressed as a function of completion performance in the two tasks (U = E / (1 – A)).

The process dissociation procedure makes a critical assumption about the relationship between aware and unaware perception. The equations used to estimate aware and unaware processing rest on the assumption that these two types of processing act independently of each other (for support of independence, see Jacoby et al., 1997). However, ceiling and floor effects in either task can disrupt estimations of unaware processing by violating this critical assumption (Jacoby, 1991). For example, if performance is perfect in the exclusion task (Exclusion = 0), then according to the process dissociation procedure, unaware perception is automatically estimated as 0. While this is a possible explanation for perfect exclusion performance, it is certainly not necessarily true. For example, if a participant perceived every prime with awareness in the exclusion task, performance would be perfect (Exclusion = 0); however, given the independence of aware and unaware influences, there is no reason why unaware processing should be estimated to be 0. It is still possible that unaware processing and aware processing were co-occurring (C*U). A similar violation of independence occurs when inclusion task performance is perfect (Inclusion = 1). In this case, unaware perception is automatically estimated as 1. This becomes evident if the equation estimating unaware perception is rewritten (U = E / (1 – [I – E])), and I = 1 is substituted (therefore, U = 1). Again, this is unlikely to be accurate. Perfect inclusion performance alone does not indicate anything about unaware perception by itself.

In the current study, these ceiling effects are evident in the performance of many of the control participants. Ten of 14 control participants had perfect exclusion performance (E = 0) in at least one visual field. Additionally, 5 of the control participants had perfect inclusion performance in one visual field (I = 1).

To avoid eliminating the majority of the control data, estimates of aware and unaware perception were calculated on the mean performance (on the two tasks) for the control participants as a group, instead of for each individual. This approach is akin to treating the control group as one ‘macro-subject’ (L. L. Jacoby, personal communication, June 14, 2000). The macro-subject approach allows us to estimate unaware perception for all of the control participants as a group, since overall, the control participants are not perfect in any experimental condition. The mean estimate of aware perception is unchanged by this approach. While the ‘macro-subject’ estimates of aware and unaware perception can be used for comparison purposes, without individual data, it was not possible to perform an ANOVA or compute variability appropriately.

Amongst the 10 neglect patients, only 3 have perfect exclusion performance in their right visual field. As with the control group, mean patient performance (in the two tasks) was used to compute ‘macro-subject’ estimations of aware and unaware perception.

While no statistics could be calculated to further investigate unaware perception, neglect patients’ and control participants’ pattern of data for unaware perception could be compared. Neglect patients’ unaware perception was 0.2210 in the LVF[1] and 0.3939 in the RVF; control participants’ unaware perception was 0.3436 in the LVF and 0.4002 in the RVF. This pattern of data suggests that neglect patients’ unaware perception may be reduced in the LVF compared to their RVF perception as well as compared to control participants. To further examine unaware perception in the neglect patients’ LVF, LVF unaware perception was estimated for each individual and a t-test was conducted to compare whether these estimates differ from zero (no perception). Estimates of unaware perception were done for all neglect patients, since there were no ceiling effects for any patients in the LVF. This t-test revealed that while LVF unaware perception was reduced, it was still significantly greater than 0 ($t(9) = 4.03$, $p < 0.01$).

Because the ceiling effects do not influence estimates of aware perception, an ANOVA was computed with aware perception as the dependent variable, and Group and Visual Field as independent variables. There was a significant main effect of Group [$F(1, 22) = 32.72$, $p = 0.0001$] and Visual Field [$F(1, 22) = 24.07$, $p = 0.0001$]. Control participants ($M = 0.83$, $SD = 0.13$) had more aware perception than neglect patients ($M = 0.36$, $SD = 0.38$), and participants overall had more aware perception in the RVF ($M = 0.71$, $SD = 0.23$) than the LVF ($M = 0.55$, $SD = 0.43$). Additionally, there was a significant interaction between Group and Visual Field [$F(1, 22) = 39.86$, $p = 0.0001$]. Means comparisons revealed that neglect patients’ aware perception in their LVF ($M = 0.13$; $SD = 0.33$) was reduced compared to their intact RVF ($M = 0.59$; $SD = 0.29$) [$F(1, 22) = 53.94$, $p = 0.0001$] and compared to control participants’ LVF ($M = 0.86$; $SD = 0.13$) [$F(1, 22) = 157.71$, $p = 0.0001$]. Neglect patients also demonstrated significantly less awareness in their RVF compared to control participants ($M = 0.80$; $SD = 0.14$) [$F(1, 22) = 13.17$, $p < 0.01$].

[1]Of note, neglect patients with hemianopia ($n = 4$) did not differ from patients without hemianopia ($n = 6$) on the estimate of unaware perception in the LVF (neglect with hemianopia $M = .222$; neglect without hemianopia $M = .220$).

T-tests were conducted to ascertain whether neglect patients' aware perception was significantly greater than zero (no perception). These t-tests revealed that aware perception in the right visual field was significantly greater than zero, $t(9) = 6.40$, $p = 0.0001$, while aware perception in the left visual field was not significantly greater than zero, $t(9) = 1.20$, $p > 0.2$. This further indicates that while right visual field awareness may have been reduced for these neglect patients, left visual field awareness was absent.

In summary, it appears perception in the neglect patients' LVF is impaired such that aware perception is eliminated, while unaware perception may be impaired, but is not eliminated. Neglect patients also demonstrated a RVF impairment that appeared to only affect aware and not unaware perception.

Discussion

Briefly presented lateralized pictures affected neglect patients' stem completion performance when they were instructed to complete a centrally presented word stem with the picture name (i.e., inclusion task) as well as when they were instructed NOT to complete the stem with the picture name (i.e., exclusion task). In the inclusion task, the effect was to "prime" the picture name such that the word stems were correctly completed with the picture name on a significantly greater proportion of trials than a baseline measure in both the left and the right visual fields. As expected, the completion rate was significantly greater, however, in the RVF compared to the LVF. In the exclusion task, the effect of the lateralized picture was different depending on the visual field in which it was presented. Left visual field pictures primed the picture name, but in this condition the priming resulted in incorrect completions (i.e., completing the stem with the picture name). This finding suggests that neglect patients' performance was, at least on some trials, guided primarily by unaware perception of the LVF picture; awareness of the picture would have led to a correct rejection of that picture name as a stem completion. In other words, only unaware priming from the LVF picture could account for above-baseline performance in the exclusion task. Right visual field pictures were correctly rejected as responses to the stems. Control participants performed both tasks with little error. Inclusion performance was significantly greater than baseline in both the LVF and RVF, and exclusion performance was similar to baseline in both visual fields.

The primary purpose of conducting the current experiment was to estimate the contributions of aware and unaware influences in visual perception in individuals with hemispatial neglect. Using the process dissociation procedure (Jacoby et al., 1997), we demonstrated that neglect patients' aware perception was characteristically reduced in the LVF. In fact, the estimate of patients' aware perception was statistically not greater than zero, suggesting an absence of awareness of visual information in the neglected hemispace. Unexpectedly, we also found a reduction in awareness in the patients' RVF (compared to control participants' RVF). This reduction, however, was not as severe as was observed in the patients' LVF, as the estimate of awareness was greater than zero. Thus, it appears that individuals with hemispatial neglect have no visual awareness in the contralesional hemispace and reduced visual awareness in the ipsilesional hemispace. This finding is reminiscent of an earlier finding in which we discovered that a subset of neglect patients showed a bilateral impairment in a forced-choice discrimination task that also used the same pictures (D'Esposito et al., 1993). Interestingly, in that study, patients who demonstrated a bilateral impairment in discrimination performance all had frontal and/or frontal subcortical lesions. The current data shows a similar trend. Four of the neglect patients (J.A., M.B., E.H., G.S.) showed a relatively greater reduction in RVF awareness compared to the remaining six patients (mean RVF awareness .281 versus .792), and three of those patients (J.A., M.B., G.S) had confirmed deep frontal lesions. The fourth patient (E.H.) had a temporal aneurysm that hemorrhaged and was subsequently evacuated. While a mass effect was noted by the consulting radiologist, the extent to which the frontal lobes may have been affected was not specifically noted. Thus, bilateral attentional impairments have been observed in patients with unilateral visual neglect and these may be related to frontal lobe pathology.

Estimates of unaware perception appeared to differ as a function of visual field for the neglect patients. Specifically, patients had reduced unaware perception in their LVF (.221) compared to their RVF (.394) and compared to control participants (LVF = .344; RVF = .400). Unlike aware perception in the LVF, patients' unaware perception was greater than zero indicating some level of residual unaware processing. This finding supports the speculation noted above that exclusion performance greater than baseline observed in the LVF of neglect patients was driven primarily by unaware processing.

Using the process dissociation procedure, we have confirmed that there is at least some visual processing of information in the neglected hemispace that is not accompanied by awareness, but that can nevertheless influence patients' overt behavior. We suggest that it is this unaware processing that underlies semantic and orthographic access in other types of priming studies (e.g., (McGlinchey-Berroth et al., 1993, 1996b; Ládavas et al., 1993; Berti and Rizzolatti, 1992) and in more explicit paradigms such as cross-field matching (Berti et al., 1992; Verfaellie et al., 1995; Volpe et al., 1979; but see Farah et al., 1991). It is also possible that this preserved unaware processing is used to activate appropriate response codes such as that observed using the flanker paradigm (Fuentes and Humphreys, 1996; Cohen et al., 1995; Audet et al., 1991). These findings suggest that the locus of impairment in hemispatial neglect lies, at least in part, in the processes by which perceptual and semantic representations reach awareness.

The finding of reduced unaware processing in neglect may seem surprising, in light of the fact that numerous studies have shown that semantic priming is fully intact in the neglected field. Does this suggest that the priming demonstrated in earlier studies was contaminated by aware perception? We would argue that this is unlikely, as the present study demonstrated a complete absence of awareness in the neglected field. Rather, we feel that the visual processes that are preserved in neglect are sufficient to support semantic priming, but may be insufficient to allow access to object identity, which was required for normal performance in the current stem completion task. For example, the activation of simple features may be sufficient for normal semantic priming, as priming only requires broad activation of a network of related items. In contrast, object identification in the stem completion task requires the integration of features and the activation of specific object representations. One possibility is that neglect patients are able to analyze features normally, but are unable to integrate these features into higher-level representations. Support for this notion comes from a recent study by Esterman et al. (2000) in which neglect patients showed normal LVF performance in a preattentive search for simple visual features but impaired LVF performance on an attentionally mediated search for feature conjunctions. It is likely that the extent to which unaware processing and higher-order integration processing are engaged in any given task varies and thus affects the normalcy of neglect patients' performance depending on processing demands.

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