P.B., Ehri, L.C. and Treiman, R., eds), pp. 107‴143, Erlbaum
10 Goswami, U. (1997) Learning to read in different orthographies: Phonological awareness, orthographic representations and dyslexia, in *Dyslexia: Biology, Cognition and Intervention*, (Hulme, C. and Snowling, M., eds) pp. 131–152, Whurr
11 Hinton, G. and Shallice, T. (1991) Lesioning an attractor network: Investigations of acquired dyslexia *Psychol. Rev.* 98, 74–95
12 Plaut, D. *et al.* (1996) Understanding normal and impaired reading: Computational principles in quasi-irregular domains *Psychol. Rev.* 103, 56–115
13 Hulme, C. and Snowling, M. (1994) *Reading Development and Dyslexia*, Whurr
14 Hulme, C. and Snowling, M. (1997) *Dyslexia: Biology, Cognition and Intervention*, Whurr
15 Willows, D.M., Kruk, R.S. and Corcos, E. (1993) *Visual Processes in Reading and Reading Disabilities*, Erlbaum
16 Brady, S. and Shankweiler, D., eds (1991) *Phonological Processes in Literacy*, Erlbaum
17 Bradley, L. and Bryant, P.E. (1978) Difficulties in auditory organisation as a possible cause of reading backwardness *Nature* 271, 746–747
18 Snowling, M. (1995) Phonological processing and developmental dyslexia *J. Res. Reading* 18, 132–138
19 Scarborough, H.S. (1990) Very early language deficits in dyslexic children *Child Dev.* 61, 1728–1743
20 Fowler, A. (1991) How early phonological development might set the stage for phoneme awareness, in *Phonological Processes in Literacy: A Tribute to Isabelle Liberman* (Brady, S.A. and Shankweiler, D.P., eds), pp. 97–117, Erlbaum
21 Snowling, M. and Hulme, C. (1994) The development of phonological skills *Trans. R. Soc. B* 346, 21–28
22 Wagner, R.K. *et al.* (1993) The development of young readers' phonological processing abilities *J. Edu. Psychol.* 85, 1–20
23 Brown, G.D.A. Connectionism, phonology, reading and regularity in dyslexia *Brain and Lang.* (in press)
24 Rack, J.P., Snowling, M.J. and Olson, R.K. (1992) The nonword reading deficit in dyslexia: a review *Read. Res. Quart.* 27, 29–53
25 Plaut, D. *et al.* (1996) Understanding normal and impaired reading: Computational principles in quasi-irregular domains *Psychol. Rev.* 103, 56–115
26 Hulme, C. *et al.* (1995) Building phonological knowledge into a connectionist model of the development of word naming *Lang. Cognit. Proc.* 10, 387–391
27 Stothard, S.E. and Hulme, C. (1992) Reading comprehension difficulties in children: The role of language comprehension and working memory skills *Reading and Writing* 4, 245–256
28 Van Orden, G.C., Johnston, J.C., and Hale, B.L. (1988) Word identification in reading proceeds from spelling to sound to meaning *J. Exp. Psychol: Learning, Memory & Cognition* 14, 371–386
29 Bruck, M. (1990) Word-recognition skills of adults with childhood diagnoses of dyslexia *Dev. Psychol.* 26, 439–454
30 Olson, R.K., Forsberg, H. and Wise, B. (1994) Genes, environment, and the development of orthographic skills, in *The Varieties of Orthographic Knowledge I: Theoretical and Development Issues* (Berninger, V.W., ed.), pp. 27–71, Kluwer
31 Pennington, B.F. (1994) Genetics of learning disabilities *J. Child Neurol.* 10, S69–S76
32 Paulesu, E. *et al.* (1996) Is developmental dyslexia a disconnection syndrome? Evidence from PET scanning *Brain* 119, 143–157
33 Bryne, B. *et al.* Assessing the child's contribution to reading acquisition: what we know and what we don't know, in *Cognitive and Linguistic Foundations of Literacy Acquisition* (Blachman, B., ed.), Erlbaum (in press)
34 Hatcher, P.J., Hulme, C. and Ellis, A.W. (1994) Ameliorating early reading failure by integrating the teaching of reading and phonological skills: The phonological linkage hypothesis *Child Dev.* 65, 41 57
35 Snowling, M. (1996) Annotation: contemporary approaches to the teaching of reading *J. Child Psychol. Psychiatry* 37, 139–148

Visual information processing in hemispatial neglect

Regina McGlinchey-Berroth

R. McGlinchey-Berroth is in the Department of Psychiatry, Harvard University Medical School and the Geriatric Research Education and Clinical Center (GRECC), Brockton/West Roxbury Veterans Administration Medical Center, 1400 VFW Parkway, West Roxbury, MA 02132, USA.

tel: +1 617 323 7700
fax: +1 617 363 5503
e-mail: mcglinchey-berroth.regina@brockton.va.gov

Hemispatial neglect is a complex neuropsychological disorder characterized by a severe attentional deficit that produces a lack of awareness for information appearing in contralesional hemispace. Despite this lack of phenomenal awareness, recent studies suggest that a great deal of visual information processing does occur and can influence the performance of patients in certain tasks. The current review will present this evidence and suggest a new theoretical framework that may help to direct future research into uncovering the underlying mechanism(s).

The disorder of unilateral hemispatial neglect is perhaps the most striking of all neuropsychological syndromes. It is an acquired disorder marked by an individual's inability to acknowledge, report or otherwise make explicit use of information falling in the visual hemispace contralateral to the responsible lesion. This disorder can be just as severe and debilitating as disorders of language or memory. As Mesulam[1] noted: 'the patient may behave almost as if one half of the universe had abruptly ceased to exist in any meaningful form'. It is a very heterogeneous disorder and patients can be classified according to a number of different schemes (such as attention/intention or peripersonal/personal). It can be demonstrated

 1364-6613/97/$17.00 PII: S1364-6613(97)01016-4

in the somesthetic, auditory and visual modalities, despite the fact that the primary sensory receiving and projection systems are often intact. Thus, neglect has been characterized as a deficit in looking, listening, touching and searching, rather than a deficit in seeing, hearing, feeling or moving.

Hemispatial neglect occurs most commonly and severely following right hemisphere (RH) damage but it has been observed in patients with left hemisphere damage (LH; Refs 2,3). Demonstration of neglect can be found in the everyday activities of the patient. For example, a patient may only shave, dress and groom the non-neglected side of the body[4]. Similarly, he or she may eat from only the non-neglected side of a plate, read only parts of words or sentences and attend to people and events on only one side of space[5]. The bias to ignore one side of space can be very pronounced. For instance, Critchley[6] reported the case of an orchestra conductor who ignored all of the musicians on one side of the stage! On clinical tests, patients with hemispatial neglect will fail to cross-out target stimuli (such as the letter 'A') that appear on the left side of a page of randomly arrayed letters and judge the middle of a horizontally oriented line to be to the right of the actual midpoint, suggesting that they are neglecting the left-most portion of the line (see Fig. 1).

Hemispatial neglect can be a functionally devastating disorder, carrying a very unfavorable prognosis for recovery[7]. Unlike many other neuropsychological disorders, neglect is extremely variable with regard to both the severity and duration of the disorder as well as the presence or absence of accompanying disorders. For example, neglect may be observed following damage to a number of structures, both cortical and subcortical[8,9], it may or may not be associated with any permanent motor or sensory dysfunction (such as hemianopia or hemiplegia) and it may range in duration from several weeks to months and can, in some cases, be permanent. One factor complicating recovery is that patients are often unaware of their limited representation of the environment and consequently minimize or even deny completely that they have any deficits (anosognosia)[10].

Visual neglect has been the primary focus of investigations into the underlying mechanisms of neglect and for the delineation of the neuroanatomical underpinnings of neglect in humans. This review will likewise focus on left hemispatial neglect for visual information following a RH lesion, although the constructs developed are intended to be multimodal.

Theoretical accounts

John Hughlings Jackson was probably the first person to describe a patient who today would be diagnosed to have left visual neglect[11]. The most outstanding clinical feature of this patient was her 'imperception' of the left half of space. Jackson attributed this patient's imperception to a defect in speech. He felt that visual ideation was located in the right parietal lobe and when damaged led to an inability to name persons, objects and places. Other early writers attributed neglect to a loss of cortical sensibilities[12,13]. Pick[14] believed neglect arose from damage in either the right parietal lobe or thalamus, which he felt contained a representation of our three-dimensional body image. Damage to either of these areas effectively wiped out the contralateral side of a person's body image. Brain[15] argued that the parietal lobes mediated spatial perception and body schema, and suggested that when they were damaged, visual disorientation and an 'amnesia' for half of the body resulted. Brain felt that the RH may play a more important role in these functions than the LH, and was thus the first to note an asymmetry in the lateralization of hemispatial neglect.

Modern theorists use contemporary concepts derived from cognitive psychology and neuroscience to understand hemispatial neglect. For example, Bisiach has postulated a representational account[16,17] based on the finding that patients who are asked to visually image a scene report only information from the ipsilesional side of space. Rizzolatti and Berti[18] have advanced a neural representational account that asserts that space is represented in several brain centers which interact and are jointly responsible for conscious space awareness. Furthermore, they suggest that these brain centers code space using viewer-centered coordinates. Damage to these brain areas will lead to neglect.

A number of theories attribute neglect to a deficit in attentional processing. Riddoch and Humphreys[19] have suggested that neglect occurs because of impaired orienting of attention to contralesional stimuli; this theory is based on the finding that line bisection performance improved when patients were cued to the neglected side of the line. Similarly, Heilman and colleagues[20] suggested that

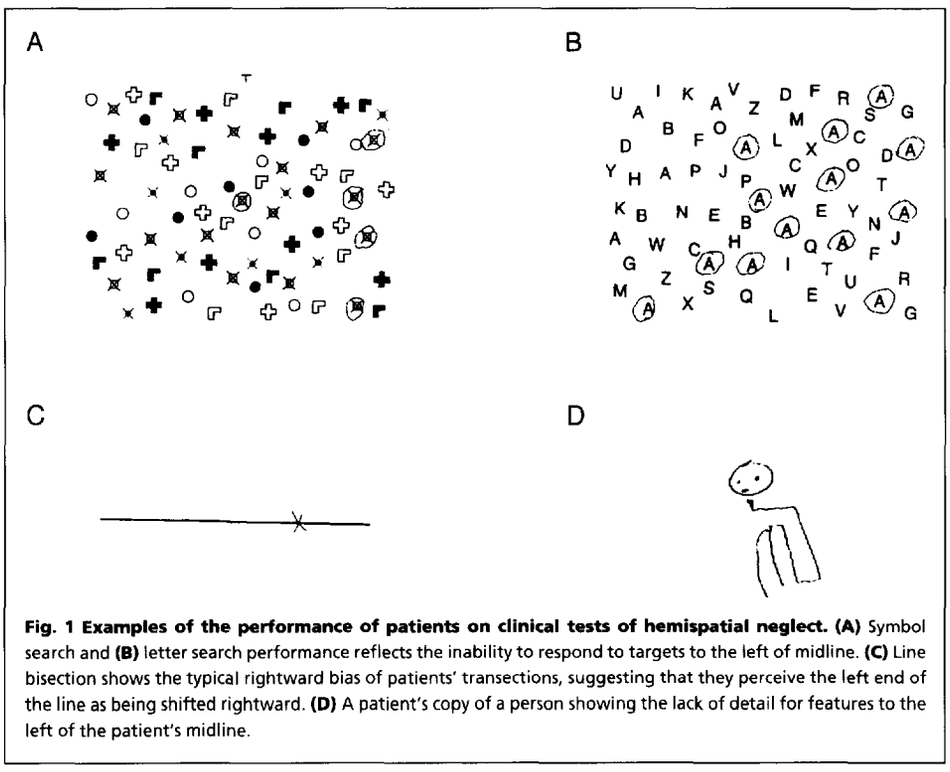

Fig. 1 Examples of the performance of patients on clinical tests of hemispatial neglect. (A) Symbol search and **(B)** letter search performance reflects the inability to respond to targets to the left of midline. **(C)** Line bisection shows the typical rightward bias of patients' transections, suggesting that they perceive the left end of the line as being shifted rightward. **(D)** A patient's copy of a person showing the lack of detail for features to the left of the patient's midline.

Box 1. Semantic priming paradigm

This is a cognitive paradigm that assesses the contents of semantic memory by determining what effect semantic context has on behavior without requiring the subject to make explicit decisions or judgments about the context. In a semantic priming task, the subject is first presented with a semantic context (such as a word, a sentence or a picture) that is followed by a target stimulus to which the subject must respond. If the target stimulus is related to the context in which it was presented, responses are typically faster than if the target stimulus was not related to the priming context. The decrease in the amount of time to process target words preceded by related contexts ('facilitation') is theorized to result from both an automatic, passive spread of activation within the semantic network as well as a more controlled strategic component[a,b]. The presentation of the priming stimulus is presumed to automatically cause activation to spread to related concepts in memory; thus if the target is related to the prime, response times are faster because the target has already been partially activated by the spreading activation of the prime. Also, if the subject is led to believe that a related target will be presented or is given sufficient time to process the prime, the degree of facilitation is greater than when facilitation results from spreading activation alone[b]. This is not without cost, however: if the subject expects the target to be related to the prime (thus directing attention to a specific location in the memory) but an unrelated target is actually presented, the subject's response time will be longer than if no such expectancy had been generated, a phenomenon known as 'inhibition'.

References

a Collins, A.M. and Loftus, E.F. (1975) A spreading activation theory of semantic processing *Psychol. Rev.* 82, 407–428

b Neely, J.H. (1977) Semantic priming and retrieval from lexical memory: roles of inhibitionless spreading activation and limited-capacity attention *J. Exp. Psychol. Gen.* 106, 226–254

the RH normally controls attentional orienting to both sides of space, whereas the LH controls orienting to the right side of space only. Given this lateralization, neglect for left space occurs following right-sided lesions because the LH cannot orient attention to that space and, thus, cannot compensate for the RH loss. Taking this line of argument one step further, Kinsbourne suggests that there are opponent attentional systems residing in the right and left hemispheres. These opponent processors control the lateral orienting of attention and action to the left and right hemispace, respectively. He argues that the rightward orienting processor (located in the LH) is more 'potent' than the leftward processor (located in the RH). Following RH damage, the LH's orienting processor is unopposed and produces a marked hemispatial neglect. Consistent with this view are findings that neglect patients demonstrate overly strong orienting to the ipsilesional side of space[21–23]. Perhaps exacerbating this deficit, Posner and his colleagues[24] have proposed that there is a selective inability to disengage from stimuli presented in the ipsilateral side of space.

While these theories have provided a valuable framework for characterizing the attentional impairments in neglect, relatively little was known about the actual fate of information falling in the neglected hemispace, until recently. Studies have shown that even though patients may be unaware of information in the contralesional space, information is processed to some degree and can influence behavior implicitly.

Implicit visual information processing in hemispatial neglect

Interest in the level(s) of processing achieved for information falling within the neglected hemispace was spurred on by the observations of Kinsbourne and Warrington[25] who noted that patients with RH lesions often retain word length in their reading errors. For example, patients may misread the word 'mailman' as 'milkman'. Since that time, several paradigms have been used to explore residual visual processing in neglect including cross-field matching, semantic priming (see Box 1), and flanker tasks. Most studies use an objective criterion of awareness[26] in which patients are asked to identify, in some way, stimuli in the neglected hemispace.

Cross-field matching paradigm

Volpe, Le Doux and Gazzaniga[27] tested four patients with extinction as a result of RH lesion. 'Extinction to double simultaneous stimulation' refers to a phenomenon in which patients fail to report the stimulus on the contralesional side when two stimuli are presented simultaneously to the ipsilateral and contralateral side of space. Although some clinicians take extinction as a useful method of diagnosing less severe neglect (which may not be apparent with the presentation of a single stimuli) the relationship between neglect and extinction remains controversial. Patients were presented with lateralized displays of two pictures simultaneously, one presented in each visual field. Surprisingly, patients performed better than chance when they were asked to indicate whether the two pictures were the same or different, even though they were unable to name the picture presented in the left visual field (LVF). These findings were later replicated in patients with clear signs of severe visual neglect[28,29].

Berti *et al.*[30] manipulated the level of visual representation required to perform the cross-field matching task by using three types of 'same' stimuli: physically identical, same object but from a different viewpoint and two different objects with the same name. They found that patients' performance was above chance even in the condition that required a comparison of the two different objects with the same name. Berti *et al.* concluded that unattended stimuli were processed to a categorical level. This interpretation, however, was later challenged by Farah *et al.*[31] who argued that cross-field matching may simply be an easier task and require less perceptual analysis than naming. To examine this possibility, Farah *et al.* tested three patients with extinction and compared their performance on a cross-field matching task and a forced-choice discrimination task, which equated the amount of visual information required

Box 2. Picture priming and discrimination methodology

The semantic priming, lexical decision task used lateralized picture primes and centrally located target letter strings. The prime displays were composed of one line drawing of an object and one nonsense figure presented simultaneously for 200 ms to opposing visual fields. We felt that the double simultaneous displays, together with the short display duration, maximized the probability that the prime picture would be neglected and that compensatory eye movements would not occur. The target letter strings followed the offset of the prime displays by 200 ms and remained visible until a word/nonword judgment was made. The discrimination task was virtually identical to the priming task, except that the target letter strings were replaced by the forced-choice alternatives that were aligned vertically.

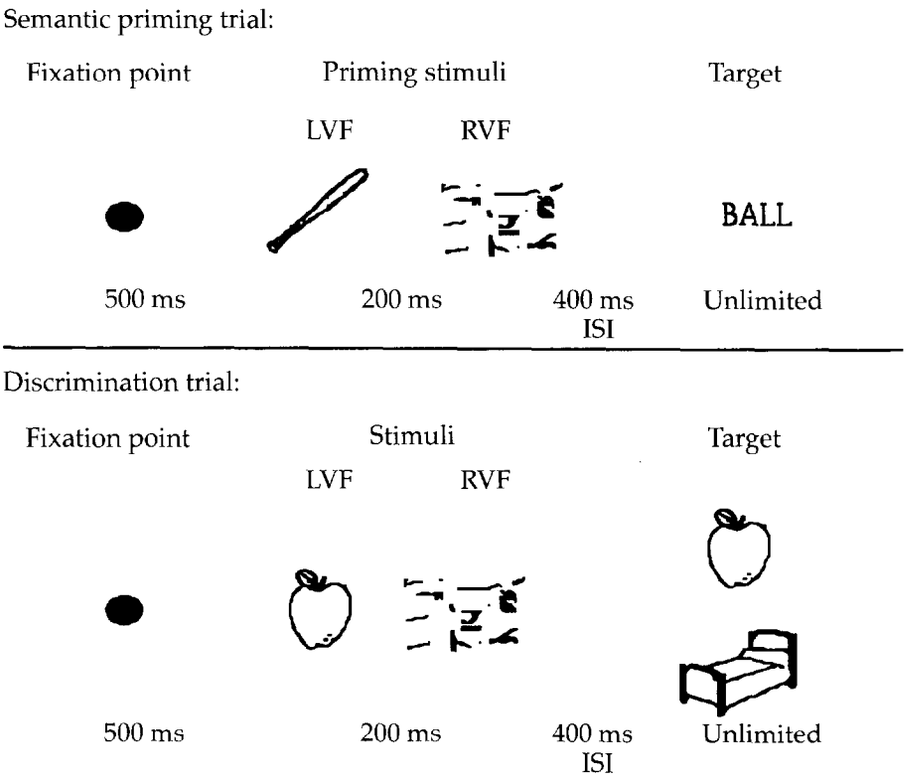

Fig. Picture priming and discrimination trial and time course. (From Ref. 34.) LVF, left visual field; RVF, right visual field.

for performance. Under these conditions, the patients, as a group, performed the two tasks equally well. The authors concluded that there was no evidence to suggest that extinguished information is unconsciously perceived.

Although the results were persuasive, Verfaellie *et al.*[32] noted several limitations in the Farah *et al.* study – limited stimulus set, pre-exposure to the stimuli and one patient who did perform at chance on the discrimination task. Consequently, they compared cross-field matching and forced-choice discrimination in a larger group of patients with varying severity of neglect. Trials requiring a 'different' response were of three types: semantically similar, physically similar and dissimilar. Verfaellie *et al.* found that, as a group, neglect patients performed at chance on the discrimination task and significantly better than chance on the cross-field matching task. When considered individually, however, the dissociation was present only for patients whose discrimination performance was at chance. In addition, semantically related and physically similar 'different' judgments were slowed in comparison to unrelated judgements. Verfaellie *et al.* concluded that whether cross-field matching and discrimination are dissociable depends on the severity of neglect. Also, the fact that all patients were slower at matching stimuli that were physically or semantically similar suggested that neglect patients have access to visual and semantic information regarding left-sided stimuli.

Semantic priming paradigm

The evidence from cross-field matching studies suggests that some level of visual information processing occurs in the neglected hemispace that is sufficient to implicitly influence behavior, although it is not sufficient for identification. We investigated this dissociation in a series of experiments[33,34] that addressed the possibility that information in the neglected field may be processed for meaning, even though the meaning itself is not available for report[26,35]. We used an implicit semantic priming, lexical decision task and a yoked forced-choice discrimination task that is described in Box 2. As can be seen in Fig. 2, the lateralized picture primes significantly influenced the latency with which our patients responded (and did so in a manner similar to control participants). In particular, in each of the four cases (and in the two cases reported in Ref. 33), decision latencies were significantly faster for targets preceded by related picture primes compared to unrelated picture primes. Moreover, access to semantic information was as efficient based on information presented in the neglected visual field as it was for information

presented in the intact field. The semantic activation observed in the priming experiment was not sufficient for identification, however, as patients performed at chance in the discrimination task for items initially presented in the neglected hemispace (Fig. 3). Notably, semantic priming was not observed in a patient with a dense left hemianopsia due to a small right occipital hemorrhage in the medial portion of the calcarine fissure. It is unlikely, therefore, that spared semantic priming in our neglect patients was supported by visual information carried through the extrastriatal visual system (i.e., blindsight)[36].

Berti and Rizzolati[37] also used a priming paradigm to examine visual processing of neglected information. In that study, prime-target pairs were either highly congruent (both stimuli belonged to the same category and were physically identical), congruent (both stimuli belonged to the same category but were physically dissimilar) or noncongruent (stimuli were from different categories). Significant priming was found in both congruent conditions, suggesting that information appearing in the neglected field is processed to a categorical level.

As is clear from the preceding discussion, studies demonstrating intact implicit processing in neglect have typically used pictures of common objects as stimuli. In part, these earlier studies used pictorial representations because pictures require relatively little transformation before activating representations in the semantic memory system[38]. This raises the question as to whether the visual representation of neglected stimuli is specific enough to support the formation of orthographic and lexical representations that themselves form the basis of semantic activation. The ability of neglect patients to process orthographic and perhaps lexical information is implied by the length effect in neglect dyslexia[25]. More direct evidence was provided by Ládavas *et al.*[39], who reported semantic priming from lexical information in the study of a single patient who could not read aloud the priming words that produced the effect.

Expanding the Ládavas *et al.* study, we examined whether orthographic semantic priming was due to explicitly perceived orthographic information contained within the rightmost portion of the prime word or to fully specified and implicitly processed orthographic representations[40]. This was accomplished using the identical semantic priming and discrimination paradigms depicted in Box 2, except we used word primes rather than picture primes. There were two critical conditions. In the semantic priming condition, the critical word primes were semantically related

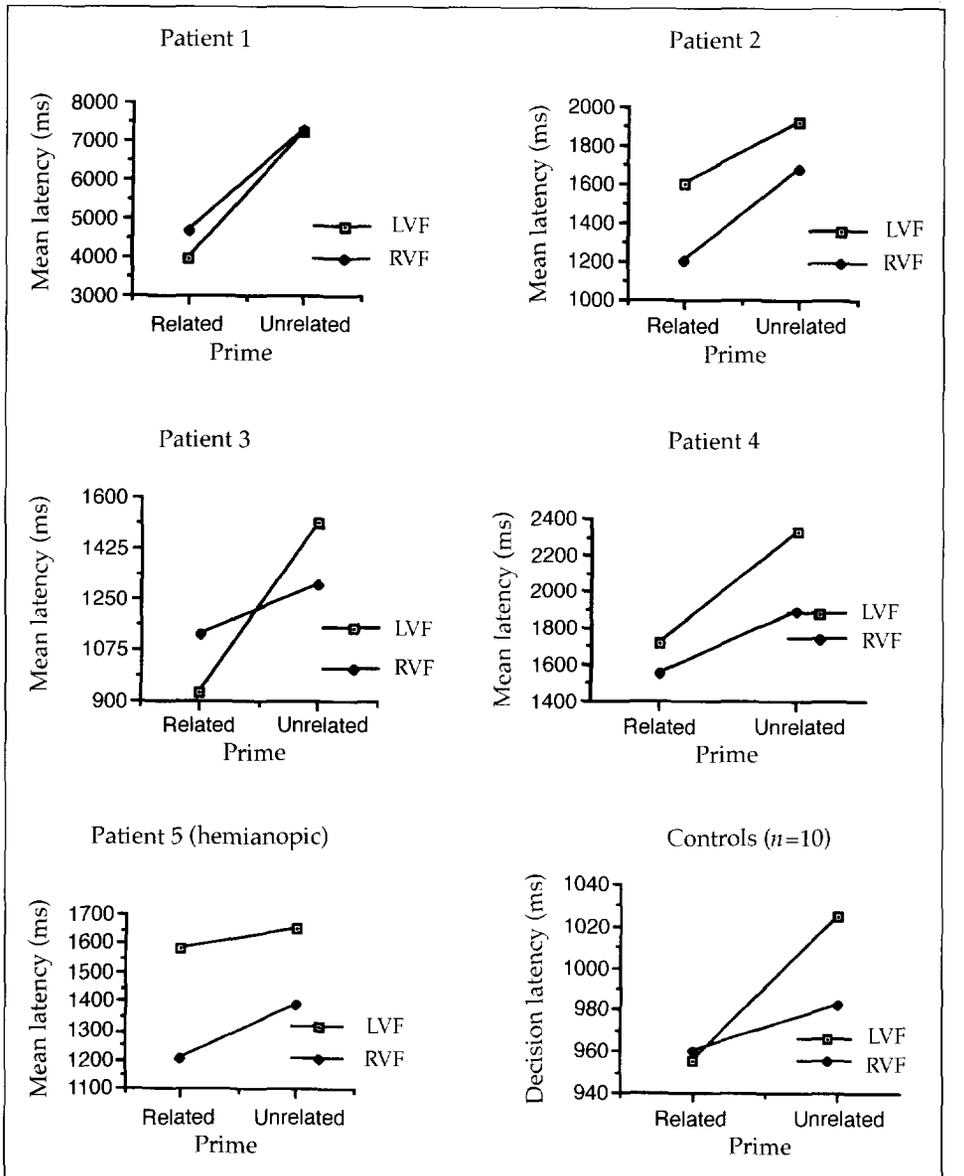

Fig. 2 Mean decision latency for the picture priming task for individual neglect patients, a hemianopic patient and the control group. This figure displays the effect of the related compared with unrelated prime word on lexical decisions. In all cases of neglect (and in the control data) there is an effect of prime that is equivalent in the two visual fields. The hemianopic patient showed significant priming only from right visual field primes. Note: the scales are different in order to represent the individual data better. Statistical significance was assessed on an individual basis. (From Ref. 34.) LVF, left visual field; RVF, right visual field.

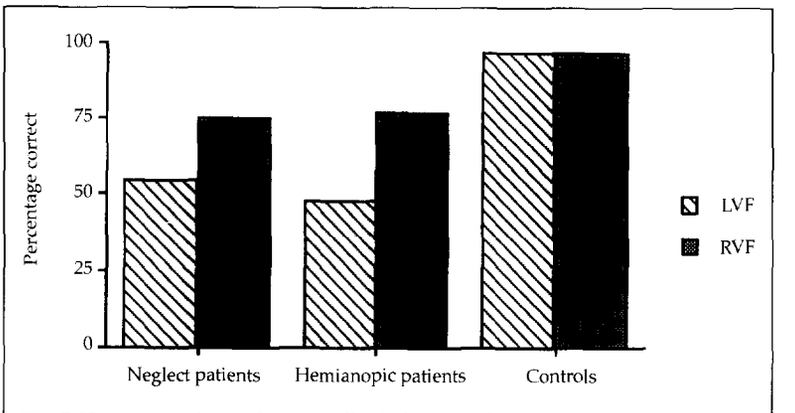

Fig. 3 Mean percentage of correct discriminations for the picture discrimination task. The performance of neglect and hemianopic patients was dependent on visual field. Performance was no better than chance for targets initially presented in the left visual field but was significantly better than chance for targets initially presented in the right visual field. LVF, left visual field; RVF, right visual field.

(PAW–DOG) or unrelated to the target word. In the orthographically mediated condition, the first letter of each prime word from the semantic condition was changed to form a semantically unrelated prime word that was orthographically similar to a semantically related word (SAW–DOG). We reasoned that if the word priming effect in patients with neglect results from explicitly perceived information of the rightmost part of the prime, priming should be observed equally in both the semantic and the orthographically mediated conditions because this account assumes that all left-sided completions would be equally likely prime words. On the other hand, if neglect patients do implicitly process the prime word in total, greater priming should be found in the semantic condition, with negligible priming, if any, in the orthographically mediated condition. The data are represented in Fig. 4. In the semantic condition, there was a significant semantic priming effect in both visual fields. In the orthographically mediated condition, we found an unexpected significant negative priming effect for LVF primes and normal semantic priming for right visual field (RVF) primes. This pattern of results is not consistent with a partial processing account and was interpreted within the context of an implicit processing account based on the findings of Dagenbach, Carr and Barnhardt[41]. In both conditions, the discrimination performance of neglect patients was at chance in the LVF and above chance in the RVF.

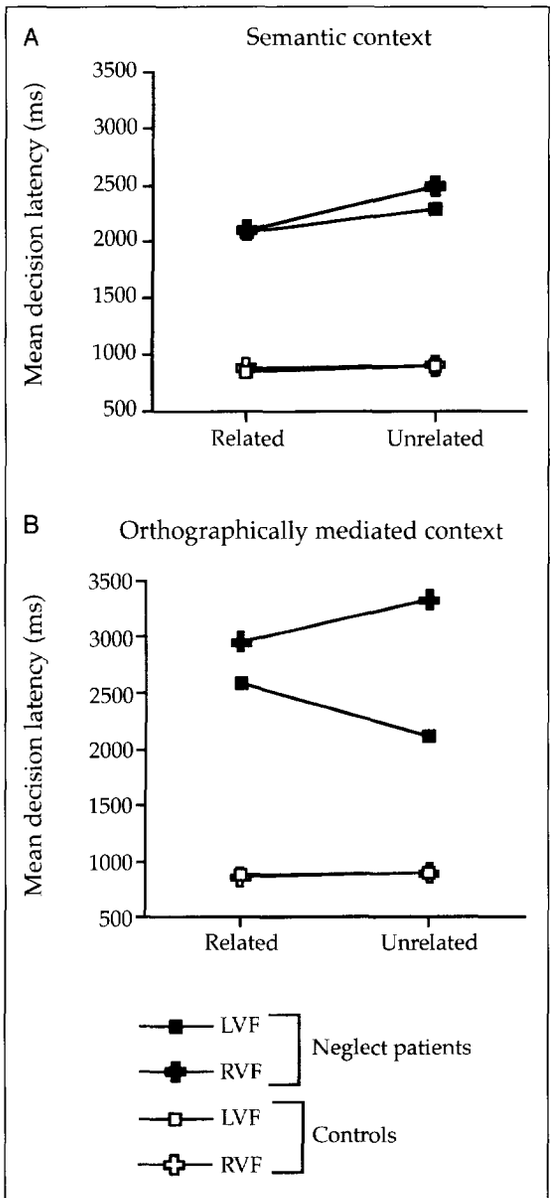

Fig. 4 Mean decision latency for the word priming experiment. (A) There is significant semantic priming from both visual fields in the semantic condition. **(B)** In the orthographically mediated condition there is significant negative priming for left visual field primes and significant semantic priming in the right visual field. (From Ref. 9.) LVF, left visual field; RVF, right visual field.

Flanker paradigm

Regardless of the specificity with which objects are defined in the neglected hemispace, a critical final step required to adequately detect or respond to contralesional stimuli lies in the activation and selection of appropriate response codes. Note that a primary difference between semantic priming and cross-field matching, on the one hand, and forced-choice discrimination, on the other hand, is the fact that the former tasks do not require overt responses to contralesional stimuli. Several investigators have used the flanker paradigm to examine the ability of neglect patients to activate response codes to contralesional stimuli. In this paradigm, a central stimulus is flanked, usually to the left or the right, by another stimulus. The flanking stimulus can either facilitate responses by activating the same response code required to respond to the central stimulus or it can inhibit responses by activating a response code that competes with the one required to respond to the central stimulus.

Three studies have used the flanker task to examine activation of response codes independent from overt responding. A reliable flanker effect has been found in three patients with extinction[42,43] and only in some conditions in the milder of two patients with neglect[44]. These data suggest that neglect patients may be able to activate response codes normally. However, patients may not be able to associate the activated response code to a specific stimulus because inhibition was not found in either the Audet *et al.* or Fuentes and Humphreys studies. Cohen and Rafal did find evidence of inhibition, but their patients were relatively mild and only showed signs of extinction.

Concluding remarks and future directions

To summarize, the application of cognitive research techniques has uncovered a great deal of evidence indicating that neglected visual information is processed to levels sufficient to activate semantic and response code information. We have recently begun an analysis of neglect based on the possibility that it may be due to an inability to bind or integrate pieces of information at one or more levels of processing. For instance, patients with neglect may not be able to integrate features into coherent objects or bind representations of objects (regardless of their level of coherence) to specific spatial locations. In addition, it is possible that even if featural and spatial information were fully specified they may not be sufficient to guide behavior because of an inability to bind response codes to a specified spatial location.

That is, patients may be able to activate response codes implicitly, but cannot overtly respond in kind. Although these processes are, to some extent, interdependent it is important to note that deficits in binding at one level (such as feature-integration) do not necessarily impose deficits at another (such as object-space binding). For example, a patient may not be able to integrate features into an object but, nonetheless, may be able to coarsely localize those features in space. This approach provides a novel way to examine the underlying deficit(s) in hemispatial neglect, and should provide new insights into this perplexing disorder.

Outstanding questions

- Which visual processes are impaired and which processes are preserved in hemispatial neglect?
- Is the fact that neglect can occur following damage to a number of different regions in the brain systematically related to the heterogeneity of the disorder?
- If impaired binding operations do, in fact, underlie hemispatial neglect, can we manipulate the extent to which this operation is necessary and thus reorient patients with neglect to 'see' information in the contralesional field? Would altering binding processes change the clinical manifestations of neglect?
- Is binding a unitary function or are there separate binding functions that are specific to certain levels of processing? Also, is binding a focally represented function in the brain or is it widely distributed?

Acknowledgements

This work is supported by the National Institute of Neurological Disease and Stroke Grant NS29342 and by Grant AG08812 to the Claud D. Pepper Older Americans Independence Center. The author thanks her colleagues William Milberg, Mieke Verfaellie, Michael Alexander, Mark D'Esposito, Laura Grande and Patrick Kilduff for all of their contributions to the work presented in this manuscript.

References

1 Mesulam, M-M., ed. (1985) *Principles of Behavioral Neurology* pp. 125–168, F.A. Davis
2 Albert, M.L. (1973) A simple test of visual neglect *Neurology* 23, 658–664
3 Gainotti, G. *et al.* (1986) Mechanisms of unilateral spatial neglect in relation to laterality of cerebral lesions *Brain* 109, 599–612
4 Heilman, K.M. *et al.* (1987) in *Neurophysiological and Neuropsychological Aspects of Spatial Neglect* (Jeannerod, M., ed.), pp. 115–150, Elsevier
5 Friedland, R. and Weinstein, E. (1977) Hemi-inattention and hemisphere specialization: introduction and historical review *Adv. Neurol.* 18, 1–31
6 Critchley, M. (1966) *The Parietal Lobes,* Hafner
7 Denes, G. *et al.* (1982) Unilateral spatial neglect and recovery from hemiplagia: a follow-up study *Brain* 105, 543–552
8 Heilman, K.M. *et al.* (1993) in *Clinical Neuropsychology* (Heilman, K.M. and Valenstein, E., eds), pp. 279–336, Oxford University Press
9 McGlinchy-Berroth, R. *et al.* (1996) The assessment of neglect reveals behavioral but not neuroanatomical sub-types *J. Int. Neuropsychol. Soc.* 2, 441–451
10 Prigatano, G.P. and Schacter, D.L. (1991) *Awareness of Deficit after Brain Injury: Clinical and Theoretical Issues,* Oxford University Press
11 Jackson, J.H. (1876) in *Selected Writing of John Hughlings Jackson* (Taylor, J., ed.), pp. 144–152, Hodder and Stoughton
12 Dejerine, J. (1914) In discussion of paper by Babinski, J. (1914): Contribution a l'études des troubles mentaux dans l'hémiplégie organique cérébrale (anosognosie) *Rev. Neurol.* 25, 845–848
13 Babinski, J. (1918) Anosognosie *Rev. Neurol.* 25, 365–367
14 Pick, A. (1908) *Ueber Störungen der Orientierung am eigenen Körper in Arbeiten aus der Psychiatrischen,* Karger
15 Brain, R. (1941) Speech and handedness *Lancet* 2, 837–842
16 Bisiach, E. *et al.* (1979) Unilateral neglect, representational schema and consciousness *Brain* 102, 609–618
17 Bisiach, E. *et al.* (1981) Brain and conscious representation of outside reality *Neuropsychologia* 19, 543–551
18 Rizzolatti, G. and Berti, A. (1990) Neglect as a neural representation deficit *Rev. Neurol.* 146, 626–634
19 Riddoch, M.J. and Humphreys, G.W. (1983) The effect of cueing on unilateral neglect *Neuropsychologia* 21, 589–599
20 Heilman, K. and Valenstein, E. (1979) Mechanisms underlying hemispatial neglect *Ann. Neurol.* 5, 166–170
21 Ládavas, E. (1990) Selective spatial attention in patients with visual extinction *Brain* 113, 1527–1538
22 Marshall, J.C. and Halligan, P.W. (1989) Does the midsagittal plane play any privileged role in left neglect? *Cognitive Neuropsychol.* 6, 403–422
23 Mark, V.W. *et al.* (1988) Hemispatial neglect affected by non-neglected stimuli *Neurology* 38, 1207–1211
24 Posner, M.I. *et al.* (1984) Effects of parietal injury on covert orienting of attention *J. Neurosci.* 4, 1863–1874
25 Kinsbourne, M. and Warrington, E.K. (1962) A variety of reading disability associated with right hemisphere lesions *J. Neurol. Neurosurg. Psychiatry* 25, 339–344
26 Cheeman, J. and Merikle, P.M. (1986) Distinguishing conscious from unconscious perceptual processes *Can. J. Psychol.* 40, 343–367
27 Volpe, B.T. *et al.* (1979) Information processing of visual stimuli in an 'extinguished' field *Nature* 282, 722–724
28 Karnath, H.O. and Hartje, W. (1987) Residual information processing in the neglected half-field *J. Neurol.* 234, 180–184
29 Karnath, H.O. (1988) Deficits of attention in acute and recovered visual hemineglect *Neuropsychologia* 26, 27–43
30 Berti, A. *et al.* (1992) Levels of processing for visual stimuli in an 'extinguished' field *Neuropsychologia* 30, 403–415
31 Farah, M.J. *et al.* (1991) Unconscious perception of 'extinguished' visual stimuli: reassessing the evidence *Neuropsychologia* 29, 949–958
32 Verfaellie, M. *et al.* (1995) Comparison of cross-field matching and forced choice identification in hemispatial neglect *Neuropsychology* 9, 427–434
33 McGlinchey-Berroth, R. *et al.* (1990) Semantic processing in the neglected visual field: evidence from a lexical decision task, International Neuropsychological Society (Abstr.), Orlando, FL
34 McGlinchey-Berroth, R. *et al.* (1993) Semantic processing in the neglected visual field: evidence from a lexical decision task *Cognitive Neuropsychol.* 10, 79–108
35 Marcel, A.J. (1983) Conscious and unconscious perception: experiments on visual masking and word recognition *Cognitive Psychol.* 15, 197–237
36 Weiskrantz, L. (1985) *Blindsight: a Case Study and Implications,* Oxford University Press
37 Berti, A. and Rizzolatti, G. (1992) Visual processing without awareness: evidence from unilateral neglect *J. Cogn. Neurosci.* 4, 345–351
38 Potter, M.C. and Faulconer, B.A. (1975) Time to understand pictures and words *Nature* 253, 237–438
39 Ládavas, E. *et al.* (1993) Implicit associative priming in a patient with left visual neglect *Neuropsychologia* 32, 1307–1320
40 McGlinchey-Berroth, R. *et al.* (1996) Semantic processing and orthographic specificity in hemispatial neglect *J. Cogn. Neurosci.* 8, 291–304
41 Dagenbach, D. *et al.* (1990) Inhibitory semantic priming of lexical decisions due to failure to retrieve weakly activated codes *J. Exp. Psychol.* 16, 328–340
42 Cohen, A. *et al.* (1995) Activating response codes by stimuli in the neglected visual field *Neuropsychology* 9, 165–173
43 Fuentes, L.J. and Humphreys, G.W. (1996) On the processing of 'extinguished' stimuli in unilateral visual neglect: an approach using negative priming *Cognitive Neuropsychol.* 13, 111–136
44 Audet, T. *et al.* (1991) Visual neglect and left-sided context effects *Brain Cognit.* 16, 11–28