Published in final edited form as:

Cortex. 2008 October ; 44(9): 1215–1220. doi:10.1016/j.cortex.2006.02.002.

Dissociation between Egocentric and Allocentric Visuospatial and Tactile Neglect in Acute Stroke

Elisabeth B. Marsh¹ and Argye E. Hillis^{1,2,3}

¹Department of Neurology, The Johns Hopkins University School of Medicine

²Department of Physical Medicine and Rehabilitation, The Johns Hopkins University School of Medicine

³Department of Cognitive Science, The Johns Hopkins University School of Medicine

Abstract

Previous investigations provide evidence for distinction between egocentric (viewer-centered) and allocentric (stimulus- or object-centered) hemispatial neglect. However, it has not been determined whether this dissociation is modality-independent or modality-specific. We identify the incidence of egocentric and allocentric neglect in visual and tactile modalities, as well as the frequency of their co-occurrences in each modality.

One-hundred patients with acute, right supratentorial ischemic stroke were administered tests for egocentric and allocentric hemispatial neglect in visual ($n = 98$) and tactile ($n = 58$) modalities. The visual test consisted of a page of 30 circles; 10 with no gap, 10 with a gap on the right side, and 10 with a gap on the left. Patients were asked to circle all complete circles and cross out all circles with gaps. A tactile version consisted of the same stimulus types presented as raised circles. Patients were asked to explore the board of circles with their dominant hand and report whether each circle had a gap. To determine the presence of egocentric or allocentric neglect, each test was analyzed for a significantly higher number of errors on the contralesional versus ipsilesional side of the page/board, or of the stimulus, using the Chi square analysis.

On the visual test, 17 patients exhibited egocentric neglect; four exhibited allocentric neglect; and only two exhibited both. In the tactile modality, 19 exhibited egocentric neglect; one exhibited allocentric neglect; and none demonstrated both. Only four patients showed egocentric neglect on both visual and tactile tests. We found one patient with bilateral lesions who showed left egocentric visual neglect and right allocentric tactile neglect.

These data provide strong evidence that egocentric and allocentric neglect are distinct syndromes that often dissociate and likely reflect damage to different brain areas. They also show that selective egocentric or allocentric neglect can occur in visual or tactile modalities.

Keywords

Acute stroke; Cognitive impairment; Hemispatial neglect

It is widely agreed that hemispatial neglect is a heterogeneous disorder, although the categories of neglect remain a matter of controversy (Binder et al., 1992, Stone et al., 1998

and Vallar et al., 2003). Some authors have distinguished between intentional neglect or directional hypokinesia (impaired movements toward the contralesional side), and attentional neglect or visuospatial inattention (Heilman et al., 1985). Other investigators have distinguished between near versus far neglect, and personal versus extrapersonal neglect. Still others have identified dissociations between viewer-centered or egocentric neglect (errors on the contralesional side of the viewer), and stimulus-centered or allocentric neglect (errors on the contralesional side of individual stimuli irrespective of the side of the viewer).

Various tests have been developed to disentangle these forms of neglect. Ota et al. (2001) described an elegant test that distinguishes egocentric from allocentric neglect, in which the patient is presented with a page of circles or triangles, half of which have a gap on one side. Half of the gaps are on the left and half are on the right. The patient is instructed to circle all the complete stimuli and cross out any stimulus with a gap. Egocentric neglect is demonstrated by failure to mark (circle or cross out) the stimuli on the contralesional side of the paper; allocentric neglect is documented by failure to detect contralesional gaps (incorrectly circling stimuli with contralesional gaps, on both sides of the paper). These forms of neglect can also be distinguished in reading tests. Viewer-centered neglect is reflected by errors on the contralesional side of viewer, such as omissions of words on the left side of the paper. Stimulus-centered neglect is reflected by errors on the contralesional side of words (e.g., clover → mover) on both sides of the paper (Nichelli et al., 1993, Hillis and Caramazza, 1995, Hillis et al., 1998b and Haywood and Coltheart, 2000). Stimulus-centered neglect can also be distinguished from object-centered neglect (errors on the contralesional side of the canonical representation of the object) in reading. Patients with stimulus-centered neglect make errors on the contralesional side of the stimulus, such as errors on the initial letters in standard reading (the left side of the stimulus), but the final letters of the word (on the right side of the stimulus) when reading mirror-reversed or upside down print. In contrast, patients with left object-centered neglect make errors on initial letters of the words in both standard reading and when reading mirror-reversed or upside down print (Barbut and Gazzaniga, 1987, Hillis and Caramazza, 1990 and Warrington, 1991). The tests described by Ota et al. do not distinguish between stimulus- and object-centered neglect; but these two forms of neglect might both be considered allocentric.

Several authors have proposed that allocentric neglect is just a special form of egocentric neglect in which the attentional window is restricted to an individual stimulus (Driver and Pouget, 2000), or that either pattern of neglect can emerge depending on the task instructions (Baylis et al., 2004). Mozer (2002) and Pouget and Sejnowski (2001) have provided computational models of spatial attention that can simulate viewer-centered and stimulus-centered neglect without having distinct reference frames. However, these models and theories cannot account for object-centered neglect as we have defined it (errors restricted to the contralesional side of a canonical representation of the object, irrespective of its orientation relative to the viewer). Furthermore, they cannot easily account for patients who consistently show only allocentric or only egocentric neglect across a variety of tests, using the same instructions for all tests for patients with egocentric and patients with allocentric neglect (Hillis and Caramazza, 1995 and Hillis et al., 2005).

Although the dissociation between egocentric and allocentric neglect has generally been demonstrated in the visual modality, Moscovitch and Behrmann (1994) have described egocentric neglect in the tactile modality. They reported that patients with right parietal lesions showed left tactile extinction with double simultaneous stimulation (with “left” defined as the side of space relative to the midsagittal plane of the viewer), by extinguishing either the thumb side or the little finger side of the wrist, depending on whether the hand was turned up or down. Several authors have reported that tactile extinction of the left hand decreases when the left hand is moved to the right side of the midsagittal plane of the trunk, or that extinction of tactile stimulation to the right hand is observed when the right and left hands are crossed over the body (so that the right hand is in the left side of egocentric space) (e.g., Bartolomeo et al., 2004, Moro et al., 2004 and Valenza et al., 2004). Several studies have documented impaired tactile exploration in egocentric space in patients with visual neglect, in some cases showing a gradient of tactile neglect that increased further toward the left side (Beschin et al., 1996) and in other cases showing a shift of the normal pattern of exploration to the right (Karnath and Perenin, 1998 and Konczak et al., 1999). Others have reported the absence of tactile neglect in patients with egocentric visual neglect (Chokron et al., 2002). Regardless, the distinction between egocentric and allocentric neglect has not been extensively studied in the tactile modality.

This study was carried out to determine the incidence of egocentric versus allocentric neglect as assessed by a modified version of the test described by Ota et al. in visual and tactile modalities after acute stroke in the right hemisphere. In addition, we sought to determine the frequency with which these two forms of neglect dissociate in each modality, and to evaluate whether these forms of neglect are modality-specific or modality-independent. Patients were tested within 48 h of onset of stroke, to determine the incidence before recovery through reorganization and before rehabilitation. To validate our results, we first established the stability of these forms of neglect in acute stroke, as measured by the experimental tests.

1. Methods

1.1. Subjects

The population consisted of a consecutive series of 100 patients admitted to Johns Hopkins Hospital with acute, right hemisphere supratentorial ischemic stroke identified on diffusion-weighted MRI (DWI). Additional inclusion criteria included: the ability to complete testing within 48 h of symptom onset, the ability to give informed consent or to indicate a family member to do so, a premorbid proficiency in English, and age greater than 21 years. Patients were excluded from the study if they had acute stroke limited to the brainstem or cerebellum, a hemorrhage, required intubation and/or ongoing intravenous sedation impairing their level of consciousness, or were unable to get an MRI (e.g., due to pregnancy, severe claustrophobia, a cardiac pacemaker, or ferromagnetic implants). Two patients had an additional chronic left hemisphere lesion. Patients with old lesions were not excluded, given that the objective was to determine if the various types of hemispatial neglect are dissociable, and not to identify the specific brain regions responsible for each type. Mean age of the population was 61.3 years (range = 23–89 years) and mean level of education was

13 years (range = third grade to MD/graduate degree). There were 60 male and 40 female patients. The protocol received approval from the Johns Hopkins Institutional Review Board, and informed consent was obtained from all 100 patients prior to their participation in the study.

1.2. Neglect testing

Each of the 100 patients was administered several tests designed to detect hemispatial neglect within 48 h of onset. The experimental tests that were the focus of this study included a visual test and tactile test for distinguishing egocentric and allocentric neglect. The visual test was a gap detection test adapted from Ota et al. (2001). A page of 30 circles was placed in the patient's midline. Ten circles were complete circles; 10 had gaps on the right; and 10 had gaps on the left. Fifteen circles were on the right side of the page, and 15 were on the left. Patients were asked to circle all complete circles and cross out any circles with gaps. This test was identical to the test described by Ota et al., except that our test had 30 visual stimuli instead 60. Of the 100 patients, 98 were administered the visual test (two were not, because they did not have their glasses). Of the 100 patients, 58 with no identified hemianesthesia were also given a tactile version of this test, in which raised circles were arranged on a board in an identical layout and placed in the patient's midline. With their eyes closed, they were asked to move their hand over the board and determine whether the circles they felt were complete or had gaps in them. Thus, 56 patients had both the visual and tactile tests. Each test was administered twice for each modality; once with small stimuli (15 mm in diameter) and once with large stimuli (22 mm in diameter).

Other tests of neglect that were administered included: copying a scene of two trees, a house, and a fence (Ogden, 1985); copying a clock; modifications of the line cancellation test (Albert, 1973) and line bisection in which the page was presented 45 degrees to the left, and 45 degrees to the right, of the midsagittal plane, and at the midsagittal plane of the viewer (10–12 inches from the trunk); reading words and sentences; and spelling words and sentences to dictation.

1.3. Analysis

Cases of egocentric neglect, allocentric neglect, or both were identified in each modality. Egocentric neglect was defined as significantly more omissions of circles on the contralesional versus ipsilesional side of the page (by the Chi square analysis; $p < .05$). Allocentric neglect was defined as significantly more errors in determining whether a gap was present on the contralesional versus ipsilesional side of the circle (by the Chi square analysis; $p < .05$). A patient was found to have neglect for the modality if they demonstrated significantly more errors on the contralesional side for either the small or the large stimuli. We used this criterion of significantly more errors on the left than the right to avoid categorizing a patient as showing neglect if the majority of their errors occurred on the contralesional versus ipsilesional side simply by chance. So as not to overlook a deficit, a patient was also determined to have neglect if the difference between errors was statistically significant when the scores for the two tests in the same modality were combined.

Normative data for these tests were obtained from 42 hospitalized control subjects with no history of neurological or psychiatric disease who consented to cognitive testing and MRI before surgery. Control subjects were also excluded for history of somatosensory loss or uncorrected visual loss. None had evidence of stroke on MRI; mean age was 65.8 years (range = 47–81). None of these patients met our criteria for either type of neglect. On the visual test, the mean rate of omission of gaps was .4%. No individual missed more than one gap. No subject failed to mark any of the stimuli (mean omission of stimuli = 0%). On the tactile test, the mean rate of omission of gaps was .9%. Again, no individual failed to mark any of the stimuli. To summarize, individuals with no stroke rarely make errors on the tests used in this study and none exhibit a statistically significant difference in their performance with respect to the left versus right of the page or stimulus.

2. Results

2.1. Stability

When performance on the two visual tests (one with small circles and one with large circles) was compared, none of the patients varied between tests in the frame of reference for which they showed neglect. That is, no patient showed egocentric neglect on one test and allocentric neglect on the other test. There were also no patients who displayed contralesional neglect on one test and ipsilesional neglect on the other. In addition, 16 patients had repeat testing 2–3 days after the initial tests. No patient showed allocentric neglect on one date and egocentric neglect on the other date. All but four patients (25%) showed consistent performance (neglect or no neglect) on both administrations of the tests. The patients who showed a discrepancy each showed neglect on the first test and no neglect on the subsequent testing. This improvement may have been due to reperfusion of areas critical for neglect, or another cause of neurological improvement.

Similarly, in the tactile modality, all patients were consistent in the frame of reference for which they displayed neglect across the two tactile tests (one with small and one with large circles). Also, none of the patients showed contralesional neglect on one test and ipsilesional neglect on the other. Of the 11 patients who had repeat tactile tests 2–3 days after the first test, no patient showed egocentric neglect on one date and allocentric neglect on the other date of administration. All but four patients (36%) showed consistent performance (neglect versus no neglect) on the two dates. Again, the patients who showed a discrepancy each showed recovery, possibly due to reperfusion of areas critical for neglect.

2.2. Incidence of allocentric versus egocentric neglect detected after right hemisphere stroke

Of the 98 patients who were administered the visual test, 17 (17%) met our criteria for egocentric neglect, while four (4%) met our criteria for allocentric neglect in the visual modality. Of the 58 patients who were administered the tactile test, 19 (33%) met our criteria for egocentric neglect, while one (2%) met our criteria for allocentric neglect in the tactile modality.

Thus, the visual test detected neglect in 19 of 98 patients (19%), and the tactile test detected neglect in 20 of 58 patients (34%). In the 100 patients, other tests of neglect administered detected neglect in 12–30% of patients who completed the tests.

2.3. Dissociation between egocentric and allocentric neglect

In the visual modality, only two patients (2% of all patients tested; 10.5% of patients with visual neglect) showed both egocentric and allocentric neglect (see Fig. 1). In the tactile modality, none of the 58 patients (20 with tactile neglect) demonstrated both egocentric and allocentric neglect.

2.4. Dissociation between visual and tactile neglect in each reference frame

Of the 56 patients who were administered both visual and tactile tests, only four (7%) showed egocentric neglect on both the visual and tactile tests. No patients had allocentric neglect in both modalities. One patient with an acute right hemisphere lesion and an old left hemisphere infarct on MRI seemed to display left egocentric visual neglect and right allocentric tactile neglect (see Fig. 2).

3. Discussion

Results of this study provide further evidence that egocentric and allocentric neglect are distinct impairments that frequently dissociate after brain damage. Purely egocentric neglect was most common, followed by purely allocentric neglect; the co-occurrence of egocentric and allocentric neglect was least common. Similar results were reported in a study of patients with acute right subcortical infarct in whom neglect was associated with distinct regions of cortical hypoperfusion on perfusion-weighted imaging (PWI) (Hillis et al., 2005) and in smaller studies of chronic stroke patients (Chatterjee, 1994 and Hillis and Rapp, 1998). The fact that these forms of hemispatial neglect occur independently of one another indicates that they likely reflect damage to different areas of the brain. This study was not designed to evaluate the areas of brain damage or dysfunction that were responsible for neglect, since not all of the patients had imaging that would reveal areas of low blood flow that may have contributed to the deficit (demonstrable only with PWI). That is, recent studies have shown that neglect in acute stroke can be caused by specific areas of hypoperfusion revealed by magnetic resonance perfusion imaging that are not visible on structural MRI (Hillis et al., 2002 and Hillis et al., 2005). However, since patients were consistent across tests in terms of the frame of reference in which they displayed neglect, and since performance on the gap detection tests used here appears to be a reliable way to test for these forms of hemispatial neglect, future studies will evaluate associations between the type of neglect shown on these tests and the various areas of tissue damage or dysfunction. That is, we plan to extend this study to additional patients who have both structural and perfusion MRI to identify the areas of infarct and/or hypoperfusion associated with each type in each modality.

Our results also confirm that hemispatial neglect can be modality-specific, restricted to either the visual or tactile modality (see also Villardita, 1987, Umiltà, 1995 and Chokron et al., 2002). Moreover, we demonstrated that egocentric and allocentric neglect are

demonstrable in the tactile, as well as the visual, modality. This finding suggests that there may be areas of the brain critical for computation of modality-specific spatial representations in a particular frame of reference. Motor neglect (failure to use a contralesional limb even in the absence of weakness or apraxia) also occurs independently of visual neglect (Hillis et al., 1998a and Appelros et al., 2003). However, since egocentric neglect sometimes occurred in both visual and tactile modalities in this study and previous studies (Weintraub and Mesulam, 1987 and Gentilini et al., 1989), it is likely that some brain regions are responsible for computing modality-independent, viewer-centered spatial maps for directing movements in space. This hypothesis is consistent with evidence from electrophysiological studies in primates revealing modality-independent spatial representations defined by various viewer-centered coordinates for guiding goal directed behavior, located in posterior parietal cortex (Andersen and Buneo, 2002 and Andersen and Buneo, 2003).

The incidence of these forms of neglect, as detected by the tests we used, may well underestimate the true incidence of neglect after right hemisphere stroke. The reported incidence depends on the sensitivity of the tests used to identify it. The sensitivity of our tests compared to other tests was not evaluated. The sensitivity of other tests for hemispatial neglect is quite variable, with ranges reported to be 37–100% (Halligan et al., 1989), 19–51% (Azouvi et al., 2002), and 13–82% (Bowen et al., 1999). The majority of studies have indicated that the most sensitive tests require searching for a specific target among other similar targets and that multiple tests are more sensitive than a single test (Azouvi et al., 2002 and Halligan et al., 1991). However, the latter finding may simply indicate that different tests identify patients with different forms of neglect, so that using them in combination identifies all the patients with the various forms. Alternatively, neglect may reflect a combination of deficits; and various tests are differentially sensitive to the distinct deficits. For example, Corbetta et al. (2000) argue that neglect results from a combination of a bias in spatial attention to the ipsilesional side and nonspatial attentional deficits in vigilance and reorienting attention to unattended locations. Danckert and Ferber (2006) (see also Malhotra et al., 2004 and Milner and McIntosh, 2005) argue that neglect results from a combination of impairments in spatial working memory, attentional orienting, and exploratory behavior.

Impaired spatial working memory, even on the ipsilesional side, has been well-documented in patients with neglect (Ferber and Danckert, 2006, Wojciulik et al., 2001, Husain et al., 2001, Malhotra et al., 2004 and Malhotra et al., 2005), and may have contributed to impaired performance, particularly on the tactile neglect test. For example, Wojciulik et al. reported that neglect errors were more frequent in cancellation tasks with invisible marks than in similar tasks with visible marks. In both tasks, but particularly in those with invisible marks, patients repeatedly marked the same items on the ipsilesional side, consistent with the hypothesis that deficient spatial working memory contributed to impaired performance in cancellation deficits. Likewise, in our tactile neglect test, patients verbally reported when they touched targets (and whether or not there was a gap in the circle), so there was no evidence that they had already identified the target. Many patients did touch the same ipsilesional targets several times, indicating that impaired spatial working memory may have contributed to their egocentric neglect on this task. However, it is less clear how spatial

working memory would contribute to reporting whether or not there was a gap in circle (on the left or right side of the board).

In summary, these data provide evidence that right hemisphere ischemic stroke frequently results in egocentric neglect in the visual and/or tactile modalities, and less frequently results in allocentric neglect in the visual and/or tactile modalities. Within individual patients, the form of neglect is quite stable across tests of the same input modality, but is often detected in only one modality.

Acknowledgements

The research reported in this article was supported by a Student Scholarship in Cardiovascular Disease and Stroke from the American Heart Association to EBM, as well as by an NINDS grant (ROI NS047691) to AH. The authors gratefully acknowledge their support.

References

- Albert ML. A simple test of visual neglect. *Neurology*. 1973; 23:658–664. [PubMed: 4736313]
- Andersen RA, Buneo CA. Intentional maps in posterior parietal cortex. *Annual Review of Neuroscience*. 2002; 25:189–220.
- Andersen, RA.; Buneo, CA. Sensorimotor integration in posterior parietal cortex. In: Siegel, AM.; Andersen, RA.; Freund, H-J.; Spencer, DD., editors. *The Parietal Lobes, Advances in Neurology*. Vol. 93. London: Lippincott Williams & Wilkins; 2003. p. 159-177.
- Appelros P, Nydevik I, Karlsson GM, Thorwalls A, Seiger A. Assessing unilateral neglect: shortcomings of standard test methods. *Disability and Rehabilitation*. 2003; 25:473–479. [PubMed: 12745942]
- Azouvi P, Samuel C, Louis-Dreyfus A, Bernati T, Bartolomeo P, Beis JM, et al. Sensitivity of clinical and behavioural tests of spatial neglect after right hemisphere stroke. *Journal of Neurology, Neurosurgery and Psychiatry*. 2002; 73:160–166.
- Barbut D, Gazzaniga M. Disturbances in conceptual space involving language and speech. *Brain*. 1987; 110:1487–1496. [PubMed: 3427398]
- Bartolomeo P, Perri R, Gainotti G. The influence of limb crossing on left tactile extinction. *Journal of Neurology, Neurosurgery and Psychiatry*. 2004; 75:49–55.
- Baylis GC, Baylis LL, Gore CL. Visual neglect can be object-based or scene-based depending on task representation. *Cortex*. 2004; 40:237–246. [PubMed: 15156782]
- Beschin N, Cazzani M, Cubelli R, Della Sala S, Spinazzola L. Ignoring left and far: an investigation of tactile neglect. *Neuropsychologia*. 1996; 34:41–49. [PubMed: 8852692]
- Binder J, Marshall R, Lazar R, Benjamin J, Mohr JP. Distinct syndromes of hemineglect. *Archives of Neurology*. 1992; 49:1187–1194. [PubMed: 1444886]
- Bowen A, McKenna K, Tallis RC. Reasons for the variability in the reported rate of occurrence of unilateral neglect after stroke. *Stroke*. 1999; 30:1196–1202. [PubMed: 10356099]
- Chatterjee A. Picturing unilateral spatial neglect: viewer versus object-centred reference frames. *Journal of Neurology, Neurosurgery, and Psychiatry*. 1994; 57:1236–1240.
- Chokron S, Colliot P, Bartolomeo P, Rhein F, Eusop E, Vassel P, et al. Visual, proprioceptive and tactile performance in left neglect patients. *Neuropsychologia*. 2002; 40:1965–1976. [PubMed: 12207994]
- Corbetta M, Kincade JM, Ollinger JM, McAvoy MP, Shulman GL. Voluntary orienting is dissociated from target detection in human posterior parietal cortex. *Nature Neuroscience*. 2000; 3:292–297.
- Danckert J, Ferber S. Lost in space—the fate of memory representations for non-neglected stimuli. *Neuropsychologia*. 2006; 44:320–325. [PubMed: 15946711]
- Driver J, Pouget A. Object-centered visual neglect, or relative egocentric neglect? *Journal of Cognitive Neuroscience*. 2000; 12:542–545. [PubMed: 10931777]

- Ferber S, Danckert J. Lost in space – the fate of memory representations for non-neglected stimuli. *Neuropsychologia*. 2006; 44:320–325. [PubMed: 15946711]
- Gentilini M, Barbieri C, De Renzi E, Faglioni P. Space exploration with and without the aid of vision in hemisphere-damaged patients. *Cortex*. 1989; 25:643–651. [PubMed: 2612181]
- Halligan PW, Cockburn J, Wilson B. The behavioural assessment of visual neglect. *Neuropsychological Rehabilitation*. 1991; 1:5–32.
- Halligan PW, Marshall JC, Wade DT. Visuospatial neglect: underlying factors and test sensitivity. *Lancet*. 1989; 2:908–911. [PubMed: 2571823]
- Haywood M, Coltheart M. Neglect dyslexia and the early stages of visual word recognition. *Neurocase*. 2000; 6:33–44.
- Heilman KM, Bowers D, Coslett HB, Whelan H, Watson RT. Directional hypokinesia: prolonged reaction times for leftward movements in patients with right hemisphere lesions and neglect. *Neurology*. 1985; 35:855–859. [PubMed: 4000486]
- Hillis AE, Caramazza A. The effects of attentional deficits on reading and spelling. In: Caramazza, A., editor. *Cognitive Neuropsychology and Neurolinguistics: Advances in Models of Cognitive Function and Impairment*. London: Lawrence Erlbaum Associates; 1990. p. 211–275.
- Hillis AE, Caramazza A. A framework for interpreting distinct patterns of hemispatial neglect. *Neurocase*. 1995; 1:189–207.
- Hillis AE, Newhart M, Heidler J, Barker PB, Herskovits EH, Degaonkar M. Anatomy of spatial attention: insights from perfusion imaging and hemispatial neglect in acute stroke. *Journal of Neuroscience*. 2005; 25:3161–3167. [PubMed: 15788773]
- Hillis AE, Lenz FA, Zihl TA, Dougherty PM, Eckel TS, Jackson K. Hemispatial somatosensory and motor extinction after stereotactic thalamic lesions. *Neurocase*. 1998; 4:21–34.
- Hillis AE, Rapp BC. Unilateral spatial neglect in dissociable reference frames: a comment on Farah, Brunn, Wallace, Wong, & Carpenter (1990). *Neuropsychologia*. 1998; 36:1257–1262. [PubMed: 9842770]
- Hillis AE, Rapp B, Benzing L, Caramazza A. Dissociable coordinate frames of unilateral spatial neglect: viewer-centered neglect. *Brain and Cognition*. 1998; 37:491–526. [PubMed: 9733562]
- Hillis AE, Wityk RJ, Barker PB, Beauchamp NJ, Gailloud P, Murphy K, et al. Subcortical aphasia and neglect in acute stroke: the role of cortical hypoperfusion. *Brain*. 2002; 125:1094–1104. [PubMed: 11960898]
- Husain M, Mannan S, Hodgson T, Wojciulik E, Driver J, Kennard C. Impaired spatial working memory across saccades contributes to abnormal search in parietal neglect. *Brain*. 2001; 124:941–952. [PubMed: 11335696]
- Karnath HO, Perenin MT. Tactile exploration of peripersonal space in patients with neglect. *Neuroreport*. 1998; 9:2273–2277. [PubMed: 9694214]
- Konczak J, Himmelbach M, Perenin MT, Karnath HO. Do patients with neglect show abnormal hand velocity profiles during tactile exploration of peripersonal space? *Experimental Brain Research*. 1999; 128:219–223. [PubMed: 10473763]
- Malhotra P, Jager HR, Parton A, Greenwood R, Playford ED, Brown MM, et al. Spatial working memory capacity in unilateral neglect. *Brain*. 2005; 128:424–435. [PubMed: 15644422]
- Malhotra P, Mannan S, Driver J, Husain M. Impaired spatial working memory: one component of the visual neglect syndrome? *Cortex*. 2004; 40:667–676. [PubMed: 15505977]
- Milner AD, McIntosh RD. The neurological basis of visual neglect. *Current Opinion in Neurology*. 2005; 18:748–753. [PubMed: 16280689]
- Moro V, Zampini M, Aglioti SM. Changes in spatial position of hands modify tactile extinction but not disownership of contralesional hand in two right brain-damaged patients. *Neurocase*. 2004; 10:437–443. [PubMed: 15788283]
- Moscovitch M, Behrmann M. Coding of spatial information in the somatosensory system: evidence from patients with neglect following parietal lobe damage. *Journal of Cognitive Neuroscience*. 1994; 6:151–155. [PubMed: 23962367]
- Moser MC. Frames of reference in unilateral neglect and visual perception: a computational perspective. *Psychological Review*. 2002; 109:156–185. [PubMed: 11863036]

- Nichelli P, Venneri A, Pentore R, Cubelli R. Horizontal and vertical neglect dyslexia. *Brain and Language*. 1993; 44:264–283. [PubMed: 8513404]
- Ogden J. Contralesional neglect of constructed visual images in right and left brain-damaged patients. *Neuropsychologia*. 1985; 23:273–277. [PubMed: 4000463]
- Ota H, Fujii T, Suzuki K, Fukatsu R, Yamadori A. Dissociation of body-centered and stimulus-centered representations in unilateral neglect. *Neurology*. 2001; 57:2064–2069. [PubMed: 11739827]
- Pouget A, Sejnowski TJ. Simulating a lesion in a basis function model of spatial representations: comparison with hemineglect. *Psychological Review*. 2001; 108:653–673. [PubMed: 11488381]
- Stone SP, Halligan PW, Marshall JC, Greenwood RJ. Unilateral neglect: a common but heterogeneous syndrome. *Neurology*. 1998; 50:1902–1905. [PubMed: 9633758]
- Umiltà C. Domain-specific forms of neglect. *Journal of Clinical and Experimental Neuropsychology*. 1995; 17:209–219.
- Valenza N, Seghier ML, Schwartz S, Lazeyras F, Vuilleumier P. Tactile awareness and limb position in neglect: functional magnetic resonance imaging. *Annals of Neurology*. 2004; 55:139–143. [PubMed: 14705125]
- Vallar, G.; Bottini, G.; Paulesu, E. Neglect syndromes: the role of the parietal cortex. In: Siegel, AM.; Andersen, RA.; Freund, H-J.; Spencer, DD., editors. *The Parietal Lobes*, *Advances in Neurology*. Vol. 93. London: Lippincott Williams & Wilkins; 2003. p. 219-315.
- Villardita C. Tactile exploration of space and visual neglect in brain-damaged patients. *Journal of Neurology*. 1987; 234:292–297. [PubMed: 3612201]
- Warrington EK. Right neglect dyslexia: a single case study. *Cognitive Neuropsychology*. 1991; 8:191–212.
- Weintraub S, Mesulam MM. Right cerebral dominance in spatial attention. Further evidence based on ipsilateral neglect. *Archives of Neurology*. 1987; 44:621–625. [PubMed: 3579679]
- Wojciulik E, Husain M, Clarke K, Driver J. Spatial working memory deficit in unilateral neglect. *Neuropsychologia*. 2001; 39:390–396. [PubMed: 11164877]

Fig. 1.

Only two patients displayed both egocentric and allocentric visual neglect and there were no overlaps seen in the tactile modality. Only four patients exhibited egocentric neglect on both the visual and tactile tests.

Visual: Missed 4/15 stimuli on left of viewer; 0/15 stimuli on right of viewer ($\chi^2=4.6$; $p=.03$)

(Missed no left or right gaps in stimuli that were detected)

Tactile: Missed 7/18 right gaps; 2/19 left gaps among stimuli that were detected in 2 trials ($\chi^2=4.0$; $p<.05$)

(Missed 3/30 stimuli on left, 2/30 stimuli on right)

Fig. 2.

One patient with bilateral lesions showed left egocentric visual neglect, but right allocentric tactile neglect. The yellow dots highlight errors. In the visual task, he omitted stimuli only on the left (left egocentric neglect), but made no errors in gap detection. In the tactile task, he failed to detect gaps predominantly on the right sides of circles but on both sides of the page.