Visual Neglect

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Visual neglect is a common neurological syndrome in which patients fail to acknowledge stimuli towards the side of space opposite to their unilateral lesion. This disability affects many aspects of their life. For example, after a right lesion, patients typically fail to eat the food located on the left side of their plate, or to shave or make-up the left side of their face, and, in extreme cases, may no longer acknowledge the left side of their body as their own. In a common clinical test known as line cancelation, they fail to mark lines towards the left of the page (see figure 1-A) despite often being able to detect isolated lines presented in their left visual field, demonstrating that they are not simply blind on that side.

This syndrome is observed primarily after unilateral lesions to the parieto-occipital junction, especially in the right-hemisphere (Heilman *et al.* , 1985; Bisiach, 1996). Lesions to the right frontal cortex, and to various subcortical sites can also trigger neglect-like symptoms, although with subtle differences from parietal neglect (Heilman *et al.* , 1985; Guariglia *et al.* , 1993). Here we concentrate on parietal neglect, as it is the most common form, and can be related to recent data on the parietal lobe from non-human primates.

Theories of neglect. Two major accounts have been proposed for neglect. Some theories posit a deficit in directing attention towards contralesional events (Posner *et al.* , 1984; Kinsbourne, 1987) (see ATTENTION and ATTENTION IN THE HUMAN BRAIN). For instance, right parietal patients– who suffer from left neglect– tend to have particular difficulty in detecting stimuli in the left hemifield if their attention has previously been drawn to the right side(Posner *et al.* , 1984). By contrast, many "preattentive" aspects of vision appear to be spared on the affected side (Driver *et al.* , 1992; McGlinchey-Berroth *et al.* , 1996; Mattingley *et al.* , 1997).

Other accounts argue that the patient's lesion simply disrupts the neuronal coding of contralesional space, at relatively high levels of representation (Bisiach & Luzzatti, 1978; Bisiach *et al.* , 1979; Rizzolatti & Berti, 1990; Halligan & Marshall, 1991; Karnath *et al.* , 1991). This perspective has drawn support from the finding that even mental imagery can be impaired in some left-neglect patients (Bisiach & Luzzatti, 1978)(see IMAGERY), such that they fail to report what would appear on their left when retrieving from memory the view of a familiar visual scene.

The dichotomy between attentional and representational accounts has recently been challenged by several authors using neural network models in which attentional and representational functions are interwoven (Mozer & Behrmann, 1990; Cohen *et al.* , 1994; Pouget & Sejnowski, 1997a). This work suggests a compromise view, whereby neglect results from damage to cortical areas that are located at the interface between sensory and motor systems, and which are responsible for both, the representation of the position of objects and the selective control of spatial action, that is to say, 'attention'.

Frames of reference. In principle, "left" neglect might refer to the left of the visual field, or the left of the head, or the trunk, or even of the surrounding environment. To determine the frame of reference for hemineglect, one can test patients in various postures, so that a stimulus location changes in one frame of reference while remaining constant in the others. For instance, one might test a patient looking straight ahead versus with the gaze deviated 20 degrees to the right, while keeping all stimuli at the same position with respect to the retina. If neglect were purely retinotopic, these conditions should not differ, whereas if it were head- or body-centered, performance should change accordingly. Such experiments have typically revealed that neglect affects a mixture of frames of reference concurrently, rather than just one single frame. Thus, the probability that a patient will neglect a particular visual stimulus is typically a function of its position in various egocentric frames of reference, such as eye-, head- or trunk-centered, as well as showing influences from cues in the environment, e.g. as regards the gravitational upright (Bisiach *et al.* , 1985; Ladavas, 1987; Ladavas *et al.* , 1989; Calvanio *et al.* , 1987; Farah *et al.* , 1990; Karnath *et al.* , 1991; Behrmann & Moscovitch, 1994).

Object-centered neglect. A few experiments suggest that visual neglect can also be "object-centered", i.e., patients tend to neglect the left side of an object regardless of its position and/or orientation (Driver *et al.* , 1994; Tipper & Behrmann, 1996). For example, Driver *et al.* (1994) devised a situation in which left neglect patients could detect a gap in part of a triangle when this gap was perceived to be on the right side of object, but missed the same gap when it was seen as belonging to the left side, even though it still fell at the same location relative to the patient (figure 1-B). Such results seem consistent with the existence of object-centered representations in the parietal cortex.

Many other studies claim to have found evidence for object-centered neglect (Driver & Halligan, 1991; Arguin & Bub, 1993; Halligan & Marshall, 1994) but as pointed out by Driver *et al.* (1994), their results could be explained instead by what we will call *relative* neglect in strictly egocentric coordinates (see also Kinsbourne, 1987, Mozer and Behrmann, 1990, Desimone and Duncan, 1995, and Pouget and Sejnowski, 1997a for variations on this idea). When confronted with two competing objects, patients may neglect the one further to the left even if both fall in right hemispace egocentrically, likewise for the subparts of a single object (Driver & Halligan, 1991; Driver *et al.* , 1992; Driver *et al.* , 1994; Halligan & Marshall, 1994). Thus, it appears that the *relative* position of objects or their subparts, is just as important as their *absolute* position with respect to the patient. This phenomenon can be explained if the lesion induces a *gradient* of neglect with increasing severity in the egocentric contralesional direction (Kinsbourne, 1987; Driver *et al.* , 1994; Pouget & Sejnowski, 1997a).

Neural basis. There have been several attempts to relate neglect to what is known of the response properties of parietal neurons from single-cell recordings in monkeys (Mozer & Behrmann, 1990; Duhamel *et al.* , 1992; Anderson, 1996; Mozer *et al.* , 1997; Pouget & Sejnowski, 1997a) (See also MODELING NEUROPSYCHOLOGICAL DEFICITS and SPATIAL PERCEPTION). Such models generally rely on cells in the parietal cortex having retinotopic receptive fields, with each hemisphere tending to overrepresent the contralateral visual field (see, however, Duhamel *et al.* 1992, for a different approach). Consequently, a right lesion leads to a neuronal gradient in which the left side of retina is less strongly represented than the right side, producing left neglect. In such models, there is no particular dividing midline such that any stimulus to the left of it is invariably neglected. Instead, neglect depends only on the *relative* position of competing stimuli, as discussed above, with objects or object-parts that are further towards the retinal left than their competitors being neglected. These models readily capture the behavior of patients in tasks such as line bisection, line cancellation, and in some of the paradigms discussed above that have revealed relative neglect.

Parietal neurons, however, do not simply respond to visual stimulation, but also integrate sensory responses with posture signals such as eye and head position. Andersen and colleagues have shown that the retinotopic receptive fields of parietal cells are *gain modulated* by such posture signals (Andersen *et al.* , 1985; Andersen *et al.* , 1997) (see figure 1-C for an example in which the visual receptive field of a cell is modulated by eye position). These response properties can be modeled as *basis functions* of the inputs, a type of function which is particularly well-suited for the computational demand of sensori-motor transformations (Pouget & Sejnowski, 1997b).

A simulated unilateral lesion in such a basis-function representation produces an impairment which resembles clinical neglect, in that the deficit affects a mixture of egocentric frames of reference as found in patients (Pouget & Sejnowski, 1997a). This approach can also be generalized to encompass object-centered neglect, as in the Driver *et al.* (1994) experiment depicted in figure 1-B, by considering the perceived orientation of the object as providing a signal analogous to the posture signals integrated by the basis functions (Deneve & Pouget, In press). This basis-function framework can explain why neglect may be influenced by stimulus position relative to the retina, head, body, to other objects, and other parts of the same object, all at the same time, without requiring cells in the parietal cortex to have visual receptive fields explicitly defined in any single one of these frames of reference.

Neglect remains a fascinating but disabling disorder, which still poses a major challenge to rehabilitation. Its further study will hopefully lead to more effective treatments, as well as revealing more about how the brain represents space, and allows for selective spatial attention.

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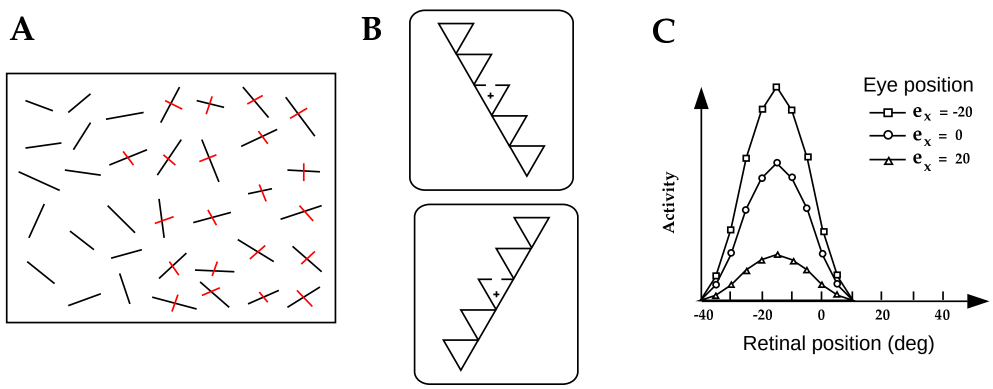
Figure Caption

Figure 1: A. Left items neglected in a cancellation task. B. Visual displays from the Driver *et al.* (1994) experiment. The cross indicates the fixation point. Left-neglect patients performed better for the bottom configuration than the top one, even though the gap to be detected was at the same retinal location. This pattern is consistent with left object-centered neglect. C. Visual receptive field of a typical monkey parietal neuron, for three different eye positions. The retinotopic position of the receptive field is invariant across eye positions but the gain of the response changes. Adapted from Andersen *et al.* 1985


A
B
C
Eye position
e_x = -20
e_x = 0
e_x = 20
Activity
-40
-20
0
20
40
Retinal position (deg)