A temporal/nasal asymmetry for blindsight in a localisation task: evidence for extrageniculate mediation

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Some patients with hemianopia due to striate cortex lesions show above chance ability in reporting visual stimuli presented in the blind visual field, a phenomenon commonly known as blindsight. Here we report a patient with a dense right hemianopia whose blindsight shows a temporal/nasal asymmetry. MP was tested in a two-alternative forced-choice localisation task, with either the right eye or the left eye patched in separate blocks. When targets appeared in the contralesional temporal hemifield, MP's localisation performance was extremely accurate, whilst she performed at chance with targets in the contralesional nasal hemifield. This is the first demonstration of a temporal/nasal asymmetry for blindsight in a forced-choice paradigm, and is consistent with blindsight in MP's hemianopic field being mediated by a subcortical, extrageniculate route. *NeuroReport* 13:655–658 © 2002 Lippincott Williams & Wilkins.

Key words: Blindsight; Extrageniculate; Forced-choice; Hemianopic

INTRODUCTION

Unilateral damage to the geniculostriate visual pathway causes cortical blindness in the contralesional half of the visual field (hemianopia). However, in forced-choice testing some hemianopic patients show preserved responses to visual stimuli presented in the contralesional hemifield [1]. These residual visual capacities have been called blindsight, reflecting the paradoxical nature of the apparent dissociation between functional visual processing and subjective visual experience.

One account for blindsight postulates that it is mediated by degraded cortical processing near perceptual threshold. The apparent lack of awareness as assessed by conventional perimetery used to determine the boundary of a scotoma could reflect the patient's use of a conservative response criterion, leading to an underestimation of their level of visual awareness [2]. According to this hypothesis, the subsequent above chance responding in forced-choice testing provides a more accurate measure of visual awareness, due to the fact that the patient no longer needs to set a threshold for a positive response.

One such account postulates that intact portions of striate cortex (V1) mediate the preserved visual responses of patients with blindsight. Detailed, stabilised mapping of the blind fields of several hemianopic patients revealed islands of residual vision, which imply the existence of corresponding islands of spared primary visual cortex [3]. These islands could be capable of mediating visual responses to stimuli that are close to the perceptual threshold.

A second hypothesis proposes that preserved visual processing in the hemianopic field depends on a direct projection from the lateral geniculate nucleus to extrastriate cortex [4]. In the macaque monkey, many visual abilities which are spared after the complete removal of striate cortex are substantially impaired after the additional removal of extrastriate cortex [5,6]. In hemianopic patients, fMRI studies revealed sustained neural activity in extrastriate cortical areas in the absence of visual awareness [7].

Another possible neural basis of visual processing in the hemianopic field is the extrageniculostriate visual pathway, which projects from the retina to the superior colliculus and the pulvinar, and then to extrastriate cortex. Rafal *et al.* [8] provided support for the extrageniculostriate hypothesis. They showed that, in three hemianopic patients, a distracter in the contralesional temporal hemifield increased the latency of a saccade to a target in the ipsilesional hemifield, whilst a distracter in the contralesional nasal hemifield had no effect on saccade latency. This temporal/nasal asymmetry is consistent with the anatomical asymmetry of the extrageniculate visual system. In monkeys [9] and cats [10], the extrageniculate pathway contains more fibres from the nasal hemiretina (corresponding to the temporal hemifield) than from the temporal hemiretina (corresponding to the nasal hemifield). In humans, the behavioural evidence points to a similar anatomy: humans show a bias to orient toward signals in the temporal hemifield, an effect which occurs in newborns [11], whose vision depends on the extrageniculate visual system, and adults, under bilateral stimulation [12]. Thus, the asymmetrical distracter effect may reflect more processing of stimuli in the temporal hemifield by the extrageniculate visual system.

However, the asymmetry of the retinotectal projection has been questioned; a study on macaque monkeys found no difference between the ratio of fibres in the contralateral nasal retina and the ipsilateral temporal retina and the ratio found in the optic nerve [13]. Additionally, a subsequent study failed to replicate the oculomotor distractor effect in hemianopic patients [14]. Walker *et al.* found a temporal/nasal asymmetry for the distractor effect in normal subjects, but no distractor effect in eight hemianopic patients.

In this study we present data from a hemianopic patient, MP, who shows a similar temporal/nasal asymmetry, but in a forced-choice paradigm. Tangent screen testing, conducted with a laser pointer used to present static and moving stimuli, revealed a dense right hemianopia, with $< 1^\circ$ of macular sparing along the horizontal meridian. However, in a forced-choice localisation task with targets in the right temporal hemifield, MP's performance was extremely accurate. In contrast, performance with targets in the right nasal hemifield was at the level of chance. This temporal/nasal asymmetry in performance suggests that blindsight in the hemianopic field can be mediated by a subcortical, extrageniculostriate projection.

MATERIALS AND METHODS

Subject: MP, a 63-year-old female, had a homonymous right hemianopia resulting from a stroke in the posterior cerebral artery territory, in August, 1999, that involved the left occipital region including all of striate cortex, and the splenium of the corpus callosum. Additional deficits included alexia without agraphia, verbal memory problems and colour anomia.

Apparatus: An IBM-compatible personal computer connected to a NEC Multisync Video Array (VGA) monitor was used to present the stimulus display. An Applied Science Laboratories (Bedford, MA, USA) Eye-Trac 210 was used to monitor eye position. An Averkey device split the output from the PC so that the signal to the video display was sent both to the monitor viewed by the subject and, through the Eye-Trac device, to a scope viewed by the experimenter upon which crosshairs indicating eye position were superimposed.

Procedure: Testing was conducted in a dimly lit room. MP sat in a high-backed chair to ensure that head position remained constant, by eliminating any back movement. She sat with her eyes at a distance of 28.5 cm from the screen; at this distance the stimuli could not fall in the patient's blind spot.

All of the stimuli were black on a white background. At the start of each trial, a 1° cross appeared at the centre of the screen. After a random period of fixation (500–1000 ms), the cross disappeared and, simultaneously, a 2° target dot appeared for 1000 ms either 10° (near location) or 20° (far location) to the right of fixation. Targets always appeared to the right of fixation, in the patient's blind visual field.

MP was instructed to maintain fixation on the central fixation cross, and to report the location (near or far) of the target after the offset of the fixation point, guessing in the absence of any awareness. After each trial, the experimenter made a key press to indicate whether a near or far response had been made. Eye position was monitored throughout testing. Trials in which gaze deviated from fixation were discarded.

MP completed two blocks of trials; one block with a patch covering the left eye, so that targets appeared in the temporal hemifield of the right eye (corresponding to the nasal hemiretina), and one block with a patch covering the right eye, so that targets appeared in the nasal hemifield of the left eye (corresponding to the temporal hemiretina). There were 320 trials in each block, with 140 near target trials, 140 far target trials, and 40 no target trials. After each block of forced-choice testing, MP was asked whether she had experienced any awareness of the stimuli presented in her blind visual field.

RESULTS

Subjective report: When questioned about her subjective visual experience of the targets in her blind visual field, MP reported actually seeing 'something… a blob' when targets were presented in the temporal hemifield in the near location, and sometimes in the far location. She stated that she employed a response strategy of making a near response when she definitely saw the target, and a far response when she did not see the target as clearly. This strategy is reflected in MP's responses to target absent trials in the temporal hemifield block; she shows a strong bias to respond far when no target was present, indicating that she had not seen the target.

In contrast, MP reported no visual awareness of targets in the nasal hemifield in either the near or far location. She claimed that her responses were entirely the result of guesswork, and initially appeared confused by being asked to report the locations of stimuli that she could not see. Again, MP's subjective visual experience is reflected in her responses to target absent trials in the nasal hemifield block, with an approximately equal distribution of near and far responses.

Forced-choice localisation task: The results of the forced-choice localisation task are displayed in Fig. 1. In the temporal hemifield condition, MP made a higher percentage of correct responses than incorrect responses to both near and far targets. X^2 analysis confirmed that MP's localisation performance was above chance for targets in the temporal hemifield near location (X^2 $(n = 138) = 126$, $p < 0.001$) and for targets in the temporal hemifield far location (X^2 $(n = 140) = 113$, $p < 0.001$). In target absent trials in the temporal hemifield block, MP made a higher percentage of far responses than near responses (X^2 $(n = 40) = 28.90$, $p < 0.001$), revealing a bias to respond 'far', which is consistent with her subjective report strategy.

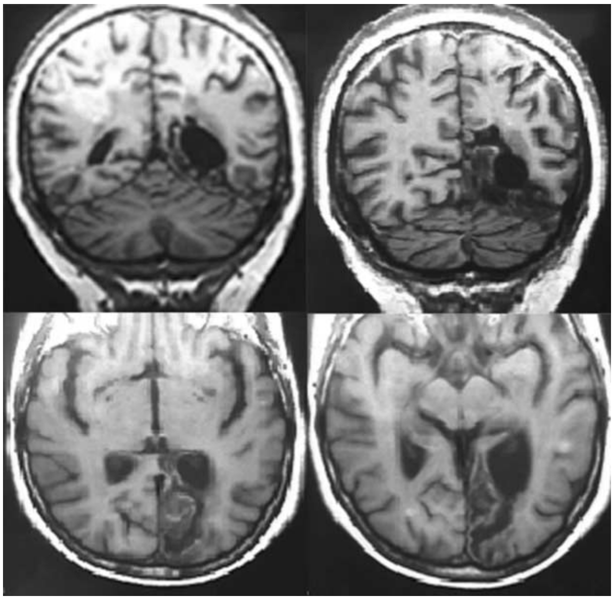

Fig. 1. Neuroimage of 63-year-old patient MP. Coronal and axial MRI scans show the complete destruction of all of primary visual cortex (V1).

In the nasal hemifield condition, X^2 analysis confirmed that MP's localisation performance was at chance for targets in the nasal hemifield near location (χ^2 ($n = 140$) = 2.31, $p > 0.05$), and for targets in the nasal hemifield far location (χ^2 ($n = 139$) = 3.16, $p > 0.05$). In target absent trials in the nasal hemifield block, MP made an equal percentage of far responses and near responses (X^2 ($n = 40$) = 0.40, $p > 0.5$).

DISCUSSION

The present study shows a temporal/nasal asymmetry for blindsight in a forced-choice paradigm. Tangent screen testing showed MP to have a dense right homonymous hemianopia, with less than one degree of macular sparing. However, in a forced-choice localisation task presented in the hemianopic field, her ability to localise targets presented in the temporal hemifield was significantly higher than chance, whilst performance with targets presented in the nasal hemifield was at the level of chance. The direction of the asymmetry found in this study is the same as in the oculomotor distracter effect reported by Rafal *et al.* [8], which showed a distractor effect only for stimuli presented in the temporal hemifield and not the nasal hemifield.

MP clearly made use of a response strategy in the temporal hemifield block. With targets in the temporal hemifield, she responded 'near' when she experienced a clear percept of the target and 'far' when she did not. This strategy is reflected in the pattern of responses to target absent trials, which shows a higher percentage of 'far' responses than 'near' responses.

The use of this response strategy accounts for the fact that performance was equally high with targets in the near and far locations in the temporal hemifield block, even though MP perceived targets in the near location more clearly. However, the response strategy cannot account for the asymmetry in performance between the temporal and nasal hemifield target conditions. Regardless of the response strategy used in temporal hemifield trials, performance in the nasal hemifield condition was at the level of chance (Fig. 2).

The present findings are inconsistent with the hypothesis that blindsight reflects a shift in response criteria between clinical perimetry and forced-choice testing. Campion *et al.* [2] suggested that blindsight could be attributed to the fact that patients employ a very conservative response criterion in perimetry, allowing them to appear completely unaware of stimuli presented in the blind field in perimetry, but able to respond accurately to stimuli presented in the blind field during forced-choice testing. However, this hypothesis cannot account for the temporal/nasal asymmetry of our results. A shift in response criteria can only explain different levels of performance in two separate tests; it cannot explain different levels of performance between different conditions of the same test, in which response requirements are held constant.

The present findings are also inconsistent with the possibility of visual processing in the hemianopic field being mediated by light-scatter. This explanation assumes that the preserved visual capacities of patients with blindsight depend on stray light from a contralesional stimulus reaching the normal, ipsilesional visual field, subserved by the intact geniculostriate pathway [1]. However, this hypothesis predicts equal performance for targets in the temporal and nasal hemifields and is thus irreconcilable with the present observation of a temporal/nasal asymmetry in performance. Also, we used dark filled circles on a bright background to ensure that light could not scatter into the intact field.

Furthermore, intact islands of striate cortex cannot have been responsible for MP's pattern of performance, since this hypothesis also predicts equal performance for targets in the temporal and nasal hemifields. Although ganglion cells are distributed asymmetrically across the retina [15], and this asymmetry persists into the geniculostriate projection [13], it only exists in the far periphery, beyond the eccentricity of the stimuli used in this study, and therefore cannot explain the asymmetry in performance for temporal and nasal targets. In any case, as Fig. 1 shows, the MRI scan revealed complete destruction of striate cortex as a consequence of the lesion.

The pattern of MP's performance is consistent with extrageniculostriate mediation. The temporal/nasal asymmetry in performance is assumed to reflect the anatomy of the extrageniculostriate visual pathway, with targets in the temporal hemifield receiving greater neuronal processing due to the temporal/nasal asymmetry in the retinal projection to the superior colliculus and the pulvinar.

This interpretation does not rule out involvement of extrastriate regions in MP's visual capacities, since extrastriate cortical areas receive projections from the superior colliculus and the pulvinar as well as from the lateral geniculate nucleus. Indeed, the extrageniculate visual system is phylogenetically older than the geniculostriate system, and mediates basic functions such as visual orienting and the control of saccadic eye movements [16]. It seems unlikely that this primitive extrageniculate visual system, functioning in isolation, can support the level of awareness experienced by MP in the present study. A more

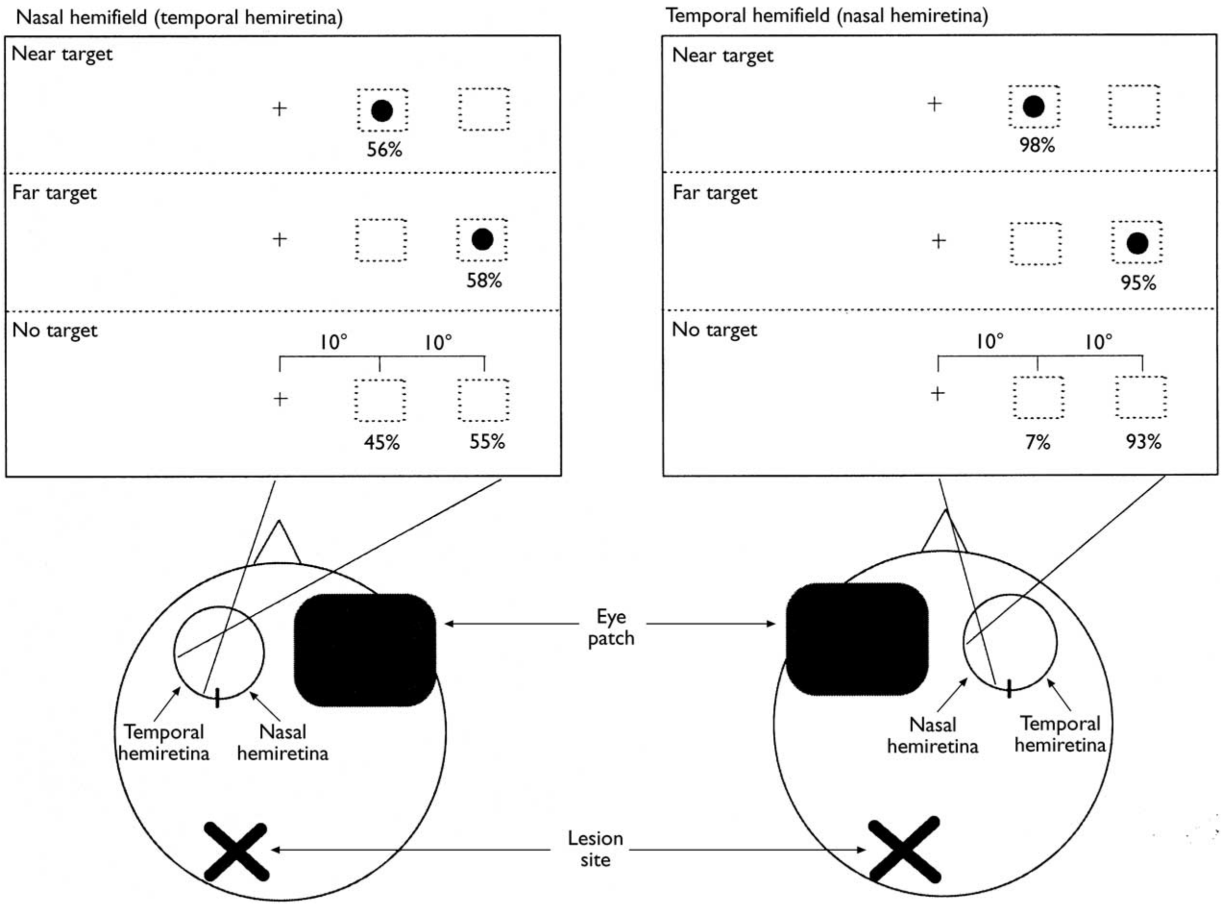

Fig. 2. Percentage of near and far responses made by MP in near target, far target and no target conditions, in the temporal hemifield and nasal hemifield blocks. Dotted boxes did not appear in the display, serving only to illustrate possible target locations. Below the experimental displays are schematic, top-down views of the patient. Diagram not to scale.

probable scenario is that, after damage to the geniculostriate visual system, the extrageniculostriate pathway provides an alternative route by which visual information can reach cortical areas.

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