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Visual motion perception from stimulation of the human medial parieto-occipital cortex

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Summary. Visual phenomena evoked by direct electrical stimulation of extrastriate cortex were observed in 30 epileptic patients as part of a presurgical investigation. An incremental sequence of low-level bipolar stimulation trains was delivered at medial and lateral pairs of contacts of stereotaxically-implanted multilead intracerebral electrodes in parietal, occipital and posterior temporal regions. Diffusion of stimulus afterdischarges was monitored by electrodes in temporal and frontal lobes and by the non-stimulated contacts of the stimulated electrode. Localized stimulations evoked few visual phenomena. The strongest anatomo-perceptual correlation was found for stimulation in the medial parieto-occipital fissure which evoked visual motion phenomena in all three patients stimulated in that region. The evoked motion perceptions were not associated with eye movements or any particular localization of the epileptic focus. These perceptions were only evoked once outside of the medial PO region at the 61 sites examined. The results suggest that the medial parieto-occipital region is closely linked to the human visual motion processing system.

Key words: Human visual cortex – Extrastriate visual areas – Brain stimulation – Motion perception

Introduction

In non-human primates, extrastriate visual cortex is composed of many areas showing some degree of functional differentiation (see Maunsell and Newsome 1987 for a review). Some have suggested that these areas are organized into distinct processing streams, a temporal stream specializing in form and color processing, and a parietal stream associated with either motion or spatial processing (Ungerleider and Mishkin 1982; Van Essen and Maunsell 1983). The parietal stream interconnects areas in posterior superior temporal sulcus (MT, MST) and in parieto-occipital cortex (V3, V3a, PO) to inferior parietal areas (DP, LIP, 7a). The temporal stream interconnects occipito-temporal areas (VP, V4, V4a) to inferior temporal areas (PIT, AIT).

In man, little is known of the regional differentiations in extrastriate cortex. Extrastriate lesions in humans can produce relatively selective location or movement perception deficits (Ratcliff and Davies-Jones 1972; Riddoch 1917; Zihl von Cramon and Mai 1983; Vaina 1989) and there are suggestions that lesions producing color perception and pattern recognition deficits are more ventral than lesions producing visuo-spatial deficits (Meadows 1974; Damasio et al. 1982), but the lesion approach has not permitted much anatomical precision. Recent PET scan data also suggest that selective attention to different visual attributes activates different extrastriate regions (Corbetta et al. 1990).

We have investigated regional differentiations in human extrastriate cortex through the effects of direct cortical stimulation on perception. Human posterior brain areas are electrically stimulated on rare occasions in which patients with medically refractory partial epilepsy show indications of possible posterior onset of seizures. Low-level bipolar cortical stimulation of chronically implanted intracerebral electrodes is used to try to reproduce the first symptoms of their seizures with a localized activation in order to confirm the site of onset of the spontaneous seizures recorded through the same electrodes (Bernier et al. 1990). Cortical stimulation can also evoke spontaneous as well as task-related phenomena that are not seizure-related and that can provide anatomo-functional associations (Bancaud et al. 1976; Lesser et al. 1987; Ojemann 1983; Penfield and Rasmussen 1950; Richer Martinez and St-Hilaire 1991).

Methods

The intracerebral stimulation protocol is part of a presurgical investigation procedure which includes scalp and intracerebral recording

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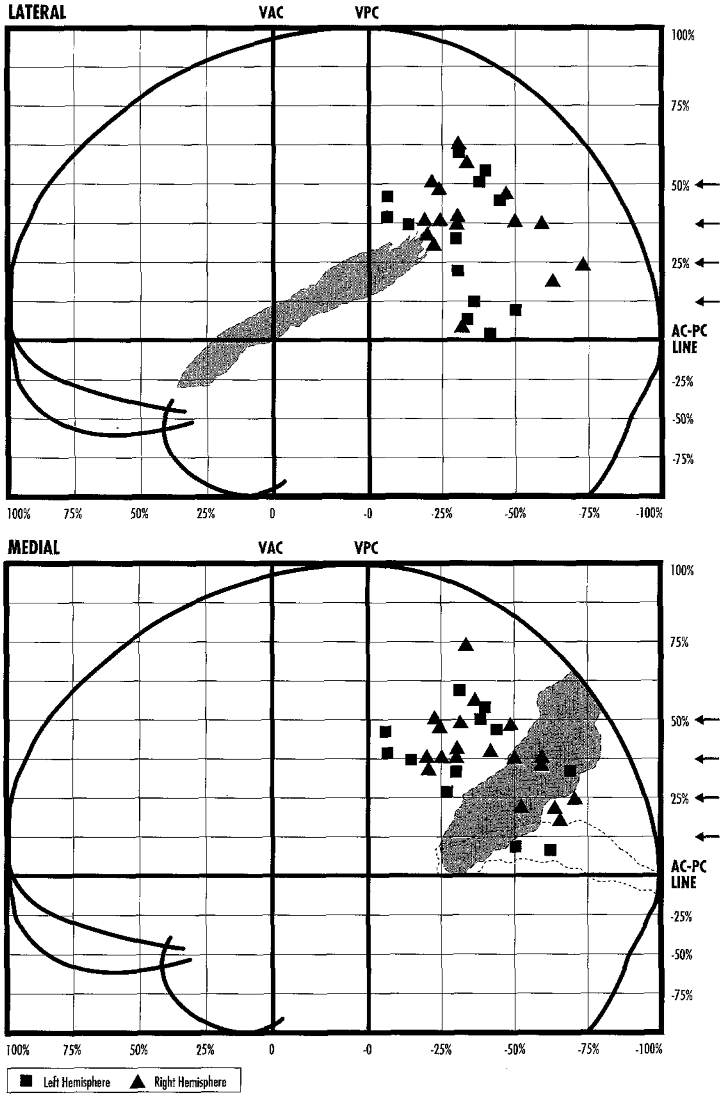

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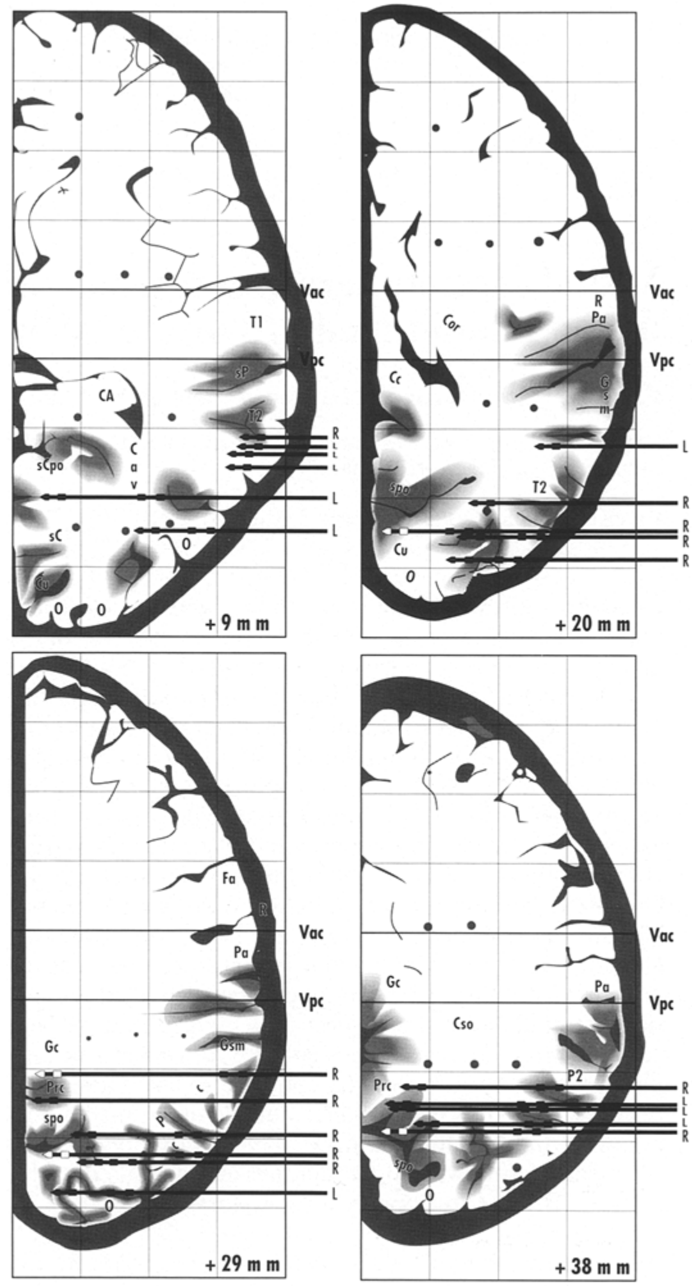

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Fig. 1. **A** Medial and lateral views of the normalized brain in the proportional stereotaxic grid system of Talairach showing the position of stimulated electrodes in coordinates proportional to brain size. Shaded regions show inter-individual variations in calcarine, parieto-occipital, and sylvian fissures (Talairach and Szikla 1967). Arrows indicate planes of horizontal cuts shown in (**B**). **B** Schematized horizontal brain slices derived from the Talairach atlas showing location of stimulation sites on the more posterior electrodes in proportional coordinates. Approximate millimeter values above intercommissural (AC–PC) line are shown. Electrode contacts eliciting visual motion phenomena are shown in white. T1: superior temporal gyrus, T2: middle temporal gyrus, GSM: supramarginal gyrus, O: occipital gyri, Cu: Cuneus, SPO: parieto-occipital fissure, SC: calcarine fissure, SCPO: common branch of calcarine and parieto-occipital fissures. Cc: corpus callosum, Gc: cingulate gyrus, P2: superior posterior parietal cortex

of seizures, as well as neuroradiological and clinical measures. Intracerebral electrode locations are selected on the basis of clinical considerations. Posterior brain regions were implanted in these patients because non-invasive clinical, radiological, or electroencephalographic measures suggested a possible posterior onset of seizures. Informed consent was obtained according to normal hospital procedures after explaining to the patients the nature, goals, and possible consequences of the stimulation procedure.

Extrastriate cortex was stimulated in 30 patients through multilead electrodes (Bouvier et al. 1987) chronically implanted in occipital, posterior temporal or parietal sites in a horizontal lateromedial axis (see Fig. 1). Electrodes were implanted stereotaxically using teleradiography and a modified Talairach frame. Electrode location was determined from post-implantation coronal and saggital radiographs referenced to the Talairach atlas (Talairach and Szikla 1967). All patients had one or two (one patient) posterior electrodes and between four and nine electrodes implanted in frontal and anterior temporal brain areas.

On each electrode, medial and lateral pairs of contacts (0.8 mm radius, 1.8 mm length, 5 mm apart) were stimulated in a bipolar fashion. At each site, five to ten stimulus trains were delivedred in an incremental sequence with a minimal delay of 55 secs. between consecutive trains. The stimulation sequence was discontinued when either: 1) a neuroelectric afterdischarge was induced at more than one site, 2) a seizure was evoked or 3) a charge density of 7.5 μC/cm²/phase was reached. The bipolar electrical stimuli consisted of 5-sec. trains of biphasic pulses (0.5 ms/pulse) delivered at 50 cycles/sec. This procedure evokes few phenomena and few diffusions of electrical afterdischarges from one structure to another. Patients were asked to report any symptom felt during the session and were unaware of the time of delivery of stimulations. Only phenomena that were not accompanied by afterdischarges at any site were considered.

Results

Stimulation of posterior cortical areas with the procedure described evoked only somesthetic or visual phenomena. Stimulation at 31 sites in lateral posterior cortex evoked only three phenomena, including somesthetic perceptions in supramarginal gyrus in two of the 12 patients stimulated in that region and a visual object distortion in lateral occipital cortex (middle occipital gyrus) in one of three patients stimulated in that area.

Stimulations in medial regions were more frequently positive. Perceptual phenomena were evoked in 12 of the 30 medial sites stimulated. Somesthetic phenomena were evoked in posterior cingulate in 4 of the 13 patients stimulated in that region. Static visual phenomena were also evoked in medial cortical sites: in the cuneus around the calcarine fissure in the form of contralateral white or colored flashes (2/2 patients), in posterior cingulate (1/13 patients) and inferior precuneus (1/7 patients) as blurred vision.

Visual motion perceptions were the only complex perceptual phenomena evoked by our medial extrastriate stimulations. Visual motion phenomena were evoked in four patients: in all three patients stimulated in the medial portion of the parieto-occipital fissure (PO) and in one of the 13 patients stimulated in posterior cingulate cortex. Stimulations at sites about 1 cm lateral to the medial PO sites (3 patients), in precuneus 1–2 cm anterior to the medial PO sites (4 patients), in occipital white matter (8 patients), or in the region of the primary visual area (2 patients) never evoked these phenomena. The motion perceptions were reproduced two to four times in each patient and all stimulations at intensities above that which evoked the first perception also evoked the same phenomena. The reported perceptions lasted only for the duration of the stimulus train and were not accompanied by any observable nystagmus.

The motion perceptions evoked in medial PO were fixed for a given patient. They were observed in one patient with a parietal epileptic focus as well as in two patients with frontal lobe foci. Patient 1 reported a transparent circle moving from the center of gaze toward the contralateral periphery during right medial PO stimulation. In this patient, seizure activity began in mesial frontal areas and her early seizure symptoms were somatosensory and bore no relationship to the stimulation-evoked phenomenon. A post-implantation magnetic resonance image showed the site evoking the motion phenomenon to be in the medial portion of the posterior bank of the PO fissure (see Fig. 2).

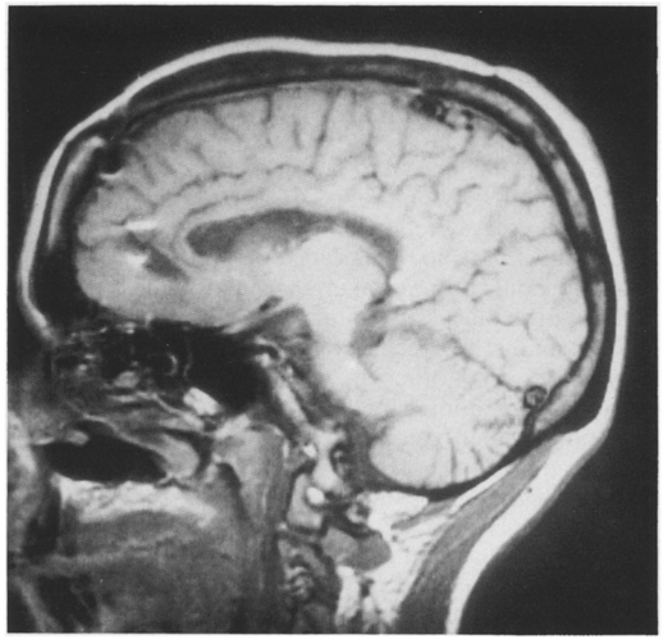

Fig. 2. Magnetic resonance image (T1-weighted, saggital cut, 1 cm from midline) of the right-hemisphere of a patient after intracerebral electrodes had been removed. Stimulation of the contact pair immediately posterior to the parieto-occipital fissure (appearing as a black dot on the image) evoked a visual motion perception in the left field toward the left periphery

In patient 2, stimulation of the right medial PO region evoked a perception of rapid and sustained lateral motion of objects in the contralateral hemifield. In this case, seizure activity began in right mesial frontal cortex and spread to homolateral parietal cortex within a few seconds, at which time the patient reported a visual phenomenon of slowing of motion of objects and people around him. Patient 3 reported seeing objects moving away from her in a sustained fashion during stimulation of the right medial PO region. In this patient, intracerebral seizure activity began in the right parietal lobe and was sometimes accompanied by the same perception as that evoked by stimulation.

The only visual motion perception evoked outside of medial PO (in posterior cingulate cortex) involved rapid motion of a small portion of the contralateral visual field. In this patient, seizure activity showed a bilateral parietal onset and was associated with alterations of consciousness.

Discussion

These data confirm the presence of regional differentiations in human extrastriate visual cortex. Indeed, the sensitivity of the human medial parieto-occipital region for stimulation-induced motion perception phenomena suggests that this region is linked to the visual motion processing system. Stimulation of the medial PO region selectively evoked perceptual experiences in which the predominant feature was sustained motion of objects laterally or in depth. The effort used to insure localized stimulations, and the absence (with one exception) of these phenomena at a large number of other sites including sites about 1 cm lateral or anterior to the PO cortex suggest that this anatomo-perceptual association is specific to this area. Moreover, the fact that the perceptions are not necessarily related to seizure symptomatology or site of epileptogenic focus suggests that this association probably holds for normal brains and not only for brains with a pathological physiology.

Of course, the specific role of the PO region and its interactions with other areas in the production of the motion perceptions cannot be derived from these observations. Other regions may show more direct involvement in motion processing but medial PO cortex has a lower activation threshold for motion perception than all other regions examined.

The parieto-occipital fissure is anatomically linked to the motion processing subsystem of the primate visual system. A possible analogue area was first described in the owl monkey in the ventral portion of the PO fissure by Allman and Kaas (1976) and shown to be specially sensitive to high stimulus velocities (Baker et al. 1981). In macaque and owl monkey, this area (PO) receives projections from area MT in the posterior superior temporal sulcus (Colby et al. 1988; Graham Wall and Kaas 1979; Ungerleider and Desimone 1986), an area which shows a high degree of specialization for visual motion processing (Dubner and Zeki 1971; Maunsell and Van Essen 1983; Newsome et al. 1985; Salzman et al 1990).

The present data cannot confirm the existence of human analogues to lateral motion processing areas of monkeys such as MT which were suggested by PET scan data (Corbetta et al. 1990), since no visual motion phenomena could be evoked from lateral cortex. However, other motion perception areas may exist in portions of lateral cortex that we did not stimulate. Moreover, the absence of evoked perceptual phenomena in an area does not mean that it does not contribute to the processing involved. Particular areas may only be sensitive to stimulation during specific testing situations; an object for future investigations. The verbal report procedure is strictly a simple screening tool for the identification of the most responsive regions involved in one type of activity. Our preliminary mapping of extrastriate cortex has revealed only one region of specific sensitivity to visual motion processing effects but the medial PO region is likely to be part of a multi-area system involved in visual motion analysis.

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References

Allman J, Kaas J (1976) Representation of the visual field on the medial wall of the occipital-parietal cortex in the owl monkey. Science 191:572–575

Bancaud J, Talairach J, Geier S, Bonis A, Trottier S, Manrique M (1976) Manifestations comportementales induites par la stimulation électrique du gyrus cingulaire antérieur chez l'homme. Rev Neurol 132:705–724

Baker J, Petersen S, Newsome W, Allman J (1981) Visual response properties of neurons in four extrastriate visual areas of the owl monkey. J Neurophysiol 45:397–416

Bernier G, Richer F, Giard N, Bouvier G, Mercier M, Turmel A, St-Hilaire JM (1990) Electrical stimulation of the human brain in epilepsy. Epilepsia 31:513–520

Bouvier G, Saint-Hilaire JM, Giard N, Lesage J, Cloutier L, Béique R (1987) Depth electrode implantation at Hopital Notre-Dame. In: Engel J (ed) Surgical treatment of the epilepsies. Raven Press, New York, pp 589–593

Colby CL, Gattass R, Olson CR, Gross CG (1988) Topographical organization of cortical afferents to extrastriate visual area PO in the macaque: a dual tracer study. J Comp Neurol 269:392–413

Corbetta M, Miezin FM, Dobmeyer S, Shulman GL, Petersen S (1990) Attentional modulation of neural processing of shape, color and velocity in humans. Science 248:1556–1559

Damasio AR, Damasio H, Van Hoesen W (1982) Prosopagnosia: Anatomical basis and behavioral mechanisms. Neurology 29:170–178

Dubner R, Zeki SN (1971) Response properties and receptive fields of cells in an anatomically defined region of the superior temporal sulcus. Brain Res 35:528–532

Graham J, Wall J, Kaas JH (1979) Cortical projections of the medial visual area in the owl monkey, Aotus Trivirgatus. Neurosci Lett 15:109–114

Lesser RP, Luders H, Klein G, Dinner DS, Morris HH, Hahn JF, Wyllie E (1987) Extraoperative cortical functional localization in patients with epilepsy. J Clin Neurophysiol 4:27–53

Maunsell JHR, Newsome WT (1987) Visual processing in monkey extrastriate cortex. Ann Rev Neurosci 10:363–401

Maunsell JHR, Van Essen DC (1983) Functional properties of neurons in the middle temporal visual area (MT) of the macaque monkey. I. Selectivity for stimulus direction, speed, and orientation. J Neurophysiol 49:1127–1147

Meadows JC (1974) Disturbed perception of colours associated with localized cerebral lesions. Brain 97:615–632

Newsome WT, Wurtz RH, Dursteler MR, Mikami A (1985) Deficits in visual motion perception following ibotenic acid lesions of the middle temporal visual area of the macaque monkey. J Neurosci 5:825–840

Ojemann GA (1983) Brain organization for language from the perspective of electrical stimulation mapping. Behav Brain Sci 2:189–230

Penfield W, Rasmussen T (1950) The cerebral cortex of man. MacMillan, New York

Ratcliff G, Davies-Jones GAB (1972) Defective visual localization in focal brain wounds. Brain 95:49–60

Riddoch G (1917) Dissociation of visual perceptions due to occipital injuries, with special reference to appreciation of movement. Brain 40:15–57

Saint-Hilaire JM (1987) Presurgical evaluation protocols: Hopital Notre-Dame. In: Engel J (ed) Surgical treatment of the epilepsies. Raven Press, New York, pp 675–676

Salzman CD, Britten KH, Newsome WT (1990) Cortical microstimulation influences perceptual judgements of motion direction. Nature 346:174–177

Talairach J, Szikla G (1967) Atlas stéréotaxique du télencéphale. Masson, Paris

Ungerleider LG, Desimone R (1986) Cortical connections of visual area MT in the macaque. J Comp Neurol 248:190–222

Zihl J, von Cramon D, Mai N (1983) Selective disturbance of movement vision after bilateral brain damage. Brain 106:313–340

Vaina LM (1989) Selective impairment of visual motion interpretation following lesions of the right occipito-parietal area in humans. Biol Cybern 61:347–359