Anatomical Basis of Spatial Attention

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Attention is a term which derives from the common experience that physically identical stimuli may be perceived at different moments with different degrees of subjective clearness. Attention includes intensive phenomena, such as arousal, alertness, or attentiveness and selective phenomena. To the group of selective phenomena belongs the capacity to orient attention to different sectors of space: spatial attention. Deficits of this capacity are frequently encountered in patients in the form usually described as hemineglect. These patients, in the absence of primary sensory or motor deficits that may justify the symptoms, have difficulties in noticing events in the space contralateral to the lesion and to explore this space actively [see 1, 3].

One finding that clearly emerges from the literature on clinical and experimental neglect is that this syndrome may result following lesion of a large variety of cortical areas and subcortical centers [3, 10]. Among cortical areas the inferior parietal lobule, the frontal eye field (FEF), and the gyrus cinguli appear to play crucial roles; subcortical centers whose lesion produces neglect are the superior colliculus, the lateral hypothalamus, the substantia nigra, and parts of the striatum. Furthermore, some evidence exists that damage to intralaminar thalamic nuclei and to some parts of the brain stem reticular formation may also produce neglect [3, 10].

It is obvious that any theory of neglect must explain why attentional deficits are obtained with lesions of so many centers. The simplest way is to postulate that this occurs because the various centers and areas whose lesion produces neglect are part of a single attentional circuit. This type of explanation of neglect has been proposed, for example, by Heilman and his co-workers [3] and, in another form, by Mesulam [10]. Although this idea is appealing, an anatomic circuit including all the above mentioned centers appears to be extremely unlikely. The connections between some parts of it are very indirect and what is more important it does not appear that connections between centers forming the circuit are more direct or richer than those between the same centers and others not involved in attention.

In this paper I shall propose that neglect can occur following lesion of several circuits, each of them being to a large extent independent of the others. Each circuit has primarily a sensorimotor function. It extracts information from the environment and, in the presence of adequate stimuli, programs motor acts directed toward a specific part of space. When one of these circuits is internally activated it facilitates

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its afferent part [see 21], thus rendering it more sensitive to particular sectors of the environment, and simultaneously it inhibits other sensorimotor circuits, acting in this way as a filter for concurrent sensorimotor activities [15].

The strongest evidence in favor of this hypothesis comes from cases that I shall refer to as cases of atypical neglect, that is from syndromes in which the neglect is present and yet the attentional deficits are different from those classically observed in right parietal patients.

One type of atypical neglect can be demonstrated in cats after a sagittal section of the tecta I commissures [9]. Animals with this lesion show motor and attentional deficits. Motor deficits consist in a marked reduction or even absence of vertical eye movements and in an abnormal posture of the head, which is held slightly ventro-flexed. At variance with normal cats, commissurotomized animals never look up and explore the space above their head. There is a clear deficit in their capacity to orient to visual stimuli abruptly presented in the upper visual space. The capacity to follow objects vertically is also impaired. When a piece of food is moved in an upward direction, starting in the lower field, the animal follows it until it reaches approximately the head midplane. Then the head movement stops and the cat appears to ignore where the food is. When the food is moved downward the animal has a startling reaction when the food reaches the lower visual space; until this moment the animal appears to be completely unaware of the stimulus. Formal testing of the upper and lower visual space carried out in our laboratory confirmed the upper space deficit. Animals with a complete lesion show a very slow recovery. Those with partial sections recover in less than 2 weeks.

In animals in which the lesion is anteriorly located and comprises the posterior commissure and the rostralmost part of the intertectal commissure, the deficits are different from those in which the intertectal commissures are severed [9]. There is no ventro-flexion of the head and no tendency to explore the lower space. In contrast, there is a slight head dorsiflexion and a preference to explore the upper space. Downward tracking head movements are slow and less accurate than upward movements. When two pieces of food held together in front of the animal are moved suddenly apart, one upward, the other downward, the animals constantly follow that moving upward. Similarly, if a piece of food is first moved downward and is then left in the lower visual space, the animal appears to be disoriented and is able to find it only after some time.

These data clearly indicate that in the cat the interruption of the midbrain commissures produces a vertical neglect. The attentional deficit is spatially correlated with postural and movement deficits. When the lesion is centered upon the posterior commissure the neglect involves the lower visual space and the head is dorsiflexed; when the lesion interrupts the intertectal commissures the neglect involves the upper visual fields and the head is ventriflexed.

Vertical attentional deficits similar to those experimentally obtained in the cat have also been observed in humans. Patients affected by progressive supranuclear palsy often show, beside other deficits, partial or total incapacity to move the eyes vertically and a slight dorsiflexion of the head [20]. These motor symptoms are accompanied by difficulties of orienting toward stimuli in the lower visual space [14]. For example, when eating they may stare straight ahead, fumbling with their meal, although they are quite able to look down on command, or they may stumble over