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THE ABSENCE OF POSITION SENSE IN THE HUMAN EYE

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It has been widely held (e.g. Sherrington, 1918; Hoffmann, 1934, p. 28) that we have a sense of position of the eyeball which depends on afferent nerve fibres from the extraocular muscles. However, the experiments of Helmholtz (1867) indicate that such a position sense, if it exists, is not used to correct visual impressions when the eye is passively displaced. The following experiments, done on four subjects, show that the eye has no position sense.

EXPERIMENTS

Passive deviation of one eye causes no sensation. One conjunctival sac was anaesthetized with cocaine. With the subject lying supine, an opaque aluminium shell, shaped to fit the eye, was placed so that it occluded the whole of the cornea and a surrounding ring of sclera about 2 mm in width. The insertion of the lateral or medial rectus muscle was seized through the conjunctiva with fine-toothed forceps, and the eye passively abducted or adducted by amounts corresponding to up to 40° of visual angle, the other (unanaesthetized) eye remaining closed or covered by the subject's hand. The subject was found to be entirely unaware of the direction of any passive movement and, if care was taken to avoid accidental disturbance of the eyelids, he was unaware that it had been made, even for sudden movements of several tens of degrees.

Passive deviation of one eye causes no substantial reflex movement of the other. If during a passive movement of the occluded eye the other eye was kept open, the subject saw no apparent movement of things around him. This strongly suggests that passive deviation of one eye does not reflexly cause movement of the other, since sudden movements of the whole retinal image through as little as 5′ are easily detected. There is, however, the alternative possibility that reflex eye movements occur, but that the brain compensates for the resulting movement of the retinal image, so that it is not detected; such compensation would be analogous to that which is well known to occur during voluntary eye movements, but much more complete. Evidence to which this objection does not apply comes from the following experiment, which was suggested by

Mr R. L. Gregory, who also kindly lent us his fixation lantern. The subject lay in darkness except for a small red fixation light surrounded by a faint blue halo which subtended 1° at his eye. As long as the red light was accurately fixated, the halo was invisible, since it fell wholly on the fovea, which is relatively insensitive to blue light; but movement through 30′ sufficed to make it easily seen. One eye was anaesthetized and its cornea occluded. Passive movements of this eye while the other eye fixated the red light were found not to make the halo visible. We conclude that passive movement of one eye through as much as 40° certainly causes no reflex movements of the other exceeding 30′, and probably (on evidence of the lack of apparent movement of things seen) causes none exceeding 5′.

Simultaneous passive movements of both eyes. William James (1890) objected to certain observations on unilateral ocular palsies adduced by Helmholtz, on the grounds that no account was taken of sensory information from the sound eye. This objection was adopted by Sherrington (1900), and the later answer of Jackson & Paton (1909) apparently escaped notice. To forestall possible criticism of the present experiments on the same lines, both conjunctival sacs were anaesthetized, both corneae occluded with opaque shells, and both eyes passively deviated in the same direction at the same time. The subject was found to be unaware of deviations of up to 30° to right or left from the mid position.

Active movements. With both corneae occluded, the subject was asked to deviate the eyes to right or left. During some of these attempted movements the eyes were allowed to move freely through 30° or more. During others both eyes were held firmly with forceps, and could move through no more than about 5°. An assistant held the lids of both eyes widely open, both to prevent sensory clues from deformation of skin by the corneal caps when they moved, and to avoid displacement of the caps at extreme deviations. With satisfactory anaesthesia of the conjunctiva, it was found that the subject could not tell whether the eyes were held or not; he regularly had the impression that he succeeded in moving them through a large angle.

Subsidiary observations. In one subject both eyes (without caps on the corneae) were held with forceps while he attempted to deviate the eyes actively. Apparent movements of external objects in the direction of the attempted movement were seen. The subject thus interprets his visual impressions as if he had succeeded in moving his eyes. Similar observations were made by Mach (1886, p. 57), who restrained movements of his eyes to the right with 'two large lumps of moderately hard putty firmly pressed against the right side of each eye-ball', and by Kornmüller (1931), who paralysed the four rectus muscles of one eye by injecting novocaine into them. One of us (P.A.M.) performed a related experiment. He

received intravenously a dose of curare sufficient to cause weakness but not paralysis of his eye muscles. On voluntary deviation of the eyes he observed apparent movements of external objects in the direction of the deviation.

DISCUSSION

We find that, when the conjunctival sacs are anaesthetized and visual clues excluded, subjects know neither the amount nor the direction of any deviation of their eyes unless that deviation has been produced by the unhindered action of their own eye muscles. The errors that they make when the muscles are prevented from moving the eyes are just those that would be expected on Helmholtz's view that non-visual knowledge of the position of the eyes depends exclusively on judgement of the effort of will employed in attempting to move the eyes. They are very difficult to reconcile with the view that it depends on any known sense organs, especially muscle spindles, although muscle spindles are known to be present in the eye muscles of man (Buzzard, 1908; Cooper & Daniel, 1949) as in those of other primates (Tozer & Sherrington, 1910, at p. 451; Cooper & Daniel, 1949). Possible functions for muscle spindles are discussed by Hammond, Merton & Sutton (1956).

Meaning of the term 'position sense'. We use the term 'position sense' with the meaning that has long been customary in clinical neurology: a part of the body is said to have position sense if the subject knows its relation to the rest of the body by information derived from mechanically stimulated sense organs in it or anatomically connected to it. Thus the knowledge of the relation of his eyes to his head which a subject can gain by seeing his nose or moustache (Mach, 1886, p. 14) is not deemed to show that he has position sense in the eye, just as a tabetic patient is not said to have position sense in his toes if he can recognize their relation to his feet only by looking at them.

Influence of anaesthesia of the conjunctival sac. Though in our experiments the conjunctival sac was always anaesthetized, it is unlikely that this anaesthesia inactivated receptors which in the normal use of the eyes give much information about their relation to the head, for the accuracy with which subjects whose eye muscles are acting without hindrance can judge or reproduce positions of their eyes is not impaired by anaesthetizing the conjunctival sac (Merton, 1960).

SUMMARY

1. Subjects cannot detect passive movements of one eye or of both together if their conjunctival sacs are anaesthetized and visual clues excluded.

2. Under the same conditions they cannot tell whether attempts to move the eyes actively are successful or are mechanically prevented.

3. Passive movement of one eye causes no detectable reflex movement of the other.

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