LOCALIZATION OF OBJECTS IN VISUAL SPACE WITH ABNORMAL SACCADIC EYE MOVEMENTS

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INTRODUCTION

IT is not clear how one has knowledge of the eyes' position. Brindley and Merton (1960) have shown that afferents from proprioceptive organs in the extraocular muscles cannot provide this information. These authors covered the corneas of subjects with opaque covers, anæsthetized the sclera, and moved the eyes about with forceps. Their subjects were unable to tell whether or not the eyes moved under these circumstances. The possibility that efferents to the extraocular muscles contribute knowledge of the eyes' position has also been considered. von Helmholtz (1925) noted that patients with an acute paralysis of the lateral rectus muscle of the eye had illusions that the environment moved on attempting to contract the affected muscle. He suggested that the patient's efforts at moving the eye provided information as to where the eye was supposed to go and the illusion of apparent motion resulted from a non-correspondence between the expectation of the move and the result. Graefe (1878) also examined the role of efferents in individuals with a recent weakness of one of the extraocular muscles. These subjects judged objects, in the field of paretic gaze, to be located beyond their actual position. Graefe reasoned that if spatial information were derived from efferents to the extraocular muscles the disorder of localization would be consistent with the extra effort these individuals exerted to move their affected eye.

Festinger and Canon (1965) have recently tested the contribution of efferents to spatial localization using tasks that distinguished efferent information arising from two types of eye movements: saccades and smooth following movements. These two types of eye movements have essentially different functions. Rashbass (1961) has shown that saccades are a response to an object's position whereas smooth following movements are a response to an object's velocity. Saccades are rapid ballistic moves (up to 600°/sec.) (Robinson, 1964) that enable the fovea to be brought promptly onto a previously eccentric point in the visual field and smooth following movements are of slow velocity (up to 45°/sec.) (Robinson, 1965) and enable the fovea to be continuously maintained on an object moving across the

visual field. Festinger and Canon found that localization was better when saccades were used to look at the target than when following eye movements were used to track a target to its final position, and concluded that efferents directing the eyes to move to a particular position, as in a saccade, provide significant information for spatial localization.

I have had the opportunity of studying the role of efferents further in an individual in whom a disease of the central nervous system had abolished saccadic eye movements without modifying smooth pursuit movements (Case 1, Starr, 1967). The purpose of the study was to determine if such a specific disorder of efferent oculomotor control would be associated with a corresponding change in spatial localization. The rarity of such a disorder has limited this study to just a single case.

Case Description

The patient was a 23-year-old man with symptoms of Huntington's chorea for three years. He was co-operative, with a verbal IQ (WAIS) of 94. There were occasional involuntary rapid movements of the fingers which disappeared on voluntary effort. Extraocular movements were marked by an absence of saccades both on voluntary gaze and during oculomotor reflexes whereas slow following movements were entirely normal. On an attempted saccade, the subject's eyes drifted slowly in the appropriate direction and came to rest when the target was achieved. The manœuvre could take as long as ten seconds for a movement of 30°. In contrast, only 100 m.sec. is required by a normal individual to complete a 30° saccade. To compensate for the oculomotor deficit, the subject employed head and neck movements to look at objects. Visual acuity, visual fields, complex visual performance as in reading and figure recognition were all normal.

The subject's disorder of extraocular motility can be attributed to a disturbance of the efferent command system for three reasons:

(1) The extraocular muscles were normal as demonstrated by full ocular movements during tracking.

(2) Electromyography of the extraocular muscles was compatible with dysfunction of efferents rather than with a disorder of the muscles themselves. During a normal saccade there is a brief (up to 150 m.sec.) burst of activity in the prime mover with complete inhibition of its antagonist muscle (Tamler *et al.*, 1959). In contrast, in the present subject, motor units were recruited only slowly in the prime mover with a parallel slowed inhibition of motor units in the antagonist. The motor units themselves were of normal amplitude and duration. The subject's inability to make saccades was thus due to a disorder of initiating rapid changes in extraocular muscle activity.

(3) Huntington's chorea affects the central nervous system, causing a degeneration of the caudate and putamen. There has never been a disorder of the peripheral nerves or muscles linked to this illness.

Methods

The subject's ability to localize objects was examined in the same room and by the same procedures as used by Festinger and Canon (1965). In brief, the subject was seated in a chair designed to maintain the head and neck immobile and the room was darkened. The light source to be localized was attached to a boom whose position in the visual field could be varied. Seven different positions ranging from 30° to the left and right of straight ahead were used with at least three trials at each of the positions chosen in a random sequence. The subject's task was to move a pointer with his hand to the light's position. Both the position of the light and the pointer could be recorded from calibrated dials and their difference represented the absolute error of localization.

The subject was tested in three situations:

(1) The light was illuminated and remained stationary while the subject pointed at the light. This procedure provides a measure of the accuracy of localization with optimal information.

(2) The light was illuminated for three seconds at a stationary point and the subject directed to look at the light. After the light was extinguished the subject was instructed to adjust the pointer to where the light had been. In this task, localization depends primarily on knowledge of where the eyes had been directed. Normally such information is derived from saccadic efferents.

(3) The light was illuminated and moved slowly across the visual field to its final position, where it remained for three seconds before being extinguished. The subject was to track the light with following eye movements and only adjust the pointer after the light had been extinguished. Localization in this situation depends primarily on knowledge of efferents regulating the rate and direction of smooth following eye movements.

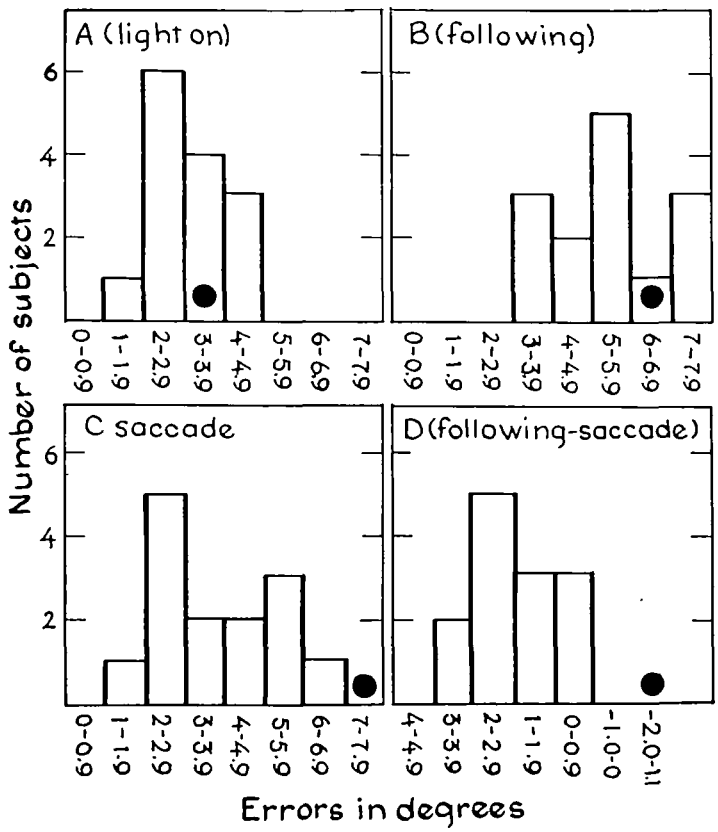

FIG. 1.—To show the performance of the subject of this report (filled circles) and 14 normal subjects (open bars) from Festinger and Canon's study (1965) on localization of a light source in three conditions. (A) When the light was stationary and illuminated during localization. (B) When the light was tracked by following eye movements to its final position and extinguished before localization, and (C) when the light was illuminated at a stationary point and fixated by a saccadic eye movement before being extinguished and localization attempted. (D) Shows the difference between localization using following eye movements and localization using saccadic eye movements.

Results and Conclusion

If efferents do contribute to knowledge of the eyes' position one should expect that a subject with a disability of efferents, as in the present instance, should have an impairment of localization in the second test situation. The results on the first and third test situations ensure that any change in performance on the critical second task could not be attributed to systematic errors of perception or of arm movement.

The results from the present subject are compared with Festinger and Canon's data from 14 normal individuals (1965) in Table I and fig. 1. The

Table I.—The Average Error of Localization in Degrees for 14 Normal Subjects (Festinger and Canon, 1965) and for the Subject of this Report

	Light-on	*Following*	*Saccade*	*Following-saccade*
Normals	3·1	5·4	3·7	1·7
Present Subject	3·0	6·7	7·8	−1·1

subject of this report was able to localize the light as well as normals when the light was on (Condition 1, fig. 1A) or when it was tracked to its final position (Condition 3, fig. 1B). Thus, information from the retina and from efferents moving the eyes in smooth pursuit could be utilized appropriately by the subject in directing the pointer. However, his performance was worse than any of the controls in the test situation in which saccadic efferents would normally be issued (Condition 2, fig. 1C). Furthermore, in each of the normals the localization was more accurate when saccades were used to look at the target than when following movements were used to track the target to its final position; the converse was true for the present subject (fig. 1D).

These results demonstrate a deficiency of localization in a subject with disordered saccadic efferents and provide an additional line of evidence supporting the hypothesis that knowledge of the eyes' position depends, in part, on efferent information.

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