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**BRAIN
AND
READING**

Edited by

Curt von Euler
Ingvar Lundberg
Gunnar Lennerstrand

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Structural and Functional Anomalies in Developmental Dyslexia with Special Reference to Hemispheric Interactions, Memory Functions, Linguistic Processes and Visual Analysis in Reading

Proceedings of the Seventh International Rodin Remediation Conference
at the Wenner-Gren Center, Stockholm, and Uppsala University,
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V

Visual Analysis and Saccadic Strategies in Reading

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Comments on Eye Movements

Ragnar Granit

At the 1980 Dyslexia Conference here in Stockholm, John Stein and Susan Fowler presented evidence to the effect that disturbance of oculomotor control is a characteristic feature of dyslexia in children. The elegant new method of recording eye movements, developed in a Polish-Swedish cooperation between Jan Ober and Per Uddén, has confirmed their findings. Thus, at least in a considerable number of cases, the binocular symmetrical eye movements in reading are replaced by a measure of independence of the saccadic patterns in the two eyes.

Recalling now that the eyes have several types of movements at their disposal and that oculomotor control is a precision instrument of a high order, the first question to raise is whether merely the saccadic movements are disturbed in dyslectics and thus are leaving the other types of movement intact. This seems to me an urgent question to answer by experimentation whether disturbed oculomotor control is a causative factor in dyslexia or merely one of its symptoms.

An easy introduction to ocular motility as a controlled event is to consider the reflex instalment of foveal vision after a turn of the head, the so-called VOR, the vestibulo-ocular reflex. This is what happens: the velocity-sensitive semicircular canals respond with a burst of impulses fed forward to the vestibular nuclei and thence to oculomotor nuclei which respond purposively by eliciting a corrective muscular contraction restoring foveal vision. Since the velocity-responsive burst precedes the excursion of the eyeball, how is the correcting controller in the brain informed about the final position of the eyeball in the head movement? The forward process is lacking a feedback to the vestibular nuclei. Masai Ito in his monumental monograph on the cerebellum says he does not know, but refers to the important centre for ocular motility in the reticular formation as a possibility. The idea at the back is that side-path activity may lengthen the discharge time beyond the vestibular burst-time.

Ito himself has direct evidence for a side-path through the cerebellar flocculus acting through the climbing fibres which are carrying information on the retinal slip to the cerebellar oculomotor output. However, while this side-path does exist and is acting in the postulated way, floccular ablations do not lead to a breakdown of the VOR, only to some reduction of its gain. Another idea is that the VOR-forward process converting head position to corrected eye position is provided with an internal integrator prolonging the effect of the brief burst from the velocity signalling vestibulum.

The extensive literature on the VOR refers to experiments on guinea pigs, cats, and monkeys, all of them with a poor outfit of muscular receptors compared with man and ungulates. Our eye muscles as well as neck muscles cooperating in the VOR belong to the spindle-richest in the body. And we have long had evidence from an Oxford team consisting of Sybil Cooper, Daniel, and Whitteridge that the spindle afferents project to all the sites that could be relevant for localization of oculomotility. The message from the spindles is maintained throughout the muscular act, their sensitivity is adjustable by the gamma motor control system and, above all, they are much faster in action than any retinal signal from the slip that has to spend some 20 msec in traversing the neuronal layers of the retinal centre.

The inventiveness of the model-makers is spurred into top performance by their efforts to neglect the well-documented existence of a gamma-spindle system that evolution has developed into such perfection in man. It is now 35 years since Kaada and I showed it to be at the disposal of most of the central stations engaged in motricity. Under gamma control the muscle spindles have proved to be extremely sensitive and to operate in conjunction with motor acts, a principle known as alfa-gamma linkage for limb muscles.

Those willing to accord the afferent spindle message a role in slow motor acts are likely to make saccades an exception. But in this regard there is a basic likeness between VOR and saccades. The saccadic movement does not either possess that component of maintenance of motor activity to the end point of a saccade, that we found characterizing VOR. Again there arises the same question: how does the brief saccadic burst of spikes inform motor control centres of the range of the resulting movement of the eyeball? Again the model-makers are willing to provide us with answers based on side-paths and integrators. Again I will remind them of the possibility that fast and highly sensitive information arriving from the ocular spindle afferents, which avoid the delay passage through the retinal nervous centre, should be perfectly capable of solving the problem.

If the slow message across the retinal slip actually is the prime message, why is it so unimportant where it is proved to

exist, by Ito, as entering the flocculus? And what about colliculus superior shown by Miss Apter already in 1945 to possess a point-to-point projection of the retina. To this structure arrive impulses from the oculomotor afferents, from the neck afferents, from the frontal eye fields. Ablation of colliculus superior seriously impaired the generation of unrewarded saccades while only a minimal deficit was induced in reward-conditioned saccades.

Here now I have presented three cases in which the postulated information from the range of the retinal slip has (i) been proved to exist but not to be relevant for saccadic control, (ii) been postulated to exist but shown irrelevant for reward-conditioned saccades while (iii) required for unrewarded saccades. There is more that meets the eye in these complexities. To me they suggest that the information from the retinal slip is too slow to be decisive in a process of fast control.

The fast muscular information from the spindles is widely available in centres controlling ocular motility. It seems to me quite likely to have established any number of connexions with motor acts simply by being practiced daily in the life of the individual. In ocular motricity subconscious purposive learning is required to explain records such as those of Yarbus in which saccadic movements are shown to explore the human face by concentrating on contours and other salient markers. We are not aware of the whole systematic process of saccadic exploration at top gamma-spindle sensitivity.

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