# Adaptation of Gaze to Eccentric Fixation in Homonymous Hemianopia

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## INTRODUCTION.

Patients with homonymous hemianopia (HH) display typical disabilities to acquire visual targets in their blind hemifield. In a HEAD FIXED situation they develop characteristic strategies of ocular motor control to overcome the HH defect (3). In a more natural HEAD FREE situation they show additional difficulties to cope with their HH defect (9). These include stair-step and one-step overshoot/backdrift saccadic strategies for target acquisition in the blind hemifield (BHF), which is also used in a head fixed condition, these patients demonstrate a significant side asymmetry of compensatory eye movements (CEM); CEM gain i.e.ratio of eye to head velocity is increased for gaze shifts to BHF and decreased for gaze shifts to SHF (seeing hemifield). Often this may cause large 'maladaptive' gaze errors. HH patients therefore tend to minimize or avoid head movements.

Experimentally normal subjects can be forced to use a similarly deranged behavior of ocular motor control. When normal subjects (Ss) learn to achieve eccentric gaze fixation using secondary visual feedback (2VFB), i.e. gaze position is displayed simultaneously with the target, they demonstrate similar strategies to superpose target and 2VFB-target (11). Initially they use stairstep saccades and macrosaccadic square wave oscillations that were earlier described (5,7) as transient responses to achieve and maintain eccentric fixation. After some training they become adapted to the task and now use slow and fast drifts to achieve eccentric fixation; they use microsaccadic square wave jerks or a nystagmus like pattern of small eccentric saccades with following backdrifts to maintain eccentric fixation.

We reasoned that early adaptation to and use of eccentric fixation could help hemianopic patients to cope better with their disability. Also they might be able to make better use of their head movements, which they otherwise avoid (9). To test this hypothesis we compared gaze responses of three normal subjects and three patients with full dense homonymous hemianopia. We compared first their initial transient responses to the task of eccentric fixation using 2VFB. Then, after some training in head fixed and head free situations, we looked for their adaptive responses. The results were compared with earlier findings (3,9,10,11).

## METHODS.

*Normal subjects and patients.* Three normal subjects (age 25,29,40 all male) served as comparision. They all had full uncorrected visual acuity (20/20) and no history of earlier neurological or eye diseases. The three patients (age: 40 female,51 male,46 male) were all admitted because of occlusion of right posterior cerebral artery; this was con= firmed by CT-scans and angiography. They all showed a complete dense left homonymous hemianopia, that was quantified by Octopus perimetry during their stay in our clinic;it was rechecked before checking their eye movements for this study. Neurological examination did not reveal additional disturbances except for discrete reflex asymmetries in two cases. All patients showed 20/20 visual acuity with correction.

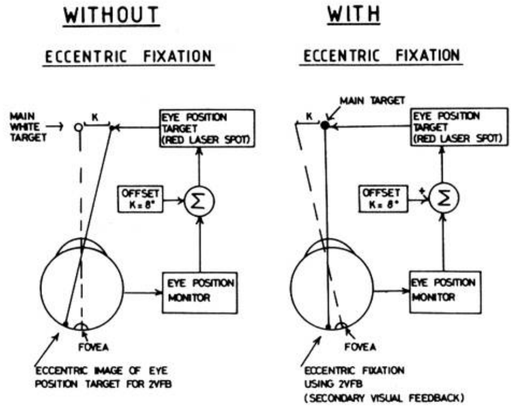

Fig.1: Setup for achieving eccentric fixation using 2VFB

*Setup and recording equipment* (cf.Fig1). Ss set in a comfortable chair with their head either fixed by a head rest and four head constraints (H.FIXED condition), or with head free to move (H.FREE condition) in a dimly lit room in a viewing distance of 100cm to a se= micircular white screen.One eye was patched, in patients this was the eye contralateral to the HH (right eye). Horizontal eye movements were recorded by monocular DC electrooculography (EOG) with a resolution of one degree.Head movements were recorded using a tight head band linked through two universal joints to a low torque ceramic potentiometer of infinite resolution. A white light spot of 1 deg visual angle served as the primary target; it was controlled by a mirror galvanometer linked to a signal generator that would generate horizontal steps of various amplitudes (+-5 to 30deg) and frequencies (0.01 - 1.5Hz). After cali= bration of eye and head movements including electronic summation to obtain gaze position a second -red laser- target of 0.3deg vis. angle was displayed. It was controlled by another mirror galvanometer that was linked to gaze position output through a low pass filter. After calibration Ss were asked to fixate the white center target and then to fixate the red laser spot as soon as it would appear. At first the laser spot had the same position as the white target when the eye fixated the target (feedback gain of 1,no offset). After 30 sec of practising Ss had to close their eyes. The position of the laser spot was now changed by an offset of about 8 deg off the center to the right i.e. towards the SHF in case of HH patients (Fig.1,left). The Ss was then required to accurately fixate the target, so that the laser spot was superimposed upon it (Fig.1,right). The same procedure was repeated several times with predictable and nonpredictable positions of the main white target and different offsets (4 deg,12 deg) of the red laser spot for eccentric 2VFB to right to obtain transient responses. Eccentric offset of 2VFB was then fixed. In this way adaptive responses to continuously applied eccentric fixation to different targets using 2VFB were tested.

öAfter a pause the head free condition began,with essentially the same procedure as with head fixed.Each set of trials lasted about 10 minutes.

## RESULTS and DISCUSSION.

### HEAD FIXED (Fig.2).

Transient responses. *Normal* Ss demonstrated transient stairstep patterns of normal latency and 3 to 4 steps when they were firstly exposed to eccentric fixation using 2VFB (upper left). To maintain this, they used saccadic square wave oscillations (upper right) of decreasing amplitude.
With non eccentric fixation HH *patients* demonstrated the earlier described (3) typical responses (Fig.2,lower left). Non predicted targets were fixated by multiple stairsteps of variable initial delay (0.3-0.5sec), and of variable total duration (up to 1.9sec). In case the target was lost, typically the target recovery strategy (3) was used (lower right), consisting of irregular macrosaccadic 'oscillations'.

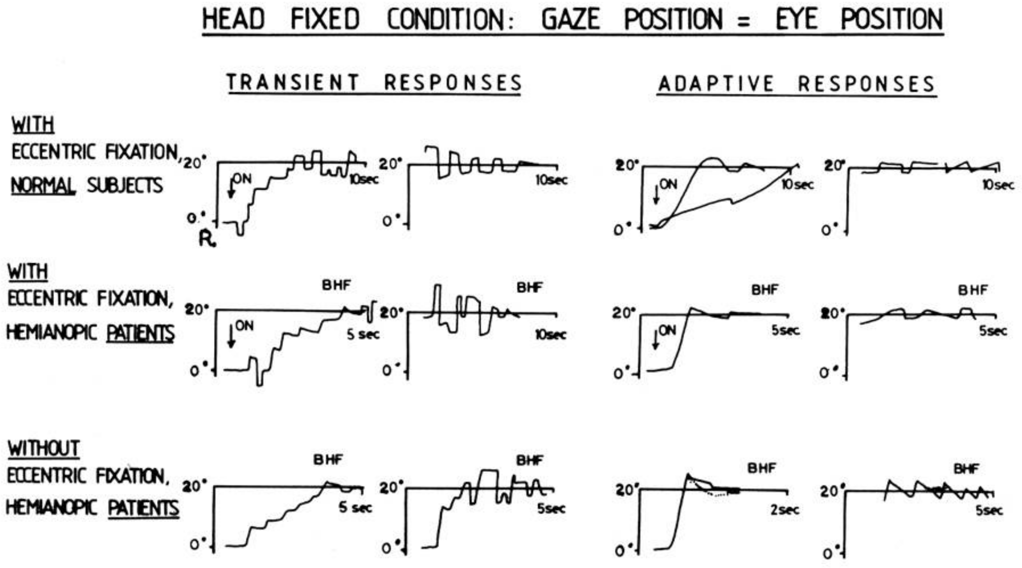

Fig.2: Gaze responses in head fixed condition.
R.=right,ordinates=gaze position,abszissae=time.On=2VFB on

A similar strategy of mostly irregular square wave oscillations occurred when HH *patients* tried to achieve and maintain eccentric fixation without training (transient;middle left). Initial capture of target using 2VFB for eccentric fixation was sometimes achieved by very time consuming multiple stairsteps.
Adaptive responses. After some training using always the same offset of 8 deg to the right, *normal* Ss tended to use slow or fast drifts instead of stairsteps to achieve eccentric fixation more rapidly (upper left). To maintain eccentric fixation, very small saccadic oscillations or slow drifts together with small oppositely directed saccades - a nystagmus like pattern - were used (upper right). In contrast, HH *patients* used large overshooting saccades followed by some slow backwards drift and small corrective saccades, when position of the eccentric 2VFB target was predictable

and the task had been trained. Maintenance of eccentric fixation was done by more irregular behavior of varying slow and fast drifts intercepted by small saccades. The former strategy resembled the strategy that was used by patients when predictable targets in the BHF were captured with foveal fixation (right, middle and lower). Of special interest was, that one patient with a longstanding acquired HH had developed a nystagmus like pattern to 'lock' on targets on the side of the BHF. A similar behavior has been described before (9,10).

HEAD FREE (Fig.3).

Transient responses. With head free to move (2nd set of experiment) Ss had of course undergone some training of the basic task. Also, the accuracy of the offset of the eccentric target was not as good as with head fixed due to limitations of the experimental setup. *Normal* Ss generally used a stairstep of only two saccades as transient responses, and then tried to match gaze position and target position using small irregular head oscillations rather than saccades to lock on target. In this way they made use of their compensatory eye movements (CEM, pursuit eye movements plus vestibular ocular reflex (VOR)) to keep on target. This included some degree of erratic, sometimes greatly off target leading gaze movements (upper left).

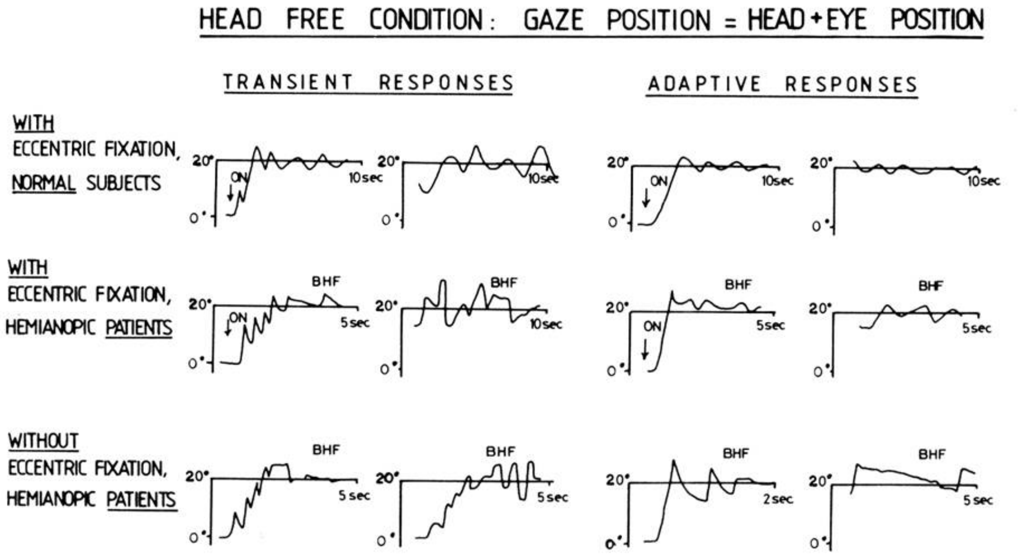

Fig.3: Gaze responses in head free condition.

With and without eccentric fixation HH *patients* used the same strategy of multiple stairsteps with fast CEMs during the head movement. CEM gain (ratio of eye to head velocity) was high for gaze shifts to the BHF, low for shifts to the SHF. They initially tried to maintain eccentric fixation in this transient state by avoiding head movements partly(left,lower),other when center fixation was permitted. Here,they completely avoided head movements.

Adaptive responses. *Normal* Ss soon learned to suppress larger saccades and to use small head movements to achieve and maintain eccentric fixation on the target (upper right). After some training they showed a gaze type III (8) like pattern when capturing a predictable target.

HH *patients* preferred to use gaze type I with eccentric fixation. With training they were able to suppress the asymmetrically high CEM gain that occured with gaze shifts to the BHF (middle right). `Locking on` the target,however, was done using a non regular combination of small head movements and some small saccades on top of CEMs. When non eccentric fixation was used, capturing the target was done through a large saccade with fast CEMs driving the target off the fovea even in this adapted state after some training. For maintaining the target in view head movements were avoided and a strategy of saccades with slow backdrift was used. This appeared to be more efficient than coping with asymmetrically CEMs of asymmetrical gain generated by head movements.

LATENCIES.

Latencies to achieve eccentric fixation ranged in *normal* Ss around 30 to 40 sec without training, around 5 to 10 sec after training. HH *patients* needed considerably longer (up to 80 sec) to achieve eccentric fixation, especially in the head free condition. After some training, however,they had almost similar latencies as *normal* Ss.

In *patients* acquisition of the primary target (predicted *and* non predicted) improved considerably after training (down to 0.25sec). This included a change of strategies from multiple stair-step to one-step gaze shifts. Subjectively they felt easier with head free to move and made therefore more often use of head movements than was expected from earlier studies.

We conclude that *short term* adaptation to eccentric 2VFB could optimize hemianopic patients' *long term* adaptation to the visual field defect. Eccentric 2VFB is a useful experimental task and it may help patients with acquired hemianopia to cope better, and perhaps faster, with their difficulties to acquire targets in their blind hemifield.

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