Virtual Reality Hemianopic Scotomas Induce Eccentric Fixation Scanpath Strategies to Optimize Highlevel Vision in Healthy Subj.

W.H. Zangemeister & U. Oechsner*

Depts. of Neurology & Informatics/AI, University Hamburg
Martinistre.52, D-20251 Hamburg,FRG, Fax +49-40-4717-5086
e-mail: whiz@uke.uni-hamburg.de

ABSTRACT

Normal Subjects (Ss) show a stairstep/ overshoot saccadic strategy similar to hemianopic patients (8) either when confronted with a virtual reality model of an artificial hemianopia using eye position feedback (H3-VRM), or when achieving eccentric fixation using 2ndVFB. Here gaze position is displayed simultaneously with the target and the subject learns either to superpose target and eye position feedback, or to position the gaze feedback target up to 9 deg off the target (eccentric fixation) which helps to keep the "blind side" in sight. Normal Ss confronted with H3-VRM as well as hemianopic patients minimize their deficit very fast and efficiently - much faster than without 2ndVFB training.

INTRODUCTION

As a new visual technical method secondary visual feedback (2ndVFB) was introduced by Zeevi & Stark(8). In 1985 Zangemeister et al.(6) showed that this technique could be applied in the therapy of hemianopic patients. Experimentally, normal subjects show a similar behaviour as hemianopics when they learn how to achieve eccentric eye fixation using secondary visual feedback. When Ss first try to achieve eccentric 2VFB they apply a stairstep saccadic strategy and/or macrosaccadic square wave oscillations comparable to the hemianopic patients **(Fig.1, upper left)**. After some training they adapt and now use slow and fast eye drifts to achieve eccentric fixation and a nystagmic pattern to maintain it **(Fig.1, upper right)**. We demonstrated that use of this technique can help hemianopic patients to overcome their deficit faster and more effectively by optimizing their visual motor strategy. Similarly as the healthy subjects they start with a stairstep pattern and, after some time that takes ca. five times longer than normal (2-4 sec), they develop their overshoot backdrift strategy using 2VFB of eccentric fixation in the seeing hemifield as an - in this case natural - tool to keep the visual target in sight **Fig.1 two lower rows)**. The functional rehabilitation of hemianopia has been shown to be improved, i.e accelerated and optimized, using this technique (5-7).

METHODS

The **virtual hemianopia simulator** uses the observer's own eye movements to map retinal coordinates onto the visual display.The virtual reality of homonymous hemiblindness is produced in real time with a

IEEE 97CH36136

normal subject by programming a scotoma map from a patient into the graphic memory of a computer. As a virtual reality system, the close linkage between human eye movement and display change is technically demanding as the feedback delay time is crucial to the optimal virtual reality of the virtual blind field.

Here, a simulation of hemifield blindness in normal subjects was produced by linking an eye position sensor with a computer visual display. Such a form of virtual reality permits to explore the adaptability under experimental control. Accuracy was about 0.1 degree (rms). A parallel link was used for synchronisation of the two computers. Homonymous hemianopia is simulated by superposition of the stimulus with a black rectangular mask which vertically extents over the whole screen and horizontally from the current gaze position to one of the screen edges, depending on the type of hemianopia to be simulated. To minimize time lag, speed optimized graphics routines (Fastgraph, Ted Gruber Software) are used. With a 166MHz Pentium computer and an ATI-mach64 video board, the mean time lag is about 5 ms for movements less than 1 degree and about 10 ms for movements more than 15 degrees. After standardization of clinical and technical diagnostic approaches, recording of basic and sophisticated visuomotor functions as alternating & sequential fast eye movements (EMs), visual search, and scanpath eye movements. For the **quantification** of the term **"similarity of eye movements"** Markov matrices and string editing (2-4,7) have been used previously. Both methods are applied to preprocessed eye movement data: Firstly defining regions of interest (ROIs) in the image under study. 2nd, the determination of the location of the subject's fixations. The points of fixation are sequentially numbered and linked through interfixational vectors that generate the scanpath. If successive fixations are located in the ROIs CDCA, the resulting sequence of letters is "CDCA". Thus the task of comparing the eye movements of a subject while repeatedly viewing an image is reduced to the **comparison of strings.** The distance of the two words (i.e. strings) is defined as the minimum number of editing operations like deletion, insertion and substitution of a letter, which is necessary to transform one word into the other. Thus between "brown" and "town" the distance is 2 (deletion of b, substitution r->t), between "house" and "mouse" it is 1 (substitution h->m). The maximum distance of two strings n-a and n-b with n-a < n-b is given by: **D (ab)max = n-a * chi + (n-b - n-a) * delta** , where chi is the cost of exchange, and delta the cost of insertion or deletion (Choi&Stark 1995). The Similarity is then given by (7):

S (ab) = 1 - D(ab) /D(ab)max

In case of sequentially identical letters within a string it is possible to compress (c) this string, such that multiple sequential fixations in one ROI are compressed to one fixation.

RESULTS

A simulated homonymous hemianopic scotoma was stabilized on the fovea of 10 normal observers while they

attempted to maintain a moving target in clear view, or to perform a search task. Five of the subjects were naive and were free to view the target in any way they chose. Five other subjects had undergone one experimental session a week before, where they had to practice 2ndVFB for 30 Minutes.
Similarly as in 2ndVFB, eccentric eye positioning developed within two minutes of viewing time in all subjects, with a range of eccentricity between 1 and 9 deg off the virtual scotoma location. The durations of correctly positioned fixations became longer during eccentric viewing practice indicating rapid improvements in fixation stability, while fixation durations of incorrect, error fixation positions became shorter: demonstrating high level adaptation to the virtual scotoma defect.
The types of eye movements that were used by the subjects resembled very closely eye movements used by hemianopic patients to overcome their deficit, and also by normal subjects adapting to 2ndVFB: i.e. the transition from stairstep saccades to overshooting saccades with drifts and glissades for more accurate "fixation".
Those normal subjects that had a half hour training session a week before exposure to H3-VRM demonstrated a significant faster increase of eccentric total viewing time, fixations and fixation durations in their "seeing hemifield".

VISUAL IMAGERY <u>with</u> and <u>without</u> VIRTUAL HEMIANOPICA (Figs.2,3).
Following works of Hebb, Oechsner et al. 1996 compared sequences of eye movements of subjects looking at the real visual stimulus, a set of pictures and afterwards at their mental image. Using string edit analyses (2,7) they were able to demonstrate firm evidence for scanpath sequences of their subjects' eye movements in both conditions.
Shortly after the run of the last group of pictures in our simulated "patients" and normal subjects an additional run was appended where our patients had to view the empty VDT and imagine the pictures they just saw for 10 sec in the same sequence and within the same time, each picture 5, 30 and 60 sec after the real picture had appeared on the VDT. This provided us with data on imagined scanpaths in virtual hemianopic "patients" and normal subjects, and thus information as to how at this level of deficiency i.e. visual hemifield defect leads to a distorted visual image that otherwise could not be detected. Similarly as in "real" hemianopic patients the results demonstrate a "convergence of visual imagery": The three sequential visual imageries show a significantly lower similarity to the viewing of the real image than with each other in both groups, virtual hemianopic subjects and normal subjects.

DISCUSSION & CONCLUSION

Normal Subjects show a stairstep overshoot saccadic strategy similar to hemianopic patients either when confronted with a virtual reality model of an artificial hemianopia using eye position feedback (H3-VRM), or when achieving eccentric fixation using 2ndVFB. Here gaze position is displayed simultaneously with the target and the subject learns either to superpose target and eye position feedback, or to position the gaze feedback target up to 9 deg off the target (eccentric fixation) which helps to keep the "blind side" in sight. Using this technique normal Ss confronted with H3-VRM similarly as hemianopic patients minimize their deficit very fast and efficiently - much faster than without 2ndVFB training.

Normal healthy subjects when exposed to a virtual reality hemianopia apply the same eye movement strategies that the hemianopic patients use.

They learn much faster than the hemianopic patients how to optimize their eye movements with respect to the visual deficit.

This learning process can be even accelerated by a training session with the 2ndVFB eccentric fixation technique.

The same accelerating effect of 2ndVFB training has been shown for hemianopic patients learning to apply a gaze overshoot strategy.

The visual imageries of of normal subjects as well as of hemianopic patients are quite different from the primary viewing of the real image, and they converge to each other with repetition.

The eccentric fixation stairstep - overshoot optimizing strategy is a general approach that is always applied in changing random or pseudorandom situations by healthy subjects as well as patients when they face the same problem, i.e. a hemifield scotoma. Therefore it is most likely a "medium level" strategy, that is more unconsciously developed. But it can be helped by the above described actions and techniques.

The convergence of visual imageries in difference to the real image presentation argues for a high level effect that has nothing to do with the visual field defects and the strategies to overcome the deficit optimally, as it is to be found in both healthy and hemianopic subjects.

REFERENCES

1.Bertera, JH. Visual search with simulated skotomas in normal subjects. Invest.Ophthal. Vis.Sci.29: 470-478, 1988

2.Choi YS, Mosley AD, Stark LW: String editing analysis of human visual search. Optomet.& Vis.Sci. 72: 439 - 452 ,1995

3.Noton,D., Stark,L. Scanpaths in eye movements during pattern per-ception. Science 171, 308-311,1971

4.Oechsner U, Gbadamosi J, Zangemeister WH. Eye movements during visual imagery - analysed using string editing methods. Proc. Artif. Intell. PAI4 ed.by C.Freksa, Koeln 1996

5.Zangemeister WH, Meienberg O, Stark L, Hoyt WF.: Eye - Head Coordination in Homonymous Hemi anopia. J. Neurol 1982;225:243

6.Zangemeister WH,Dannheim F. Adaptation of Gaze to Eccentric Fixation in HomonymousHemianopia Adv in BioSci 1986; 57:247-52

7.Zangemeister WH & Oechsner U: Evidence for scanpaths in Hemianopic patients shown through String editing methods. In: **Visual Attention and Cognition, ed. by WH Zangemeister,** HS Stiehl & C Freksa, Elsevier N.Y.1996,212

11.Zeevi YY,Peli E,L.Stark.Study of eccentric fixation with secondary visual feedback.J Opt Soc Am 69: 669-675 1979

Fig.1: 2ndVFB responses.
Fig.2: compares the hemianopic group (left) and the normal subjects after H3-VRM exposure y-axis: median string similarity of the six methods used (RSE:region string editing, VSE:vector string editing, MA: markov c:compressed, w: weighted). Note: Both groups show significant difference between real and imagined picture scanpath; real patient group shows decrease of visual images over time (5-30-60 sec).

Fig.3 shows real and the 30 sec later imagined scanpaths of a virtual hemianopic "patient's" visual image (right) looking for 10 sec at a realistic (1st row), abstract (2nd row), random step stimulus (3rd,5th row): Upper 3 rows **before**, lower 2 rows **after** 2ndVFB training.

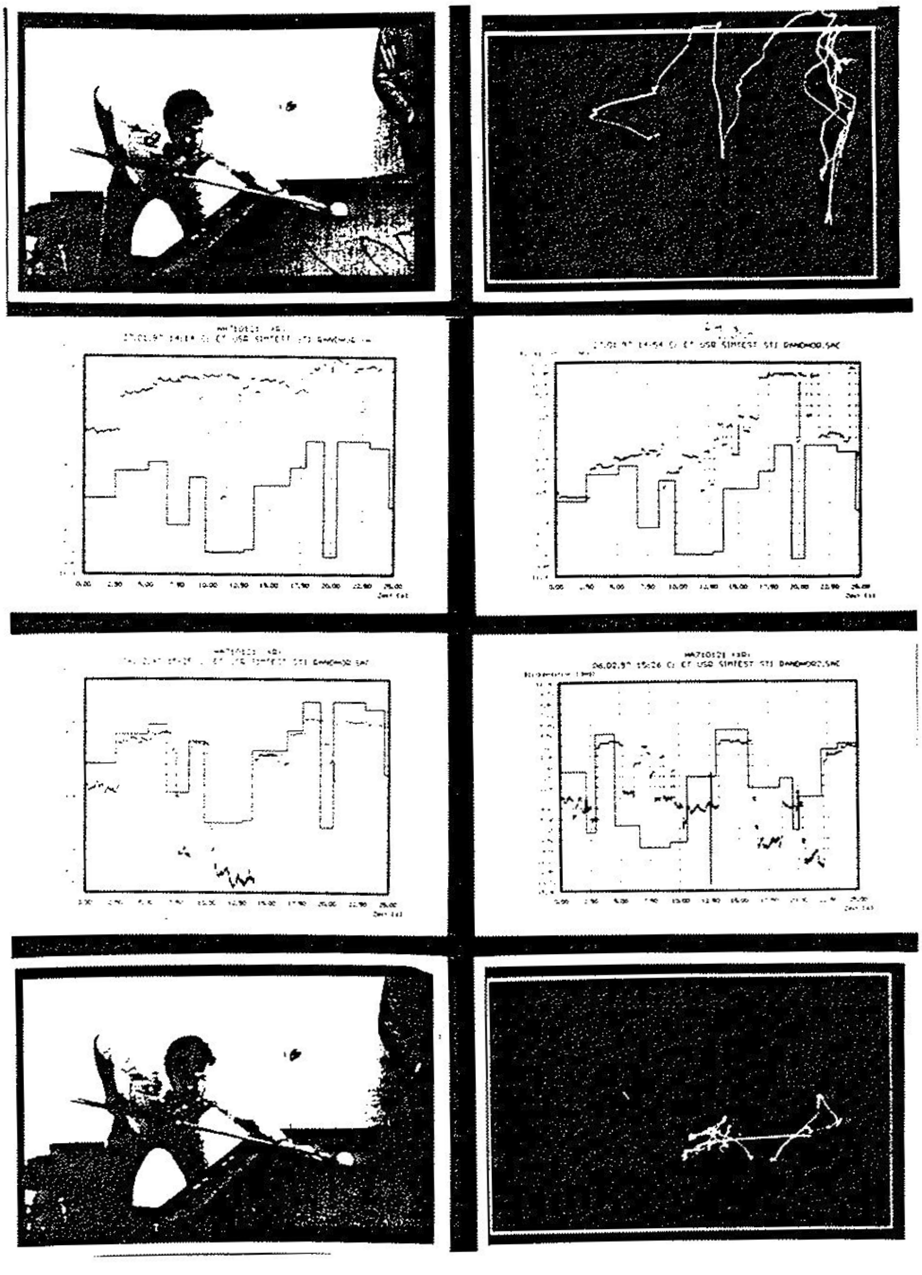

FIGURE 3

FIGURE 1

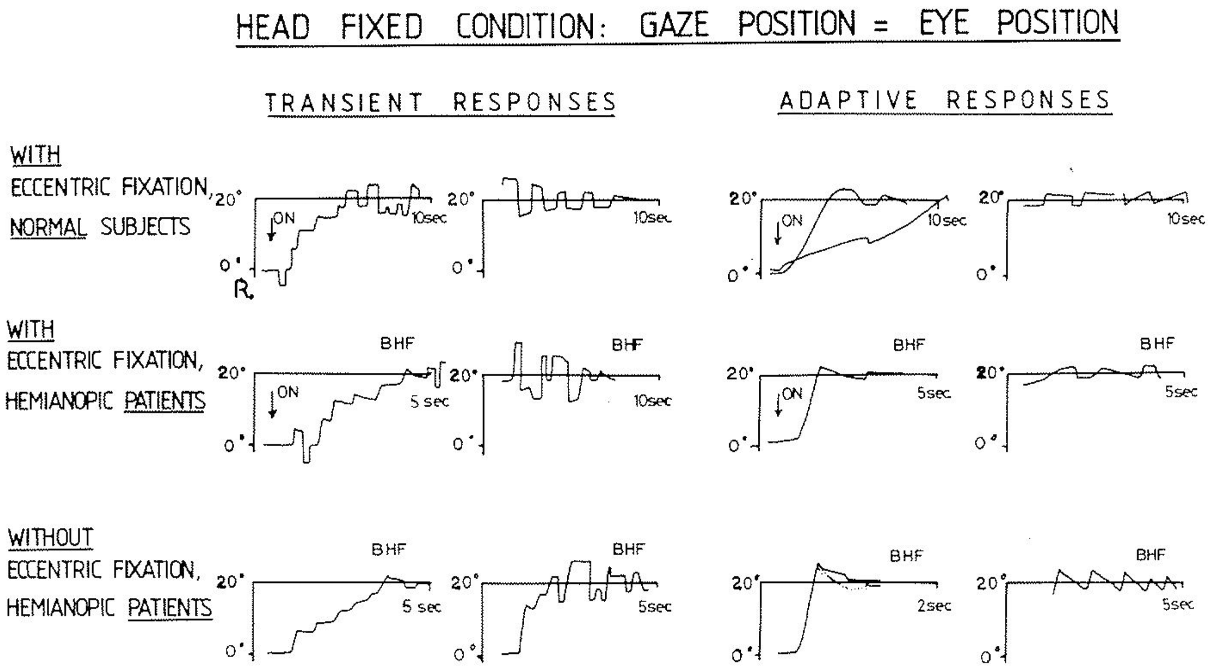

FIGURE 2