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ADAPTATION TO VISUAL FIELD DEFECTS WITH VIRTUAL REALITY SCOTOMA IN HEALTHY SUBJECTS

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1. ABSTRACT

Normal Subjects (Ss) 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 secondary visual feedback (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 as well as hemianopic patients minimize their deficit very fast and efficiently, much faster than without 2ndVFB training.

2. INTRODUCTION

As a new visual technical method secondary visual feedback (2ndVFB) was introduced by Zeevi and Stark in 1979. In 1985 Zangemeister et al. showed that this technique could be used in the treatment of reading disorders, visual discomfort and associated perceptual distortions of patients with hemianopia (Zangemeister et al. 1982). This method permits to instruct and train patients with hemianopia to apply parafoveal, eccentric vision while searching and scanning through pictures, their environment and while reading. Experimentally, normal subjects show a similar behaviour as hemianopics when they learn how to achieve eccentric eye fixation using secondary visual feedback. Here, gaze position is displayed simultaneously with the target and the subject learns to either superpose target and the gaze-feedback target (centric fixation) or to position the gaze-feedback target off the visual stimulus (eccentric fixation, ranging between 1 and 9 deg visual angle). When Ss at first try to achieve eccentric 2ndVFB they apply a stairstep

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saccadic strategy and/or macrosaccadic square wave oscillations comparable to the hemianopic patients. After some training they adapt and now use slow and fast eye drifts to achieve eccentric fixation and a nystagmic pattern to maintain it. - In the present study a simulation of virtual hemifield blindness in normal human subjects was produced by linking a high accuracy eye position sensor with a computer visual display. This eye controlled system may be classified as a form of virtual reality for safely exploring the effects of visual defects, diseases, and adaptability under experimental control (Bertera 1988).

3. METHOD

A homonymous hemianopic simulated scotoma (VirtH3) 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 and scanning task of 10 sec viewing Five of the subjects were naive and were free to view the target (alternating step or pursuit stimulus, pictures, 10sec viewing, 2min. one set of 9 trials, 15 sets in 40 min.) 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. For the quantification of the term "similarity of eye movements" Markov matrices (Stark and Ellis 1981) and string editing (Stark and Choi 1995; Zangemeister et al. 1995) have been used. Both methods are applied to preprocessed eye movement data. 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 imagery that otherwise could not be detected.

4. RESULTS AND DISCUSSION

Similarly as in normal 2ndVFB, eccentric eye positioning developed within two minutes of viewing time in all VirtH3-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 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 significantly faster increase of eccentric total viewing time, ecc.fixations and ecc.fixation durations in their "seeing hemifield" (Tab.1). Virtual hemianopics get the pursuit stimulus, about 1 to 2 cycles later than normal subjects.- Using string edit analyses, Brandt and Stark (1997), Zangemeister et al. (1995) and Gbadamosi et al. (1997) were able to demonstrate firm evidence for scanpath sequences of their subjects' eye movements in performing real viewing and visual imagery. As in "real" hemianopic patients our results

Table 1. Eccentric viewing time (VT) in % of total viewing time; % of eccentric Fixations (EF), mean duration of single eccentric Fixations in sec (DSEF) of 10 healthy virtual hemianopic subjects

	No 2nd VFB (n=5)			With 2nd VFB (n=5)		
	VT	EF	DSEF	VT	EF	DSEF
First trial (#1)	5	11	0.280	12	25	0.355
Last trial (#15)	45	52	0.450	73	86	0.525

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. The visual imageries 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 results suggest a "convergence of visualization" in all normal, hemianopic, and virtual hemianopic subjects: eye movement sequences were significantly less similar for viewing and re-visualization (but still significantly above the measure of similarity calculated for random sequences) than those for the imageries among each other. Similarities between consecutive eye movement sequences showed a major difference between real viewing and the first imagery, whereas between the first and the last two imageries there was only a comparatively slight increase in similarity. The matching results for all three goups suggest a strong top-down component in viewing an image: a mental model of the thing viewed is constructed early on, which takes an essential part in controlling eye movements during viewing.

The eccentric fixation stairstep-overshoot optimizing strategy is a general approach that is always applied in coping with 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 subconsciously developed and that can be helped by the above techniques.

Table 2. Comparison of visual imageries (5, 30, 60) later than real presentation (0) calculated from median region string similarity indices (Zangemeister et al. 1995) of 10 normal VirtH3 Ss, 10 real hemianopic patients (from Gbadamisi et al. 1997, and 10 normal Ss in response to 6 visual stimuli

Similarity index	VirtH3-sS	Real H3 pat.	Nor. Ss
Random	0.20	0.25	0.26
Real image (0) and			
5 sec later (0-1)	0.42	0.45	0.43
30 sec later (0-2)	0.40	0.38	0.42
60 sec later (0-3)	0.41	0.40	0.40
(1 - 2)	0.54	0.52	0.46
(1 - 3)	0.49	0.48	0.47
(2 - 3)	0.51	0.50	0.47

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