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Compensatory visual field training for patients with hemianopia after stroke

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Abstract

Twenty-one patients with hemianopia received 4 weeks of compensatory visual field training. Detection of and reaction time to visual stimuli were measured with eyes fixating (condition A) and with use of exploratory eye movements (condition B) before and after training. Twenty-three healthy individuals served as control subjects for measurements of parameters during both conditions. Patients with hemianopia to either side showed a marked improvement of detection and reaction time during condition B, but minimum or no change during condition A. Improvements were maintained 8 months after training. Activity of daily living skills also improved in all patients. The size of scotoma on computerized perimetry, in contrast, remained unchanged. Training improved detection of and reaction to visual stimuli without restitution of the visual field defect. © 2001 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Hemianopia; Rehabilitation; Stroke; Treatment outcome

Hemianopia accounts for more than 70% of all visual field defects [2]. Recovery from scotoma only occurs in less than 20% of all patients [11]. Patients with hemianopia may have difficulties to notice other persons or suffer from reduced visual-spatial perception [6]. Hemianopic paralexia often occurs due to impaired viewing of ensuing words toward the end of lines [9,10]. Despite these significant disabilities, therapeutic strategies are scarce. Various electronic devices using computer or television screens have been developed to train saccadic eye movements [4,5]. This technique, however, artificially reduces the size of the visual training field to 5–40°. Furthermore, transfer of monitor practice into functional skills has been difficult [3]. We therefore trained saccades with compensatory visual field training (CVFT) on a large training board to enhance the detection of and reaction to visual stimuli.

Twenty-one patients with homonymous hemianopia were studied (Table 1). Patients with previous stroke or brain damage, severe loss of visual acuity, oculomotor diseases were excluded. The study was approved by the Ethics Committee of the University of Essen. Visual fields were assessed on the day before and after training (background illumination 3.14 cd/m^2, Tübinger automatic perimeter) using a field with a radius of 80°. One-hundred and three stimuli were exposed. A difference of >four stimuli (or three stimuli in the neighborhood) was considered a clinically significant change. A difference of four stimuli (or less) was considered stable.

CVFT was performed on a 1.25 × 3.05 m training board. Right and left sidewings were moved inwards 30°. Forty red lights (diameter 1.5 cm) are distributed across the board in four horizontal lines with ten lights in each line. Patients sat 1.5 m away from the board so that visual fields of subjects were filled out by the board. A chin suspension was used to eliminate any head movements (Fig. 1). All patients underwent a pretraining evaluation of visual performance including measurements of two parameters: (1) detection of a visual stimulus and (2) reaction time (RT). To measure the detection of light stimulus (duration 1 s), patients were asked to respond to each perceived stimulus by pressing a hand-held key button. Failure to respond to a stimulus was called a 'missed stimulus'. The RT was the time that elapsed between onset of stimulus presentation and response. The

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Table 1
Clinical and demographic data of study population[a]

	Patients	Control subjects
Age, years, mean ± SEM	59.2 ± 3.5	63 ± 3.2
Sex M/F	14/7	11/12
PCA-infarct/hemorrhage	16/5	–
Side of hemianopia L/R	8/13	–
Months post stroke, median (range)	1.5 (0.5–24)	–

[a] M, male; F, female; L, left; R,right; PCA, posterior cerebral artery.

maximum interval between two stimuli was 3 s to ensure maintenance of attention to task. Some patients were unable to react within 3 s before training, but did react after training. To compare measurements in these patients, a RT of 3 s was assigned for a missed stimulus. We previously observed that patients detected the stimulus with more time when allowed to use eye movements. Therefore, the RT of these patients may be greater, but assigning 3 s was the most conservative approach for the statistical analysis. False-positive responses were also monitored. Both parameters were assessed during two different conditions. During condition A, patients were required to fixate a central point on the board and to react to single visual stimuli. Fixation was closely monitored. Eighty stimuli were presented during a period of 205 s with varying intervals between 1 and 3 s. During condition B, multiple stimuli were randomly presented on the board. Patients were asked to identify a target stimulus (e.g. square of four lights) in each hemifield with use of exploratory eye movements, but without head movements. For condition B, the duration of stimulus presentation was 3 s. Twenty-seven target stimuli appeared again at varying intervals. All control subjects underwent one set of measurements during condition A and B. Patients repeated all measurements after 4 weeks of training. Follow-up measurements were obtained from 15 patients after 8 months. A questionnaire to describe ADL was also completed by each patient (Fig. 2) [5]. Item #10 (‘reading’) was added for this study. Scoring was as follows: 0, no problem; 1, rare problem; 2, partially relevant problem; 3, frequent problem; and 4, very frequent problem. All patients received two daily training sessions of 30 min each for a total of 4 weeks. During training, multiple light stimuli appeared simultaneously on the training board. Patients were asked to scan the board for a target stimulus (horizontal line of three lights) with exploratory eye movements, but without head movements, and respond by pressing the key button. Patients were instructed to systematically scan the board horizontally (row by row). Our primary outcome measures were (1) the change in the number of missed stimuli and (2) the change in RT to stimuli during condition (A) and (B) before and after training. The secondary outcome measure was the change on the self-reported scale of related daily living functions. A paired non-parametric comparison using the Wilcoxon signed-rank test was applied to calculate differences between pre-training and post-training measurements. Unpaired comparisons were calculated with Mann–Whitney rank-sum test. A Friedmann statistic for multiple paired non-parametric

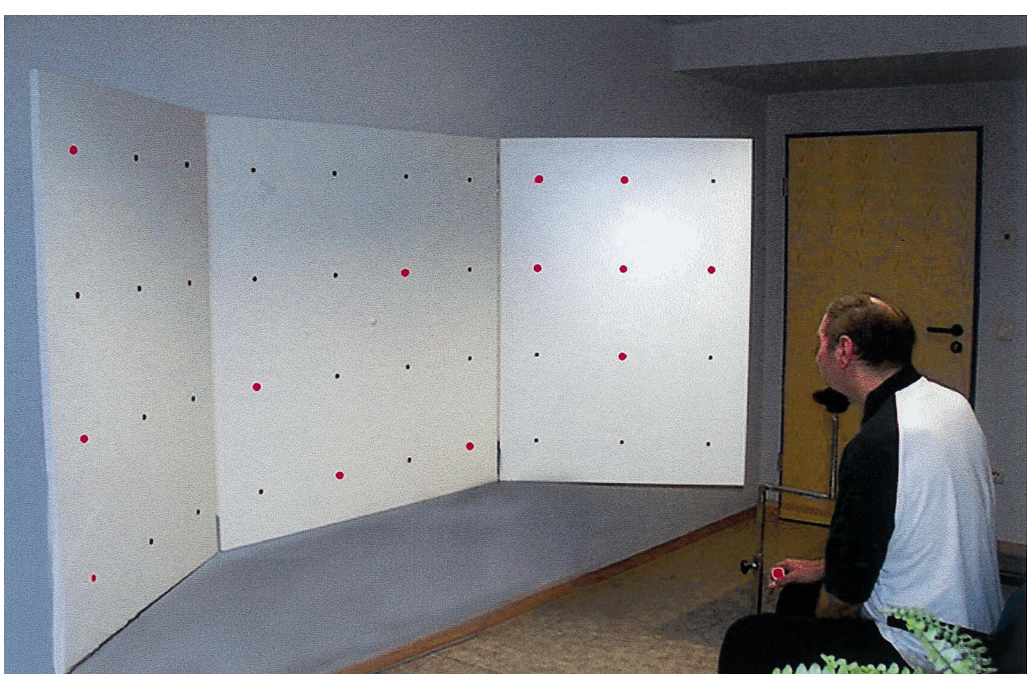

Fig. 1. Subject during compensatory visual field training sitting at a distance of 1.5 m away from the training board (see text for details).

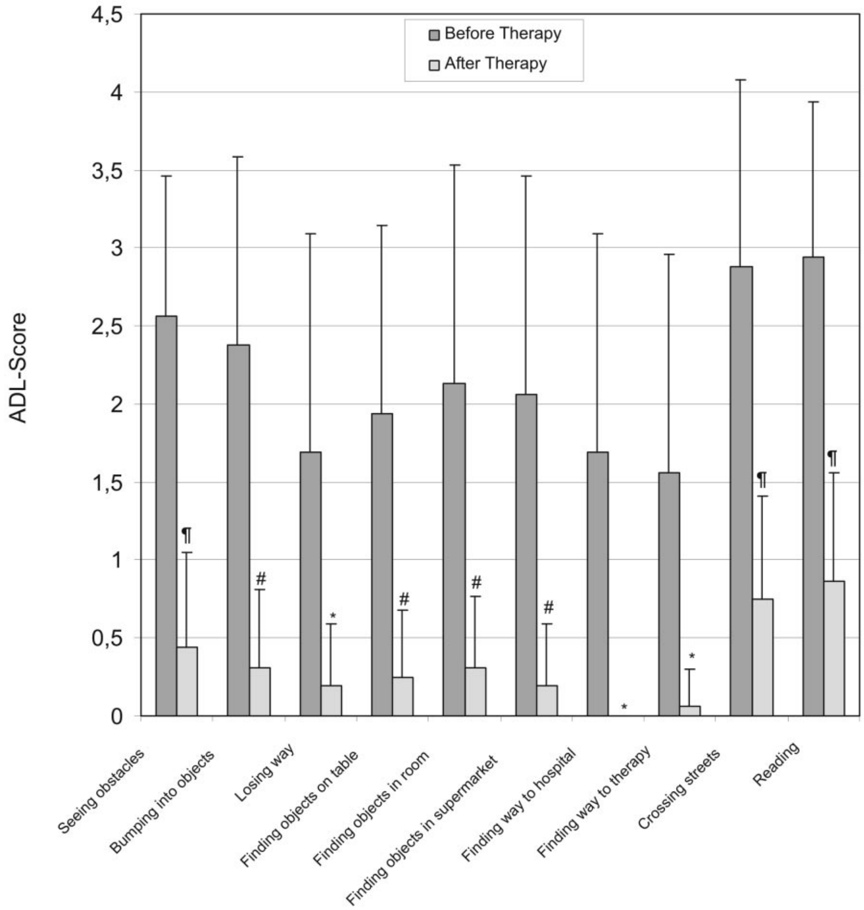

Fig. 2. Results from the self-rating scale of daily living activities before and after training. 0, no problem; 4, very frequent problem. Data are mean (SD). $*P < 0.01$, $^{\#}P < 0.001$, $^{¶}P < 0.0001$, by Wilcoxon signed-rank test.

comparison was used to calculate changes in primary endpoints at follow-up (SPSS, version 8.0).

Control subjects responded to all stimuli. Condition A: the RT to stimuli in the left and right hemifield were very similar (423 vs. 427 ms). Condition B: the RT in the right hemifield was shorter compared to the left hemifield (951 vs. 1054 ms; $P = 0.001$).

Table 2 summarizes measurements from patients. Left hemianopia, condition A: before and after training, similar numbers of stimuli (29 vs. 30) and RT (1166 vs. 1157 ms) were missed. The RT to stimuli in the intact (right) hemifield were similar before (476 ms) and after training (528 ms) and not significantly different to RT of controls. Condition B: in contrast, these patients significantly improved from 20 to 14 (of 27) missed stimuli ($P = 0.02$). The RT in the hemianopic visual field improved from 3000 to 1754 ms ($P = 0.02$). Right hemianopia, condition A: before and after training, similar RT (1074 vs. 999 ms) were observed. Patients missed slightly less stimuli after training. Again, all patients reacted much faster to stimuli presented in the intact (left) hemifield. Condition B: these patients improved from 17 to 13 (of 27) missed stimuli ($P = 0.003$). The RT in the hemianopic visual field improved from 1689 to 1311 ms ($P = 0.02$). Visual field defects on perimetry were unchanged before and after training. Fig. 2 shows results of ADL before and after treatment. Eight months after training, the number of missed stimuli in patients with hemianopia on either side was unchanged. In patients with left hemianopia, the RT were shorter during condition A (926 ms; post-training 1157 ms; n.s.) and during condition B (1582 ms; post-training 1754 ms). In patients with right hemianopia, the RT (1104 ms) was longer (post-training: 999 ms; n.s.) during condition A, but shorter (1203 ms) during condition B (post-training: 1311 ms; n.s.).

The main finding is that CVFT improved detection of and reaction to visual stimuli with use of exploratory eye movements (condition B). These improvements were maintained at follow-up. No effects were seen during fixation suggesting that training one particular task does not necessarily translate into a different task that was not specifically addressed during training. The observed improvements may not be related to the visual field defect itself, but rather to more efficient saccades. These findings support our hypothesis that CVFT contributes to a compensation of hemianopia without restitution of visual fields.

Table 2
Number of missed stimuli and reaction times in patients[a]

Parameter	Left hemifield			Right hemifield		
	Before training	After training		Before training	After training	
Patients with left hemianopia						
Condition A/missed stimuli (#)	29 (12–34)	30 (11–34)	n.s.	0	0	
Condition B/missed stimuli (#)	20 (10–23)	14 (5–18)	$P = 0.02$	0	0	
Condition A/reaction time (ms)	1166 (740–1492)	1157 (557–1498)	n.s.	476 (435–611)	528 (439–661)	n.s.
Condition B/reaction time (*ms*)	3000 (1370–3000)	1754 (943–3000)	$P = 0.02$	1466 (1216–3000)	1167 (1023–1507)	$P = 0.02$
Patients with right hemianopia						
Condition A/missed stimuli (#)	0	0		24 (14–32)	23 (9–28)	$P = 0.02$
Condition B/missed stimuli (#)	0	0		17 (12–20)	13 (7–16)	$P = 0.003$
Condition A/reaction time (ms)	490 (405–609)	497 (444–617)	n.s.	1074 (639–1442)	999 (585–1276)	n.s.
Condition B/reaction time (*ms*)	1382 (1124–1759)	1275 (924–1555)	$P = 0.02$	1689 (1085–3000)	1311 (1111–1858)	$P = 0.02$

[a] Data are median (25–75th percentile). All comparisons by Wilcoxon signed-rank test. #, number; ms, milliseconds.

Partial recovery of the scotoma has been reported after repetitive stimulation of the transition zone between the intact and damaged visual fields [11]. Kasten et al. [4] also reported a small visual field recovery of nearly 5°. Restitution of scotoma, however, has been called into question [7]. Training with repetitive stimulation at the transition area may bias the gaze towards the blind region or induce viewing on eccentric sections of the retina [8]. In another study of 12 hemianopic patients that used similar methods but controlled for these variables, no increases of visual fields were found [1]. Therefore, reports of visual restitution secondary to increases in size of visual fields should be interpreted with caution. Our data confirm that restitution of visual fields is probably not possible with existing methods.

Training exploratory eye movements to compensate for a visual field defect is a different approach that has received less attention so far. Kerkhoff and colleagues systematically trained saccadic eye movements on a computer screen [5]. Their intervention led to an increase in the visual search field, minimal reduction of scotoma in some patients, and improved functional activities. The intervention introduced in our study, however, is different because the training board offers a large area of practice that corresponds more closely to the natural visual field of healthy individuals. Patients with hemianopia to the right were less impaired before training compared to left hemianopic patients (Table 2), although the extent of visual field defect was not different. Normal subjects also reacted significantly faster to visual stimuli presented in their right hemifield compared to the left. Eye movements to the right may be faster in left-to-right readers as a result of daily practice such as reading [9]. A randomized controlled trial with patients who are not trained is needed to examine the exact therapeutic efficacy of CVFT in patients with hemianopia.

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