

## THE USE OF ROTATING CHECKERBOARD PATTERNS IN THE TREATMENT OF AMBLYOPIA

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*Abstract.* Sixty-four amblyopic children (mean age 7.5 years, age range 4-12 years) were subjected to treatment using slowly rotating patterns of different spatial frequencies. In 20 amblyopes square-wave gratings (spatial frequencies 0.26-16.84 c/deg), in 44 checkerboard-patterned structures (spatial frequencies 0.04-5.2 c/deg) were used for stimulation. The mean improvement of the distance visual acuity was significantly higher in the checkerboard-stimulated group (3.59 equidistant optotype lines) than in the grating-stimulated group (2.71). As the highest spatial frequency of the checkerboards was substantially lower than of gratings, the results cannot be explained in terms of optical qualities of the stimulating patterns. Other factors, such as short-term occlusion, accomplishment of demanding visuomotor tasks and the quality of cooperation and attentiveness of the patients are considered to be more important for the success of treatment.

### INTRODUCTION

The most widely used form of therapy for amblyopia (unilaterally reduced visual acuity without detectable organic basis) is a long-term occlusion of the non-amblyopic eye, though it is generally acknowledged to be a tedious and socially disruptive procedure with a high failure rate.

Recently (1978) a method of treatment has been suggested by Campbell et al. (2) to give a rapid improvement in both anisometropic and strabismic amblyopes. The method required an occlusion of the non-amblyopic eye once a week for only 7 min, during which the patient successively viewed a series of seven slowly rotating high-contrast square-wave gratings of different spatial frequencies, each for one minute. The gratings were located behind a clear plastic plate, on which drawing games could be played to ensure proper fixation of the gratings. The authors claimed that, in the course of three seven minute treatments, 73% of the patients achieved a 6/12 or better vision in the amblyopic eye. The new method is thought to be neurophysiologically founded, in that all visual cortical neurones are stimulated by the use of different spatial frequencies at continually varying orientations.

However, it is well known from the study of visual evoked responses that the checkerboard-structured patterns are more effective as visual stimuli than gratings, since they activate greater groups of cortical neurons (12). The aim of the present study was to compare the effects of the rotating checkerboard patterns and gratings on the visual acuity of the amblyopic eye. Preliminary results have been already published (11).

#### METHODS

A device (Fig. 1) similar to the original Campbell's visual stimulator was used to stimulate the patient's amblyopic eye. At the top of this device any one of the 7 checkerboard-patterned discs were rotated for one minute during which they completed one revolution. The child observed the rotating pattern, starting with the lowest spatial frequency, from a distance of 30 cm with the good eye occluded, and was encouraged to play drawing games with the supervisor or other patient on the transparent cover plate. The spatial frequency of the checkerboards ranged from 0.04 to 5.2 c/deg. Square-wave gratings were used instead of checkerboards for the control group of patients. Their spatial frequency ranged from 0.26 to 16.84 c/deg as was the case in the Campbell's (2) original investigations.

Six children of a group of 70 amblyopics who were referred to our ophthalmologic clinic and completely orthoptically assessed were diagnosed non-amblyopic, because their visual defect could be rectified by correct eye glasses. The remaining 64 subjects (mean age 7.5 years, range 4-12 years) were divided into two groups: Twenty subjects formed a control group and were treated using the square-wave gratings, 44 subjects were treated using the checkerboard patterns. The classification of the patients according to the type of treatment, type of amblyopia



Fig. 1. The treatment device with the checkerboard stimulus patterns.

and the initial distance visual acuity (VA) is presented in Table I. The decimal equivalent of the Snellen fraction (e.g.  $6/30 = 0.2$ ), called decimal VA, is used throughout.

Each child was subjected to about 20 weekly 7 min treatment sessions. In some cases 3-5 sessions were applied during the first week. The VA was tested immediately before and after each session using the projection line optotypes (C. Zeiss, Jena) in both eyes.

TABLE I  
Distribution of the amblyopic patients

Amblyopia type	n	Visual acuity (M±SD)		
		Checkerboards	n	Gratings
Anisometropia	17	0.17±0.17	10	0.25±0.08
Strabismus	12	0.22±0.10	3	0.27±0.12
A+S	15	0.18±0.12	7	0.21±0.08
Total	44	0.18±0.10	20	0.24±0.08

## RESULTS

*Changes of the VA in the course of treatment.* Figure 2 illustrates typical changes of the VA in the course of the treatment. On the average an end value of the VA was reached in 12 weeks using the checkerboard patterns and in 15 weeks using the gratings. Table II summarises the

results of the treatment in both groups. In this Table the improvement of the VA is expressed in normalized, equidistant optotype lines (the size differences of the two consecutive lines correspond to 0.1 log units). The mean improvement of the checkerboard group is significantly better than of the grating group (total values in Table II).

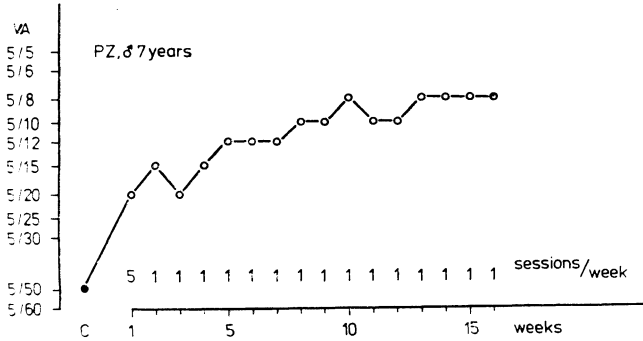


Fig. 2. The typical changes of the visual acuity (VA) in the course of treatment sessions.

The individual values of the pre-and post-treatment VA are demonstrated on Fig. 3A and B. In these scattergrams each patient is represented by a circle; symbols falling on the oblique identity line indicate no change of the initial VA, upward displacement of the circles indicates an improvement of the VA at the end of the treatment. In the checkerboard-group (Fig. 3A) the VA improved in 42 subjects of 44, in 22 of them to the clinically acceptable value of 0.5 or better. In the grating-group (Fig. 3B) 18 subjects of 22 display an improvement of their VA, in 11 of them to the value of 0.5 or better. On inspecting these scattergrams a dependence of the final VA on the initial VA can be seen. The correlation coefficient between these two values is high ( $r = 0.682$  for the checkerboard group and  $r = 0.492$  for the grating group)

TABLE II  
Improvement of the VA after the treatment (in equidistant optotype lines)

Amblyopia type	<i>n</i>	Checkerboards (M±SD)	<i>t</i> -test	<i>n</i>	Gratings (M±SD)
Anisometropia	17	3.71±1.75	$P < 0.025$	10	2.34±1.22
Strabismus	12	3.93±1.72	n·s	3	3.53±1.55
A+S	15	3.17±2.20	n·s	7	2.87±1.82
Total	44	3.59±1.84	$P < 0.025$	20	2.71±1.48

and statistically significant for both groups ( $P < 0.001$  for the checkerboard group and  $P < 0.05$  for the grating group). Therefore, for the evaluation of the treatment effects it is necessary to compare patients with similar initial visual acuities.

With respect to this conclusion the patients were divided into two subgroups: the first included the patients with an initial VA of 0.2 or lower, the second subgroup those with initial VA higher than 0.2. For both subgroups the number of patients who achieved the final VA of 0.5 or better was calculated. As the number of patients in our grating group is rather low (20), data was collected from the 10 papers published

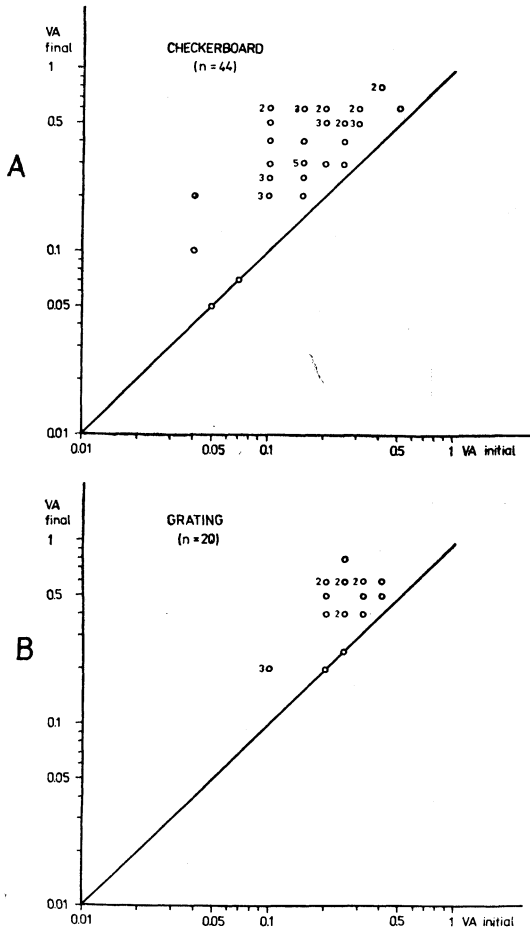


Fig. 3. Scattergrams of the values of the VA at the end of the treatment (VA final) in comparison with the VA values at the beginning of the treatment (VA initial) for the checkerboard (A) and square-wave grating (B) stimulated groups.

TABLE III

The number of amblyopes who reached the final VA of 0.5 or better and their dependence on the initial VA

	VA final $\geq 0.5$			
	<i>n</i>	Checkerboards	<i>n</i>	Gratings
VA initial $\leq 0.2$	32	11 (34%)	108	21 (19%)
VA initial $> 0.2$	12	11 (92%)	207	143 (69%)

in last years (2, 3, 5, 8-10, 13-16) and describing the effects of the grating treatment. After inclusion of our 20 subjects this group (Gratings) consisted of 315 patients (Table III).

Also in this comparison the results are in favor of the checkerboard group, but the difference is statistically significant for the group with higher initial VA ( $\chi^2 = 15.98$ ,  $P < 0.001$ ) only.

*Visual evoked potentials (VEPs) in amblyopia.* VEPs are of great value in assessing the functional state of the eye-brain system (12). In 26 amblyopic children VEPs were recorded using a pattern-reversal technique. Lower amplitudes and or prolonged peak-latencies (Fig. 4) we-

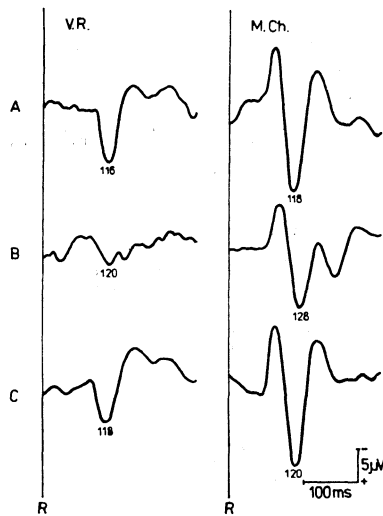


Fig. 4. Visual evoked potentials (VEPs) to the pattern-reversal stimulation in two amblyopic patients (VR, MCH). A, stimulation of the non-amblyopic eye; B, stimulation of the amblyopic eye; C, binocular stimulation. At the main positive peak of the VEPs the peak-latency values are given. Stimulation frequency 2.5 Hz, average luminance of the checkerboard stimuli 7 nits. Bipolar registration  $O_2-C_2$ . Negativity at  $O_2$  is up.

re found to the stimulation of the amblyopic eye in all the patients examined. Thus, the diagnosis of lowered VA in amblyopia is possible in this way.

Repeated VEPs examinations were performed in 13 patients in the course of treatment. However, the changes which would be concordant with the course of treatment could be found only in about 60% of subjects (Fig. 5). A major obstacle for the routine use of VEPs for the control of the treatment effects is a great intraindividual variability of the VEPs in children. It is probably caused by uncontrollable shifts of attention and concentration of the young subjects.

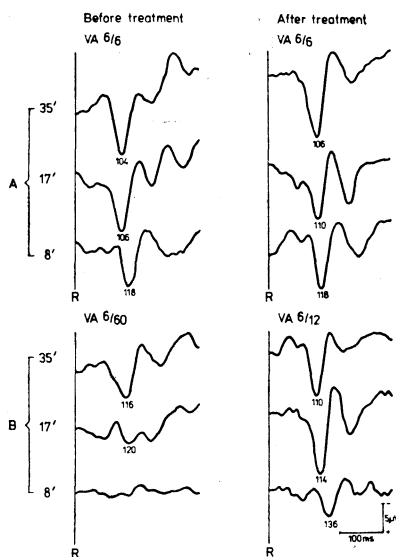


Fig. 5. Pre- and post-treatment values of the VEPs of the subject PZ to the checkerboard-reversal stimulation (angular dimensions of checkers are 35', 17' and 8'). A, stimulation of the non-amblyopic eye; B, stimulation of the amblyopic eye. VA, distance visual acuity. Other designations as in Fig. 4.

*Practice effects and the VA.* Some authors (5, 10, 13) express the opinion that the improvement of the VA reflects also practice effects gained during the frequently repeated testing of the VA. However, in the present study also the VA of the untreated eye of the patients was tested in the same way as it was done for the amblyopic eye. The mean initial VA of the non-amblyopic eye was 0.77, the final VA 0.81. Thus practice effects can play only insignificant role in improving the VA of the amblyopic eye (see also 9).

*Fixation pattern.* The patients were divided into two groups according to their fixation pattern: I) subjects with foveolar and parafoveolar (up to 2 deg. of the foveola) fixation; II) subjects with perifoveolar and peripheral fixation. The initial fixation pattern for all 64 subjects was as follows: 22 subjects were classified in the first group and 42 subjects in the second group. After the end of the treatment the fixation pattern changed in favor of a more central fixation: 53 subjects were classified in the first group and only eleven in the second group. This result is highly significant ( $\chi^2 = 30.95$ ;  $P < 0.001$ ).

*Follow-up examination of VA.* Follow-up examinations were done at an interval of 8-15 months after the cessation of treatment in 40 patients. The mean improvement of the VA in these subjects at the end of the treatment amounted to 3.48 equidistant optotype lines. After the interval of 8-15 months a value of 3.38 lines was found. The mean loss of the VA was negligible — 0.1 optotype line.

## DISCUSSION

The very promising results of Campbell's new amblyopia treatment method elicited a vivid interest among both ophthalmologists and neuro-physiologists. Some authors (1, 3, 4, 8, 9, 14, 16) confirmed the effectivity of the method, perhaps to a lesser degree as compared to Campbell's results, others (5, 7, 13, 15) reported negative outcome.

The main problem, which most authors attempt to solve, is a question in which way can an exposition of the amblyopic eye to rotating gratings for several minutes a week improve its VA. The results of the present study showing that the exposition to checkerboard leads to higher improvement of the VA than to the gratings may be of some help in this respect. The main conclusion from these results is that the effects of the treatment are surely non-specific. If they were specific, the results should be graded according to the spatial frequency values of the patterns used. But the highest spatial frequency of the checkerboard (5.2 c/deg) is about 3.2 times lower than the corresponding value of gratings (16.84 c/deg).

Several authors (1, 3, 6, 7) point out that the important factors for a successful outcome are the attentiveness, cooperation and the motivation of the subjects. On the other hand, the presence of gratings may play little role in vision improvement, as the result with uniform grey discs or black and white pictures instead of gratings were similar (4, 8, 10, 15). The only aspect in which the rotating checkerboard surpasses the grating is its "strangeness" or its amount of difference from the natural



visual environment. Thus, the rotating checkerboard may elicit more arousal or stronger alerting reactions. Under such influence the short-time occlusion of the non-amblyopic eye in combination with accomplishing demanding visuo-motor tasks can contribute most importantly to the improvement of the VA.

Another finding of the present study deserves attention: the probability of gaining the clinically acceptable value of VA (0.5 or higher) is lower in amblyopes with initial VA of 0.2 or lower (Table III). For these subjects it is necessary to combine the checkerboard or grating method with some form of conventional therapy.

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