Evaluation of the CAM treatment for amblyopia: a controlled study

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Single letter and linear acuity (near and distance) and contrast sensitivity were measured in 15 amblyopes (ages 5 to 12) before, during, and after four weekly 7 min sessions of CAM treatment. Six of the children, however, played games over a homogeneous grey disc having the same space-averaged luminance as that of the striped stimuli. Experimental and control results were indistinguishable. In a few subjects from both groups, contrast sensitivity and slight linear acuity improvement was observed. We conclude that these vision changes can be attributed to the short-term occlusion experienced by all subjects during treatment and that grating stimulation did not contribute to this improvement.

Key words: amblyopia, CAM Vision-stimulator, visual acuity, contrast sensitivity, minimal occlusion

Recently Campbell and colleagues described a new form of treatment for amblyopia and reported good results.[1-4] Their CAM treatment consists in having the child view a series of slowly rotating square-wave gratings of high contrast with the amblyopic eye while playing drawing games over the grating. They reported for some patients an improvement in acuity after one 7 min treatment session, and in many patients acuity improved to 6/6 after only three sessions. Their lack of control procedures leaves one to speculate as to what the reported improvement can be attributed. It is also unclear from their data whether their acuity measures represent linear or single-letter test results.

Considering the simplicity and apparent effectiveness of the method, as well as the implications of its "physiologically based" rationale, this CAM procedure warrants much closer scrutiny with tight controls.

Are the gratings of the CAM method the effective agent in improving amblyopic vision? The reason for using gratings is based on the assumption that if the human visual system performs something akin to Fourier analysis, and there is good reason to believe so,[5-7] then the viewing of a range of spatial frequencies of all orientations should optimally stimulate that system. The concentrated viewing of such stimuli might then be the most effective method of activating fully the spectrum of spatial frequency channels, especially those channels of the amblyopic system with reduced sensitivity.

We undertook to replicate the original CAM findings with a number of tests, including single and linear acuity and contrast sensitivity. Most importantly, we included a control group of patients that underwent the same procedures as our CAM treatment

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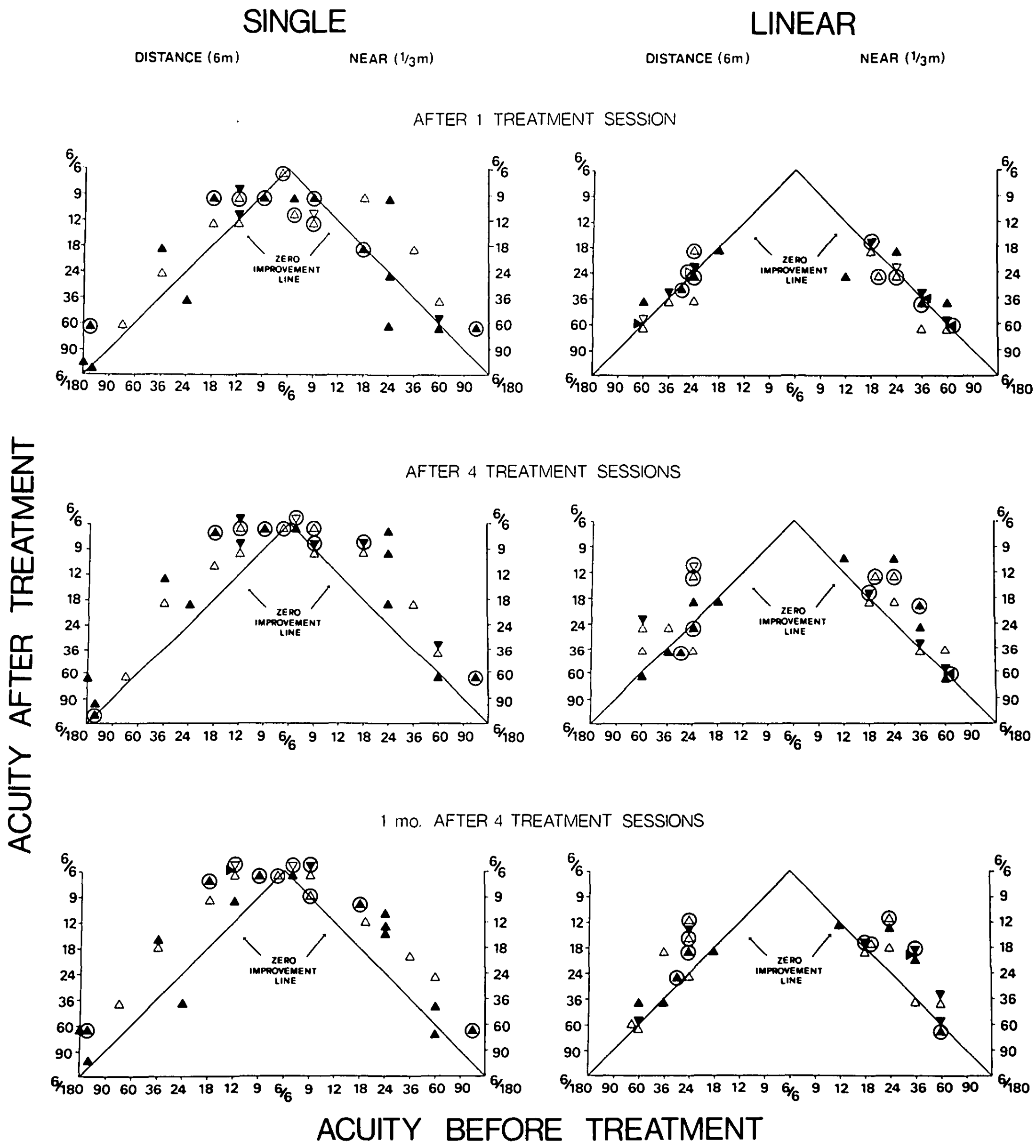

Fig. 1. Change in single and linear acuity at distance and near, measured at the indicated times after treatment for the experimental (▲) and control (△) subjects. Except in cases of superimposed datum points, the upper apex of the triangle indicates acuity. Encircled points represent subjects having had no previous treatment.

group but whose visual systems were not activated by gratings.

Methods

The 15 subjects of this study were either clinic patients or referrals. Complete visual histories were available for all. Their relevant visual characteristics are summarized in Table I. All subjects had clear medias and normal fundi.

Each subject visited the clinic for 4 consecutive weeks and returned for one visit 1 month after this trial period. Table II illustrates the tests taken on each visit. During all tests and treatment, subjects wore complete optical correction. The acuity mea-

Table I. Visual and ocular status of subjects

Subject	Age	Sex	Correction	Fixation	Type Amblyope	Previous Treatment	Pretreatment Amblyopic Acuity	
							Linear	Single
Experimental:								
KS	5	F	R +0.50	R Steady,	Strab	None	N 6/36	6/18
				mac border			D 6/30+1	6/18
			L +0.50	L Normal				
SM	6	F	R +4.50, +1.00 × 90	R Normal	Strab+	Occl	N 6/36	6/24−1
			L +6.00, +1.00 × 90	L Wandering,	aniso		D 6/60	6/36
				paramac				
CD	6	M	R Plano	R Normal	Aniso	Occl	N 6/36−1	6/24
			L +5.00	L Steady,			D 6/36−1	6/24
				mac border				
JD	12	M	R +1.00, +1.50 × 90	R Normal	Strab	Occl	N 6/24	6/24+1
			L +1.50, +2.50 × 90	L Steady,			D 6/24+1	6/12
				paramac				
SL	12	M	R −0.25	R Unsteady,	Strab	None	N 6/18	6/9
				parafov			D 6/24+1	6/9−1
			L −0.25	L Normal				
DM	7	F	R Plano, +1.75 × 105	R Normal	Aniso+	Occl;	N 6/60	6/60
			L −7.50, +4.00 × 90	L Steady,	strab	surg	D 6/60	2/60
				paramac				
JG	5	M	R +1.00	R Normal	Strab	Surg	N 6/12−2	6/6−3
			L +1.00, +0.50 × 95	L Steady,			D 6/18+1	6/12
				parafov				
CH	8	M	R +0.50	R Normal	Aniso	None	N 6/60	3/60
			L +3.50	L Steady,			D -	2−3/60
				paramac				
AR	10	M	R +3.00	R Normal	Strab+	Occl	N 6/60	6/60
				L Wandering,	aniso	tried	D -	2−3/60
			L +2.50, +2.50 × 95	mac border				
				to near disc				
Control:								
MS1	5	M	R +2.00, +0.25 × 90	R Normal	Strab	Occl;	N 6/24	6/9
			L +1.25, +0.75 × 85	L Unsteady,		P.I.+	D 6/24	6/12+1
				mac border		atropine;		
						surg		
JW	12	M	R Plano	R Normal	Aniso	Occl	N 6/60	6/60
			L +5.00	L Unsteady,			D 6/60	5/60
				paramac				
SZ	6	F	R +2.00	R Normal	Strab	Occl;	N 6/18−2	6/18−1
			L +2.00	L Steady,		occl+	D 6/36+1	6/18−1
				paramac		atropine;		
						surg		
MS2	5	F	R +4.50, +0.50 × 90	R Normal	Strab	Occl;	N 6/36	6/36
			L +5.00, +1.50 × 105	L Unsteady		surg	D 6/60	6/36−1
				paramac				
JH	6	F	R +0.50	R Normal	Strab	None	N 6/24−1	6/6−2
			L +0.50	L Steady,			D 6/24−2	6/6−2
				mac border				
RC	10	M	R −0.25, +0.50 × 180	R Steady,	Strab	None	N 6/18−2	6/9
				paramac			D 6/24+1	6/12
			L +1.00	L Normal				

Mac = macular; paramac = paramacular; parafov = parafoveal; strab = strabismus; aniso = anisometropia; occl = occlusion; surg = surgery; N = near; D = distance; P.I. = phospholine iodide.

sure represents Snellen and Sheridan-Gardiner single optotypes, both taken at 6 and 0.33 meters. When measuring acuity, we encouraged the subject to read beyond what appeared initially to be his acuity limit.

Contrast sensitivity (1/threshold contrast) to vertical sinusoidal gratings was measured for the amblyopic and nonamblyopic eye separately by a modified CRT technique described by Campbell and Green.[8] The screen subtended 13 by 10 deg

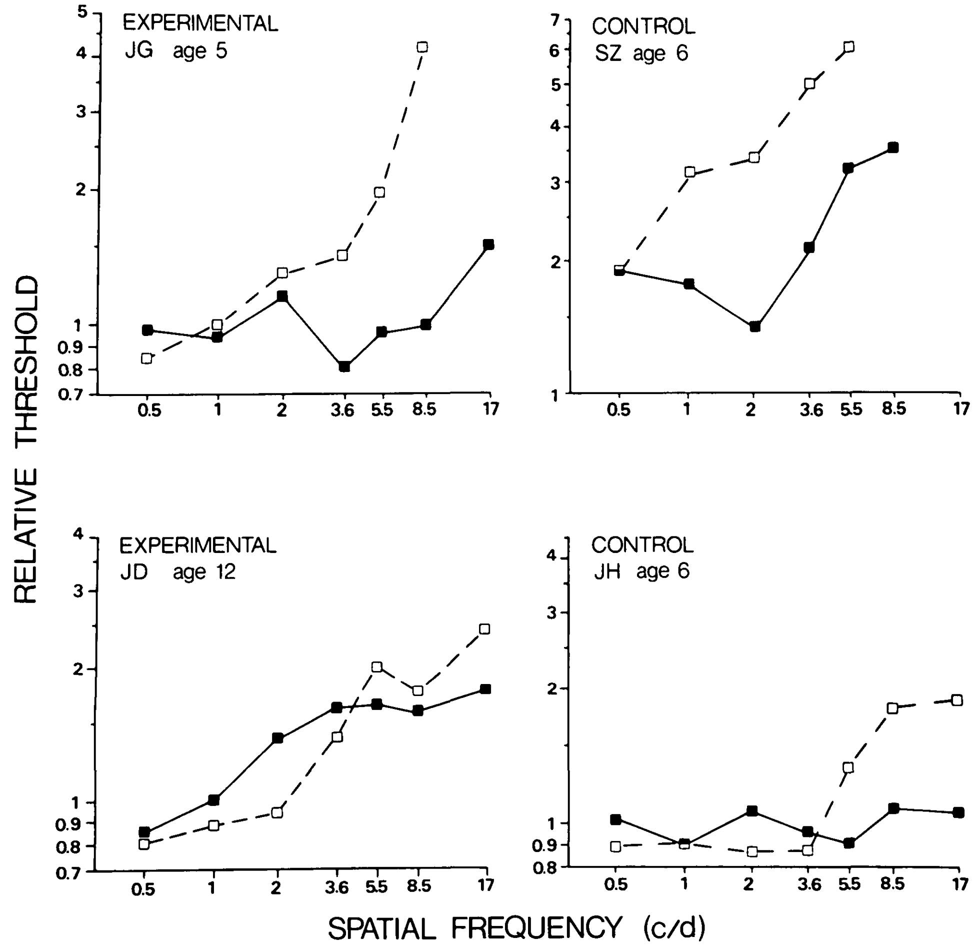

Fig. 2. Relative threshold plots representing the ratio of amblyopic to nonamblyopic threshold contrast for the spatial frequency range tested. Pretreatment (▫) and 1 month posttreatment (▪)ratios are shown. An ordinate value around 1 indicates similar contrast sensitivities between the amblyopic and nonamblyopic eye of the subject. Values greater than 1 mean the amblyopic eye is less sensitive (i.e., requires more contrast) than the nonamblyopic, by that factor.

with a 1 deg horizontal fixation line. Spatial frequency ranged from 0.5 to 17.0 cy/deg, with contrast ranging from zero to 53% about a mean luminance of 10 cd/m^2. The subject, with one eye occluded, initially adapted to the screen at mean luminance for 5 min. A high-contrast grating was then presented, its contrast logarithmically reduced, and it was the subject's task to call "Stop" the instant the grating disappeared. With contrast at zero, it was then slowly increased and the subject again called "Stop" the instant the grating reappeared. A new spatial frequency was then randomly selected, and this procedure continued until the frequency range was exhausted for the eye. This eye was then occluded, and the procedure was repeated with the fellow eye. For each eye, three such descending-ascending threshold

Table II. Order of tests taken on each clinic day

	Visit				
Test	*1*	*2*	*3*	*4*	*1 mo. after treatment*
Acuity	X	X	X	X	X
Cover test	X				X
Prism cover test	X				X
Worth four dot	X				X
Wirt stereotest	X				X
Bagolini glasses	X				X
Visuscope	X				X
Contrast sensitivity	X	X			X
Treatment	X	X	X	X	
Contrast sensitivity	X	X	X	X	
Acuity	X	X	X	X	

pairs were taken per frequency after five to 10 initial practice sessions. We placed great emphasis on having the subject *just* detect the presence or absence of the grating and for the younger children a game was made of it. With this method of limits, interest could be maintained easily in children of age 4 and older. One complete contrast sensitivity session lasted approximately 20 min.

The subjects were randomly assigned to one of two groups. For the experimental group, in which there were nine subjects, treatment consisted of having the child, with his nonamblyopic eye fully occluded, play drawing games (Xs and Os, connecting dots, etc.) on a transparent sheet positioned over a rotating (1 rpm), high-contrast square-wave grating (10 cm diameter). This play was always supervised by an orthoptist to ensure active participation. A comfortable viewing distance of 28 cm was maintained most of the time by all subjects. At this distance the seven grating plates supplied with the CAM Vision-Stimulator (Clement Clarke International Ltd.) ranged in spatial frequency from 0.25 to 16.0 cy/deg in octave increments.

The selection of spatial frequencies to be used during the 7-min treatment period was based on the contrast sensitivity results; the first grating in this period was of a frequency one octave coarser than the frequency at which the amblyopic and nonamblyopic eyes diverged in sensitivity. The child received that frequency and the remaining higher ones, in ascending order and equally timed, for the 7-min treatment session. This treatment procedure follows closely that described by the Campbell group and the instructions accompanying the CAM Vision-stimulator.

The six subjects of the control group were treated precisely as those of the experimental group, with the exception that they played games over a grey disc of the same mean luminance as that of the treatment gratings. For both groups, neither the parents nor the patients were told of the treatment condition, but the parents knew that their child could be in one of the two groups. To control for possible experimenter bias, the person administering treatment was not the person assessing acuity or contrast sensitivity.

Results

Fig. 1 illustrates the change in linear and single letter acuity from before treatment to the indicated times of measurement after treatment. Improvement is indicated by points lying above the diagonal lines. As treatment progressed, there was slow but steady improvement in single letter acuity in the majority of cases. On average, however, linear acuity gains did not approach that of single letter. Most importantly, it can be seen that the experimental group's performance was indistinguishable from that of the control group.

The four relative threshold plots shown in Fig. 2 describe the changes in contrast sensitivity as a function of spatial frequency and were chosen to illustrate the performance extremes. For all subjects tested, amblyopic contrast sensitivity before treatment was progressively reduced (with respect to the nonamblyopic fellow) as spatial frequency increased, as can be seen by the pretreatment ratio curves sloping upward to the right. Experimental Subject J. G., whose pretreatment near-linear acuity of 6/12 − 2 did not change, showed substantial middle-frequency improvement in amblyopic sensitivity. The acuity of experimental Subject J. D. improved from 6/24 to 6/12, yet he exhibited no contrast sensitivity change over the spatial frequency range tested. Of the control subjects, the acuity of Subject S. Z. remained at 6/18 − 2 throughout treatment. Her amblyopic contrast sensitivity, however, showed large improvement for the low and middle frequencies but was still significantly reduced from normal. Finally, the acuity of control Subject J. H. improved from 6/24 − 1 to 6/12 + 2, and her amblyopic contrast sensitivity equaled that of her nonamblyopic eye over the spatial frequency range we tested.

There were no changes in the size of the deviation in the strabismic subjects. Examination with a Visuscope revealed a change of fixation in only two experimental subjects and one control subject, and the change for all three was from steady paramacular to steady macular fixation. Stereoacuity improved in two experimental subjects (from 200 to 100, and 3000 to 200 sec arc) and two control subjects (from 0 to 400, and 0 to 3000 sec arc). There was no relationship between these changes in fixation or sensory status and changes in acuity or contrast sensitivity. None of our subjects developed intractible diplopia as warned by Campbell et al.[3]

Discussion

Grating vs. homogeneous grey field stimulation. In light of the acuity and contrast sensitivity results from the subjects we tested, we believe it makes no difference whether gratings are used in the CAM amblyopia treatment. A number of factors may account for the experimental and control groups' results being equal. Assuming for the moment that gratings during the stimulation period can reactivate the less sensitive spatial frequency channels of an amblyopic visual system, it might be argued that our measurement of contrast sensitivity of both the experimental and control subjects constituted grating treatment in itself. In our laboratory, as part of other research, we have measured the contrast sensitivity of numerous amblyopes, each receiving 10 to 30 times the sine-wave grating exposure of our CAM subjects. We have yet to see any change in contrast sensitivity or acuity beyond practice effects and day-to-day variability with such measurement. Improvement after the passive viewing of sine gratings has also yet to be reported in the literature. Ciuffreda et al.[9] specifically measured the effect on amblyopic acuity of the passive viewing of high contrast square-wave gratings and found no improvement.

Assuming, on the other hand, that grating stimulation is ineffective, one might attribute the equal performance between the two groups to the fact that the subjects of both groups received equal amounts of short-term occlusion while performing supervised visual tasks. Minimal occlusion has been shown to have positive effects on amblyopic acuity.[3, 10]

Has vision improved? The average amount of improvement shown by our subjects (experimental or control) pales in comparison to that shown by Campbell and colleagues for the comparable number of treatment sessions. As Burian and von Noorden[11] point out, and as is a common clinical practice, because most amblyopes exhibit substantial crowding (as do ours), it is linear acuity improvement that is sought after in the treatment of amblyopia. Although we have found increased single letter acuity scores (of two lines on average), the distance linear acuity scores after four treatment sessions remained unchanged in six subjects (two of which did not have measurable distance linear acuity before or after treatment), improved by one line in three subjects, and regressed by one line in two subjects. We feel this outcome falls within subject and testing variability. The acuity of the remaining four subjects (three of whom are control) increased by two lines. Acuity increments greater than this have been obtained with successive acuity measurement alone.[12, 13] That such nontreatment factors can account for these acuity results is particularly evident upon viewing the change in the distance linear acuity scores between the four session measure and that of 1 month post-treatment, during which there was no treatment of any kind. One sees both positive and negative changes in acuity scores.

As part of another study at this clinic, six patients (four experimental and two control to date) have undergone ten 7-min treatment sessions of CAM. Their results fit very well with those presented here. Other studies have also yielded acuity results in agreement with ours.[9, 14–17] They all find little or no acuity improvement with CAM.

Despite these negative findings in acuity performance, in six of our 15 subjects (two experimental, four control), the sensitivity to contrast did improve for low and/or middle spatial frequencies, depending on the subject. The data from three of these subjects are shown in Fig. 2. Since on all occasions of contrast sensitivity measurement both the amblyopic and nonamblyopic eyes were tested, these positive changes in amblyopic sensitivity cannot be due to increased familiarity with the technique or to criterion shifts and therefore probably represent true improvements in sensitivity. Amblyopic contrast sensitivity for experimental Subject J. G. is now equal to his nonamblyopic sensitivity for gratings of 0.5 to 8.5 cy/deg, and control Subject J. H. now has equal contrast sensitivity for gratings up to 17 cy/deg. Because we have found no difference in response to treatment with or without gratings, we tentatively conclude that these improvements in contrast sensitivity are due to short-term occlusion, as mentioned earlier. (Parenthetically, another contributing factor to this improvement may be that these six subjects were of the youngest we tested—5 or 6 years of age—and possibly still within the visual critical period.) This contrast sensitivity finding and the questionable two-line acuity improvement of four subjects has prompted us to begin additional investigation into the efficacy of short-term or "minimal" occlusion in conjunction with supervised close work.

In conclusion, although the rationale for the CAM treatment for amblyopia as "physiologically based" is certainly appealing, based on the 15 children we tested whose ages ranged from 5 to 12 years, we have found that the presence of gratings plays no role in vision improvement and that it may be simply the minimal occlusion that is the effective component of the treatment for those children exhibiting improvement.

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