The Effect of Minimal Occlusion Therapy on Binocular Visual Functions in Amblyopia

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The binocular visual functions of amblyopic children were studied during treatment involving brief weekly periods of occlusion of the unaffected eye while the child performed demanding visuomotor tasks against either a background of rotating gratings or a stationary uniform gray stimulus. The gains in stereoacuity were quite significant and in most cases more obvious than the rather small gains in letter visual acuity. On initial presentation only 21 of the 60 patients showed evidence of stereopsis and of these only seven possessed a stereoacuity of 100 secs or better. Following six treatment sessions the number of patients that demonstrated stereopsis increased to 36 of whom 17 possessed reasonably good stereoacuity (100 secs or better). However, there was no difference in the degree of improvement exhibited by those patients that viewed rotating grating patterns during treatment and others from the control group that viewed the uniform gray stimulus. Thus, there was no evidence that any of the visual gains were enhanced or promoted by active visual stimulation of the amblyopic eye with rotating gratings during the brief periods of occlusion of the unaffected eye. Finally, a comparison of the scores of the children on various stereo-tests suggest that tests comprised of small figure elements that are present in high density may be best for screening purposes. On the other hand, for quantifying the stereoacuity of children known to possess abnormal binocular vision it may be more appropriate to employ tests that use large figure elements that provide strong fusion cues. Invest Ophthalmol Vis Sci 24:778–781, 1983

It has been claimed¹ that the vision of amblyopic children can be substantially improved following brief weekly periods of occlusion of the unaffected eye while the child performs various visuomotor tasks against a background of rotating gratings patterns. We have conducted a controlled clinical trial of this procedure to assess the effect of this treatment on various visual functions in amblyopia, and to ascertain the contribution of the rotating grating patterns to any observed visual improvement. Some of our results, reported previously,² confirmed the finding that minimal occlusion therapy can produce significant improvement in visual acuity for letters, but we could not demonstrate that the rotating grating patterns made a significant contribution to the improvement. In this paper we examine the effects of minimal occlusion therapy (including rotating gratings) on binocular functions and stereoacuity, while in a companion paper,³ attention is focused upon measurements of the contrast sensitivity for sinusoidal gratings.

Materials and Methods

In order to isolate the contribution of rotating gratings to the improvement observed by the use of the treatment procedure advocated by Campbell et al.,¹ we divided our patients (60 amblyopic children between 5 and 14 years of age) into two treatment groups. One group (n = 33) received treatment with rotating grating patterns, while the other (n = 27) viewed a uniform gray disc during the weekly treatment sessions. All other aspects of the treatment and visual testing procedure were identical for the two groups. A description of the steps taken to ensure impartiality by the clinicians together with details concerning the clinical evaluation and classification of the patients are provided in our earlier report.² Briefly, following occlusion of the better eye, the patients to be treated with gratings were seated in front of a device on which one of six grating discs 20 cm in diameter (the Cambridge group used discs of 10 cm diameter) was rotated in turn at one revolution per minute behind a clear plastic plate on which the child played competitive games with the therapist. Beginning with the gratings having the largest spatial period (2 cms), each grating (whose period was half

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0146-0404/83/0600/778/$1.00 © Association for Research in Vision and Ophthalmology

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Fig. 1. Initial and final stereoacuity scores on the Titmus test after six treatment sessions. The score of 3,000 sees is the calculated retinal disparity of the “fly” plate. Patients who did not demonstrate stereopsis prior to treatment are denoted by the letters ND. The children who did not possess stereopsis on completion of treatment have been omitted. The improvement in stereoacuity is given by the amount of the vertical displacement upwards from the line at 45°. Patients that viewed rotating gratings during treatment are depicted by filled symbols, whilst those from the control group are indicated by open circles.

Prior to each of the six weekly treatment sessions, a variety of visual functions were measured with any refractive error fully corrected. In addition to the tests of visual acuity described earlier,2 the stereoscopic visual capacities of most patients were tested with the Titmus Fly Test (Wirt Fly, animals, and circles), the Frisby test, and the TNO random-dot test (2nd edition). The Titmus and TNO plates were administered using a headrest to ensure the correct observation distance of 40 cm as specified for the two tests. The Frisby test, which has three plates each representing random elements at a fixed real depth, was used at different viewing distances from 30 cm to 80 cm as recommended.4 At the beginning of the trial, only the Titmus plates were available at the two locations where the children were examined. Thus, although all children were tested with the Titmus plates, the Frisby and TNO tests were administered to only 24 of the children prior to initiation of treatment.

Results

On initial presentation, only 21 of the 60 patients showed evidence of stereopsis on either the Titmus or Frisby test. The children with stereopsis were substantially less amblyopic than those who failed the tests of stereopsis on initial presentation; the mean acuity of the former group (6/15+) was over four lines better on the Bailey-Lovie chart2 than of the latter group (6/38). Upon completion of six treatment sessions stereopsis could be demonstrated in a further 15 patients, and 19 of the children with stereopsis showed improved stereoaucuity. Thus, following treatment, 36 of the 60 children appeared to have stereopsis. The initial and final stereocuities as measured by the Titmus Plates for these 36 patients are shown in Figure 1. The largest apparent improvement occurred within the category of patients in which stereopsis was either not demonstrable (ND), or was too poor for reliable quantification (Titmus Fly). Among the 43 patients in this category 16 after treatment had measureable stereoaucuity of 400 sec or better.

The improvement in stereoaucuity achieved by the children treated with rotating gratings was not significantly different from the control group. Within the category of children with initially poor stereopsis (400 sec or worse) who then improved to have a quantifiable stereoaucuity, the average final stereoaucuity for the grating group was 186 sec while that of the control group was 291 sec. However, the difference between the latter two scores was not statistically significant (t = 1.65, df = 17). For the category of children having an initial stereoaucuity better than 400 sec, the average final stereoaucuity for the grating group was 56 sec, while that for the children in the control group was 46 sec.
Fig. 2. Stereoacuity scores for the Frisby and TNO tests plotted as a function of the corresponding Titmus test scores. These measurements were made on 24 of the children, and the results shown are those obtained following amblyopia treatment. Note that the correlations may be distorted at each end because of the different ranges that each test covers: Titmus 3000 sec to 40 sec; Frisby 600 sec to 15 sec; and TNO 2000 sec to 15 sec.

The gains in stereoacuity that were evident immediately following cessation of treatment appeared to be long-lasting. Fifteen of the children were re-examined regularly over a period of six months following completion of treatment, and in all cases the stereoacuity remained substantially unchanged from the values measured on the occasion of the last treatment session.

Of the 17 amblyopic children who manifested good stereoacuity of 100 sec or better following treatment, ten possessed anisometropia of 1D or more, two were esotropic without anisometropia, and three suffered from both conditions. The remaining two amblyopic children possessed neither a strabismus nor a significant refractive error in either eye. The 24 amblyopic children that remained stereoblind following completion of the six treatment sessions were all strabismic, and 11 were anisometropic as well. A substantial proportion (11) had received prior surgical treatment of the strabismus, and some form of occlusion therapy had been attempted on a further three.

The relationship between the final stereoacuity scores on the Titmus test and those obtained on the Frisby and TNO tests are shown in Figure 2. The correlation between the Titmus and Frisby scores was reasonably good, although most patients scored slightly better on the latter test. There did not appear to be any real evidence of spuriously good Titmus scores due to the well-known monocular cues inherent in the symmetrical design of the Titmus circles.

The scores of the TNO tests were in almost all cases very much worse than those exhibited on the Titmus and Frisby tests. The TNO test was administered to 24 children who had measurable stereopsis on one or both of the other two tests. Stereopsis could not be demonstrated in six children and a further six only demonstrated gross stereopsis on the TNO initial test plate. Only three of the remaining 12 children were able to detect disparities smaller than 100 secs.

**Discussion**

The results indicate that, in general, minimal occlusion therapy for amblyopia can produce significant improvements in stereoacuity. However, there was no evidence to suggest that the concurrent viewing of rotating grating patterns made any significant contribution to this improvement, a finding that is in agreement with our results for letter acuity. A full discussion of the many factors that may contribute to the improvement in visual functions has been presented in an earlier paper. These factors include the periods of monocular occlusion, the intense visual and eye-hand coordination tasks that were undertaken during the period of occlusion, plus the generalized level of arousal of the child. Also, practice effects as well as general familiarity with the testing procedures may contribute a measureable component to the observed improvement. Although the relative contributions of these various factors are at present unclear, recent physiologic investigations of monocularly deprived kittens provide a possible basis for some of the visual improvements observed with minimal occlusion therapy. In general, it is of considerable interest that treatment directed toward only the amblyopic eye can produce a significant improvement in binocular visual functions.

The scores obtained on the TNO test were substantially lower than those obtained on the Frisby and Titmus tests in many of our patients (Fig. 2). This finding is apparently at odds with recent results of Simons, who found that young children and adults performed better on both the TNO and Titmus plates than on the Frisby test. However, it is likely that this discrepancy can be attributed to differences in the nature of the clinical populations that were surveyed in the two studies. As stereopsis requires successively the achievement of fusion, the detection of local disparities and then the perception of the shape in depth, the stereo stimulus must provide adequate fusion cues and clear unambiguous disparities. Westheimer and McKee have shown that stereoacuity in normal sub-
jects can be reduced by contour interaction between the adjacent component elements of stereograms. In amblyopia, it is likely that the capacity for fusion is reduced and furthermore, that contour interaction effects may be enhanced. Since the size of the elements that form the fusion cues are much larger and less crowded on the Frisby test, it may be expected that this test would be the most appropriate for quantifying gross peripheral stereopsis in the presence of central suppression and/or increased crowding effects. Consequently a group of amblyopic children may find the Frisby test easier than the other tests, whereas a group of normal children may not find any particular advantage on this test (qv Simons).

This possibility should be borne in mind when selecting a test of stereopsis for use on either normal or clinical populations. In general, the choice of the most appropriate test should be related to the overall objective. If a sensitive test is desired for the purpose of screening for subtle binocular disorders, then a high dot density random-dot test such as the TNO or random-Dot-E would be most appropriate because of their exacting requirements. On the other hand, for quantifying the stereoacuity of patients known to possess abnormal binocular vision or with oculo-motor problems, a test with large fusion cues would be more suitable.

Key words: amblyopia, stereopsis, occlusion therapy, visual acuity, gratings, stereotests, strabismus, anisometropia

Acknowledgments

The authors are indebted to Mr. M. Smith for the initial clinical assessment of a number of patients and to Sue Smith and Vic Spepanow who assisted with the treatment of most patients.

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