Contour Integration Deficits in Anisometropic Amblyopia

Arvind Chandna,[1] *Philippa M. Pennefather,*[1] *Ilona Kovács,*[2] *and Anthony M. Norcia*[3]

PURPOSE. Previous retrospective studies have found that integration of orientation information along contours defined by Gabor patches is abnormal in strabismic, but not in anisometropic, amblyopia. This study was conducted to reexamine the question of whether anisometropic amblyopes have contour integration deficits prospectively in an untreated sample, to isolate the effects of the disease from the effects of prior treatment—factors that may have confounded the results in previous retrospective studies.

METHODS. Contour detection thresholds, optotype acuity, and stereoacuity were measured in a group of 19 newly diagnosed anisometropic amblyopes before initiation of occlusion therapy. Contour detection thresholds were measured using a card-based procedure.

RESULTS. Significant interocular differences in contour detection thresholds were present in 14 of the 19 patients with anisometropic amblyopia.

CONCLUSIONS. Contour integration deficits are a common, but not universal, finding in untreated anisometropic amblyopia. Differences in the prevalence of contour integration deficits between the present study and that of another study may lie in differences in treatment history and/or in the sensitivity of the two different contour integration tasks. (*Invest Ophthalmol Vis Sci.* 2001;42:875–878)

Human observers are readily able to detect contours defined by chains of Gabor elements embedded in random Gabor element backgrounds.[1,2] The perception of Gabor-defined contours relies on the ability not only to register the orientations of individual elements but also to detect long-range correlations between the orientations of the elements defining the contour. Contour detection thresholds were initially reported to be abnormal in a mixed group of observers with amblyopia.[3] Thresholds for the detection of a closed Gabor-defined contour were measured by varying the density of a random Gabor-patch background in which the contour was embedded. Most, but not all observers classified as amblyopic on the basis of optotype acuity performed abnormally in this task. Subsequently, it was reported that contour integration deficits were specific to strabismic amblyopia,[4] being present in only one of six patients with anisometropic amblyopia.[5] The contour integration task used by Field et al.,[1] Hess et al.,[4] and Hess and Demanins[5] involved the detection of open chains of Gabor patches embedded in random Gabor backgrounds. The visibility of the Gabor-defined contour was manipulated by varying the orientation-difference between elements on the Gabor-defined contour.

In the present study, we measured contour detection thresholds in 19 untreated anisometropic amblyopes using a card-based test procedure.[6] We have noted[7] that contour detection thresholds are modifiable to a substantial degree by occlusion therapy. Previous studies[4,5,8] thus run the danger of having confounded responses to treatment with the underlying natural history of the disorder. Response to treatment may differ between strabismic and anisometropic amblyopia. Given that we found deficits in a small number of anisometropic amblyopes in our initial study,[3] we examined a larger group of anisometropic amblyopes in the present study. We find that the majority of untreated patients with anisometropic amblyopia have significant interocular differences in their contour detection thresholds.

METHODS

Observers

Nineteen patients, ranging in age from 4 to 13 years (average age, 7.5 years) were tested on initial diagnosis of anisometropic amblyopia. For the purposes of this study, a patient was considered to have anisometropic amblyopia if the log minimum angle of resolution (MAR) acuity measured on a constant-crowding chart (Lea Hyvärinen Symbol Chart; Lea-Test Ltd., www.lea-test.signc.fi) differed by 0.1 log units or more between the two eyes and if there was a difference of at least 1.25 D (spherical equivalent) in refractive error between the two eyes. Ocular alignment was assessed using prism-cover–uncover and alternate-cover tests. None of the patients had a measurable deviation on cover testing. We also performed the 4-D base out (4 DBO) prism test in each patient and classified the responses as bifoveal or other than bifoveal. We used the term other than bifoveal, because in some subjects either poor acuity or noncooperation for both distance and near precluded an absolute diagnosis of microtropia. The clinical details of the patients, along with their sensory thresholds are presented in Table 1. The use of human subjects in this research conformed to the tenets of the Declaration of Helsinki.

Contour Detection Test

Contour detection stimuli were presented in a card format, and thresholds were measured using a clinical staircase.[6] Each card measured 18 × 24.5 cm. Within each card, a circular contour comprising 12 Gabor elements was embedded in a random Gabor background. The carrier spatial frequency of the Gabor elements was 5 cyc/deg at a test distance of 50 cm. Interelement spacing along the contour was fixed at seven wavelengths of the carrier, center-to-center (1.4°). Contour visibility was varied by varying the average density of the background Gabor elements, while holding the contour–element spacing constant. Contour detection thresholds in normal adults and amblyopes are determined primarily by the ratio of background element to contour element spacing (referred to as Δ).[8] The parameter Δ varied between 1.2 and 0.50 in steps of 0.05 across the set of 15 cards used to measure thresholds. At a Δ of 1.2, the contour can be detected

TABLE 1. Characteristics of Patients

Patient	Sex	Age (y)	REF			VA			CT			Stereo (Frisby)
			NAE	AE	Difference	NAE	AE	Difference	NAE	AE	Difference	
Other-than-bifoveal response												
1	M	3.7	4.50	5.75	1.25	0.02	0.40	0.38	1.00	1.00	0.00	1000
2	F	4.2	2.00	4.25	2.25	0.20	1.00	0.80	0.95	1.20	0.25	1000
3	F	4.3	1.25	3.75	2.50	0.20	1.00	0.80	0.90	1.05	0.15	600
4	M	5.3	2.50	4.50	2.00	0.10	1.00	0.90	0.90	1.05	0.15	1000
5	F	5.5	0.75	5.25	4.50	0.20	0.80	0.60	1.10	1.20	0.10	1000
6	F	5.6	4.75	6.50	1.75	0.00	0.80	0.80	0.90	1.05	0.15	1000
7	F	5.9	1.50	5.25	3.75	0.16	0.68	0.52	0.95	1.05	0.10	1000
8	F	7.7	1.25	3.00	1.75	0.00	0.40	0.40	0.75	0.90	0.15	60
9	M	9.2	2.25	3.75	1.50	0.04	0.26	0.22	0.85	0.95	0.10	1000
10	M	9.9	1.50	7.25	5.75	0.00	1.00	1.00	0.90	1.25	0.35	1000
11	F	12.2	0.75	3.75	3.00	−0.08	0.44	0.52	0.85	0.85	0.00	1000
Mean ± SEM		6.69 ± 0.82	2.09 ± 0.42	4.82 ± 0.40	2.73 ± 0.43	0.08 ± 0.03	0.71 ± 0.09	0.63 ± 0.07	0.91 ± 0.03	1.05 ± 0.04	0.14 ± 0.03	
Bifoveal response												
1	M	5.1	0.75	7.00	6.25	0.50	1.00	0.50	0.95	1.20	0.25	600
2	F	5.5	1.75	4.50	2.75	0.90	1.00	0.10	1.00	1.15	0.15	300
3	M	6.3	4.75	6.75	2.00	0.00	0.30	0.30	0.85	1.00	0.15	40
4	F	7.4	0.50	6.50	6.00	0.50	1.00	0.50	1.00	1.20	0.20	300
5	M	7.6	2.37	6.37	4.00	−0.08	0.40	0.48	0.75	0.85	0.10	1000
6	F	11.1	0.25	6.00	5.75	0.00	0.30	0.30	0.80	0.80	0.00	120
7	M	12.8	1.00	4.00	3.00	0.40	0.60	0.20	0.85	0.90	0.05	110
8	M	13.4	5.25	6.50	1.25	0.70	1.00	0.30	0.70	1.00	0.30	1000
Mean ± SEM		8.66 ± 1.17	2.08 ± 0.69	5.95 ± 0.39	3.88 ± 0.69	0.37 ± 0.13	0.70 ± 0.12	0.34 ± 0.05	0.86 ± 0.04	1.01 ± 0.06	0.15 ± 0.04	
Total group mean ± SEM		7.51 ± 0.67	2.09 ± 0.34	5.30 ± 0.29	3.21 ± 0.37	0.20 ± 0.06	0.70 ± 0.07	0.51 ± 0.06	0.91 ± 0.02	1.03 ± 0.03	0.13 ± 0.02	

Refractive errors for each eye are presented as spherical equivalents, optotype acuities as LogMAR units, and contour thresholds as Δ units. Stereo acuity is in arc sec, with 1000 indicating no measurable stereopsis. Descriptive statistics for continuous variables are presented as means ± SEM. REF, spherical equivalent refraction in diopters; NAE, nonamblyopic eye; AE, amblyopic eye; VA, visual acuity; CT, contour threshold; Stereo, stereoacuity.

on the basis of a first-order texture density cue. Contour detection at Δ of 1 or less can only be accomplished through the detection of the relative orientation of elements along the contour (second-order orientation).[8] Figure 1 presents sections of the cards containing contours for Δ of 1.2, 0.9, and 0.7. Normal adult thresholds average 0.65.[8]

Procedure

Cards were presented for monocular viewing from a distance of approximately 50 cm. All participants were naive and were familiarized with the test using practice cards containing highly visible contours. All participants were tested in a staircase paradigm modeled after that of Chandna et al.[9] which required a correct response to at least two of three presentations of the same card. Cards were reversed on representation at random to allow progression until incorrect responses led to a step down the staircase (reversal). Three reversals at adjacent cards were required to define the threshold. The observer was not masked to the contour position. Most subjects indicated the contour by pointing at the center of the contour, or they were encouraged to trace around the contour with a finger. Indication that the contour was on the right or left alone was not sufficient. Children were not given negative feedback when
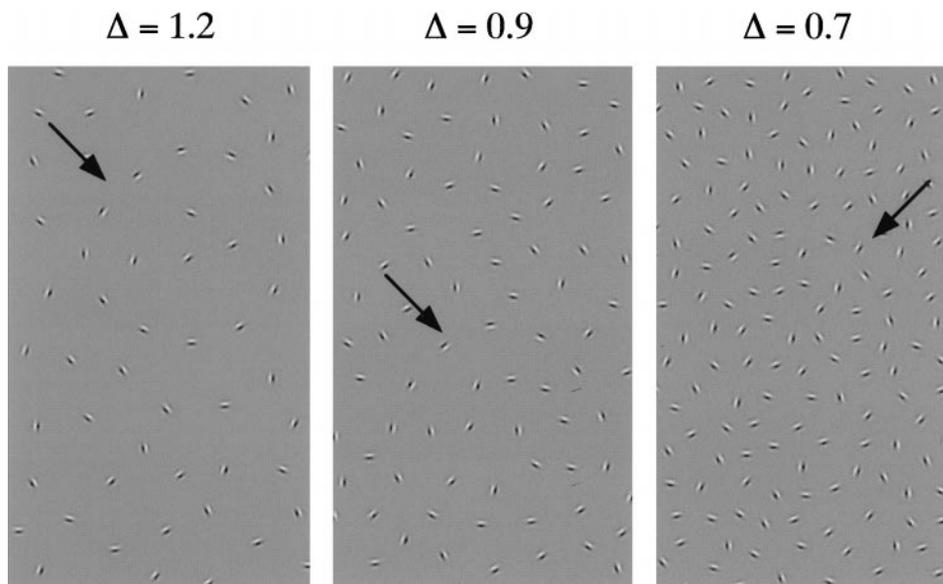
FIGURE 1. Sections of three contour cards showing the 12-element Gabor-defined contours (*arrows*) embedded in backgrounds of different noise density. The patterns shown have a ratio of background element spacing to contour element spacing (Δ) of 1.2, 0.9, and 0.7. The contour with a Δ of 1.2 can be detected on the basis of a texture density cue, as well as on the detection of colinearity along the contour. The contours with Δ equal to or less than 1.0 are only detectable on the basis of long-range comparison of the Gabor-patch orientations along the contour.

they were incorrect. To maintain their interest in the test, they received verbal encouragement, even if the contour was identified incorrectly. They were thus not made aware of incorrect responses and continued to attempt to identify contours on the cards presented by the observer.

However, the observer followed the rules of the staircase and kept a tally of correct versus incorrect responses and presented cards accordingly to determine a reliable threshold. We had established[6] that test–retest reliability in children is such that interocular differences of 0.10 Δ units (two or more cards) are significantly greater than the measurement error and are therefore indicative of a significant interocular difference in the contour detection threshold. Patients were tested with full spectacle correction (i.e., that determined by cycloplegic retinoscopy).

In addition to contour detection thresholds and optotype acuity (Lea Hyvärinen symbol chart), near stereo acuity was measured using the Frisby test, a free-space random-element stereogram (Clement Clarke, Harlow, UK).

RESULTS

Contour detection thresholds for each eye of the 19 observers with anisometropic amblyopia are presented in Table 1, along with optotype acuities, expressed as LogMAR (LogMAR of 0.0 is equal to a threshold of 1 arc min or 6/6 vision). LogMAR interocular acuity differences ranged between 0.1 and 1.0 log units, with the average interocular difference being 0.51 log units (a factor of 3). Contour detection thresholds differed between the eyes by an average of 0.13 Δ units, which is significantly different from no interocular difference (P < 0.001: one-tailed, paired *t*-test). Individually, 14 of 19 observers had interocular differences of 0.10 Δ units or more and were thus considered to have a significant contour detection deficit.[6]

Eight observers had a bifoveal response on the 4 DBO test, and 11 had an other-than-bifoveal response. There was no difference in the average contour threshold variation between eyes in the patients with a bifoveal response (0.15 ± 0.04) and those with an other-than-bifoveal response (0.14 ± 0.03; P = 0.77, two-tailed *t*-test: see Table 1.) Patients with a bifoveal response on the 4 DBO test had smaller interocular acuity differences (P < 0.01, two-tailed *t*-test) and more frequently demonstrated measurable stereopsis. The two subgroups were similar on all other measures (see Table 1).

DISCUSSION

Anisometropic amblyopia, in its untreated state, results in deficits in contour detection threshold in the majority of cases. This contrasts with the report of Hess and Demanins[5] who found that only one of six anisometropic observers was deficient. There are several differences between our study and that of Hess and Demanins that may account for the different rates of incidence of contour integration deficits.

Task Differences

Contour visibility in our task was varied by changing the density of the background noise elements while holding the contour shape (signal) constant. Hess and Demanins[5] varied contour visibility by changing the structure of the contour while holding background noise density constant. It is possible that strabismic and anisometropic amblyopes are affected differently by changes in the signal brought about by the path–angle variation. Conversely, both anisometropic and strabismic observers may be affected by increasing the density of the background noise. It would be of interest in future studies to compare performance on

the path–angle variation used by Hess and Demanins at different levels of background noise or to perform the path–angle variation task and our noise-density task in the same observers.

Treatment History Differences

None of our patients had had occlusion therapy before testing. Spectacle correction was worn for testing, but no patient had worn spectacles for longer than 4 weeks before testing, with most patients having had minimal spectacle wear before testing. In contrast, three of six of Hess and Demanins'[5] patients had a history of occlusion therapy, and three of six had a history of long-term spectacle wear. We have found[7] that contour detection thresholds are substantially modifiable by occlusion therapy. It is not known whether spectacle correction alone is sufficient to modify the contour detection threshold. Given this, it is possible, if not likely, that the amount and type of treatment as well as the timing of treatment relative to the onset of anisometropia, may influence the degree of abnormality and the observed prevalence in prospective versus retrospective studies.

Age Differences

Our group had an average age of 7.5 years compared with the group in Hess and Demanins,[5] who were all adults. It is conceivable that younger observers are less willing or able to use the amblyopic eye to the extent that highly motivated adults can. Although we cannot rule this out, neither contour threshold differences nor LogMAR interocular differences correlated with age in our sample (r = −0.36, P = 0.14 and r = −0.35, P = 0.15) which spanned ages 4 to 13 years. Furthermore, the effects of the observer's criterion were minimized by not allowing the observer to terminate the staircase. Rather, the child was always given positive feedback, even for mistakes. Moreover, the order of card presentation was controlled by the examiner. It is also possible, but unlikely, that contour detection differences dissipate spontaneously in adulthood.

Association between Optotype Acuity and Contour Thresholds

Differences in contour detection threshold between the two eyes correlated with acuity differences (r = 0.56, P = 0.01), although 5 of 19 of our observers with amblyopia did not have a measurable interocular difference in contour detection thresholds. We found a similar correlation between acuity and contour detection differences in strabismic amblyopes.[8] Exactly what accounts for the relatively frequent dissociations between acuity deficits and contour integration deficits remains to be determined. The present results, obtained before occlusion treatment, suggest that individual differences in susceptibility to anisometropia may be a factor, as may be differences in the time course of exposure to anisometropia and time-dependent changes in degree of anisometropia, the natural histories of which are unknown. Differential response to treatment of contour integration mechanisms versus optotype acuity mechanisms may be an additional factor in retrospective studies.

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