Original Scientific Article

Contrast Visual Acuity in Treated Amblyopia

MARK A. CASCAIRO, D.O., MALCOLM L. MAZOW, M.D.
JACK T. HOLLADAY, M.D. and TOM PRAGER, Ph.D.

from the Houston Eye Associates, Houston, Texas

ABSTRACT: ***Purpose:*** Contrast visual acuity was measured in both eyes of children with treated monocular anisometropic or strabismic amblyopia to determine if defects in contrast visual acuity remain after normal Snellen visual acuity has been achieved in the amblyopia eye by treatment. Also, in amblyopic eyes that did not achieve normal vision after treatment, a relationship was sought between the residual decreases in Snellen visual acuity and the corresponding decreases in contrast visual acuity. Finally, anisometropic subjects were compared to strabismic subjects.

Methods: Nineteen amblyopes (10 strabismic and 9 anisometropic) who completed therapy for monocular amblyopia were tested for best corrected Snellen visual acuity and contrast visual acuity in both eyes. The Holladay Contrast Acuity Test™ (Stereo Optical, Chicago) was used for measuring contrast visual acuity. Results from amblyopic eyes were compared to the dominant eyes in the amblyopic subjects, and these results were compared to contrast visual acuities of ten control subjects.

Results: Eyes with amblyopia, whether due to anisometropia or strabismus, showed reduced contrast visual acuity when compared to the dominant fellow eyes even after completion of amblyopia therapy. The reduction was in proportion to residual post-treatment Snellen visual acuity deficits, except at the highest contrast levels where amblyopic eyes demonstrated reductions in contrast visual acuities greater than that suggested by any residual Snellen acuity deficits. This pattern of greater reduction in contrast visual acuity at higher contrast levels was also seen in amblyopic eyes of patients with post-treatment Snellen visual acuity of 20/20. The Holladay Contrast Acuity Test™ gave reproducible results in control subjects.

Conclusions: Contrast visual acuity in both anisometropic and strabismic amblyopes was reduced for the amblyopic eye after completing amblyopia therapy. This reduction followed a Type 1 pattern (greater loss at higher contrast levels) for both types of amblyopia and was in proportion to the residual deficit in Snellen visual acuity of the amblyopic eye, except at the higher contrast levels (smaller optotypes) where a trend toward a greater reduction was seen.

Key Words: amblyopia, anisometropic / amblyopia, strabismic / amblyopia, treated / contrast visual acuity / Holladay Contrast Acuity Test™ / study, prospective / visual acuity, contrast

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Correspondence/reprint requests to: Dr. Mazow, Houston Eye Associates, 2855 Gramercy, Houston TX 77025. FAX 713-668-3823.

INTRODUCTION

Functional amblyopia has been defined as an acquired defect in vision that is due to abnormal visual experience early in life. It is usually unilateral but may be bilateral (1). Strabismus and anisometropia are the most common causes of the abnormal visual experience in unilateral amblyopia which is characterized by a reduction in Snellen visual acuity. Other visual functions have been shown to be impaired in amblyopic eyes as well. These include contour interaction (2) and contrast sensitivity (3).

Contrast sensitivity has been measured in amblyopic patients using a variety of modalities. The search for simple, yet accurate, testing methods for the pediatric amblyope has presented a considerable challenge. Also, the expense and cumbersome nature of some testing equipment limits its clinical usefulness. Forced preferential looking systems (4), electronic sine-wave grating generators (5), and letter charts for distance (6) and near (7) measurements have been described.

The majority of investigators report reduced contrast sensitivity in the amblyopic eye at both high and low contrast levels, whether the amblyopia is due to strabismus or anisometropia. Earlier studies had suggested that the two subgroups of amblyopes manifest different characteristics in contrast sensitivity deficit (6,8,9). This, combined with evidence that strabismic and anisometropic amblyopes function differently under various levels of illumination, led some authors to suggest a different neural basis for the reduced visual function for each subtype of amblyopia (10).

The characteristics of contrast sensitivity deficit previously attributed to type of amblyopia (strabismic versus anisometropic) have since been shown to be more related to visual acuity than to type of amblyopia (11). Some of the previous studies, however, reported that contrast sensitivity function (CSF) remains reduced in an amblyopic eye following treatment of the amblyopia: Rogers et al (3) noted reduced CSF in a subgroup of 5 amblyopes with Snellen acuity of 20/20, and Regan (7) reported 17 of 37 treated patients retained some CSF deficit after attaining normal vision (defined as 20/25 or better). Since contrast sensitivity has been used as a more sensitive measure of visual function in certain patients (e.g., those with optic neuritis) (12), and in view of reports of residual deficits in CSF in amblyopes treated to 20/20 visual acuity like those cited above, some have questioned whether contrast sensitivity testing may be used as an indicator, more sensitive than Snellen visual acuity measurement, of treatment success in amblyopia.

The current study was designed to test contrast visual acuity function in unilateral strabismic and anisometropic amblyopes who have been treated to endpoint, stable Snellen visual acuity. Incongruities between endpoint Snellen acuities and contrast visual acuity function were sought, as were any differences between subtypes of amblyopia. The Holladay Contrast Acuity Test™ was used, because of its design for easy use in the clinical setting with literate subjects. Also, the design of the acuity charts is based on the LogMAR format which allows for easy calculation of mean visual acuity and comparison to normative contrast visual acuity values.

MATERIALS AND METHODS

Contrast visual acuity function was tested monocularly for both eyes in nineteen amblyopic subjects who had achieved stable, endpoint Snellen visual acuity in the amblyopic eye through appropriate occlusion therapy, glasses, or both. Amblyopia was defined as a difference of two lines or greater in Snellen visual acuity between eyes, in the absence of organic pathology. Endpoint vision was defined as that vision which was stable in the amblyopic eye after three successive appropriate treatment periods in children younger than 11 years of age, or vision at, or better than, the 20/30 level in treated amblyopes 11 years of age or older.

Subjects demonstrated sufficient ability to recognize the ten Sloan letters used in the test charts. Ages ranged from 6 years to 14 years. Figure 1 (below) illustrates an increasing average age of subjects from controls (7.9 years) to strabismic amblyopes (9.3 years) to anisometropic amblyopes (10.6 years). Post-treatment Snellen visual acuities for the amblyopic eyes were 20/30 or better in 16 of 19 patients. Five of these subjects achieved 20/20 vision in the amblyopic eye. One anisometropic subject had a final visual acuity of 20/40 after treatment, and two strabismic subjects manifested 20/40 and 20/50 visual acuities, respectively. Ten control subjects (ages 5-10 years) had bilateral visual acuities of 20/20 in all but two 5 years old subjects who measured 20/25 bilaterally on Snellen testing. The control subjects were children encountered in vision screening who had normal vision measured at distance and near for both eyes.

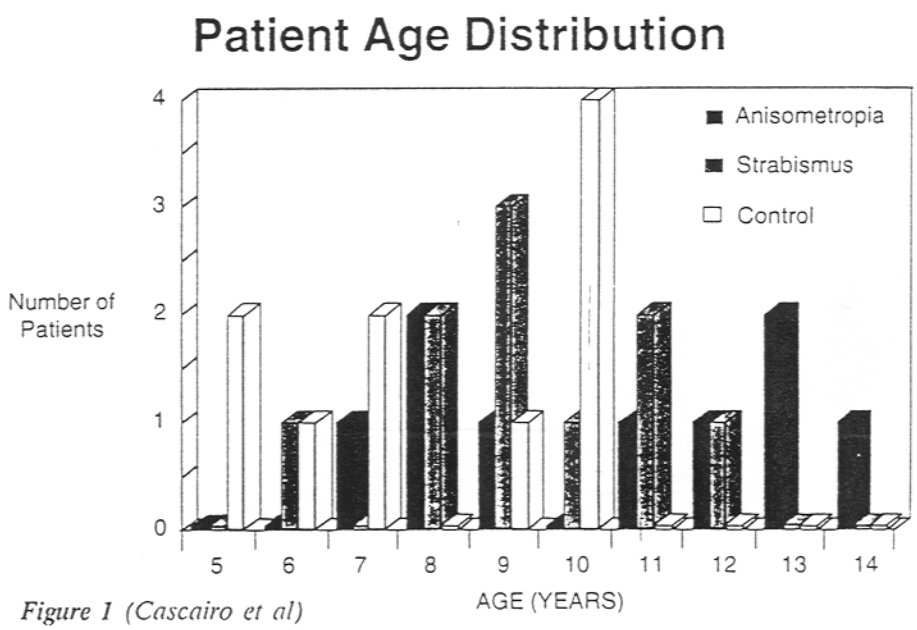

Figure 1 (Cascairo et al)

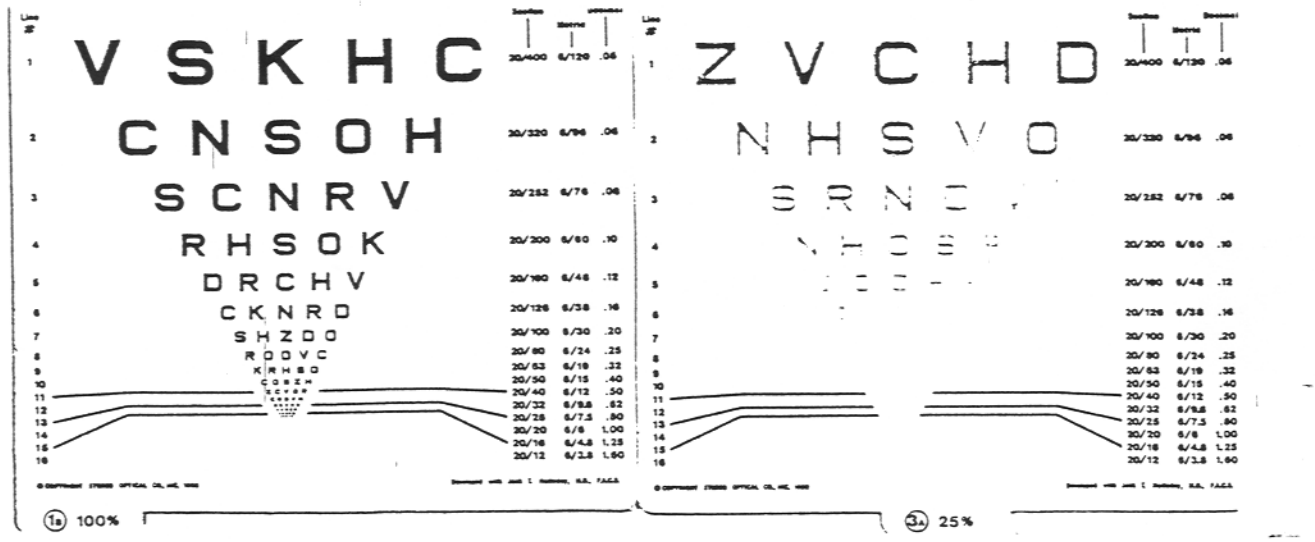

Figure 2 (Cascairo et al): Two cards of the Holladay Contrast Acuity Test (Stereo Optical, Chicago) reduced for reproduction. Left 100%, right 25% contrast. Xerography poorly reproduced the reduced contrast optotypes in the 25% card, and the smaller optotypes are missing, simulating in part the effect of reduced contrast on visual acuity.

Ten strabismic amblyopes and nine anisometropic amblyopes were included in the study, having met the study criteria. These were all patients of one practice (MLM), selected in consecutive fashion as they presented for followup office visits. Patients with both strabismus and anisometropia were excluded from the study.

After obtaining parental consent for each subject, the distance Snellen visual acuity at 20 feet was measured for each eye. The vision was recorded as the smallest acuity line in which all letters were correctly identified or only one letter was missed. The Holladay Contrast Acuity Test™ (Figure 1, above) was then utilized to test contrast visual acuity. The test utilizes 10 acuity cards (5 for each eye) which use the LogMAR notation allowing for easy calculation of mean visual acuity for each contrast level (13). The cards were used at successively decreasing contrast levels (100%, 50%, 25%, 12.5% and 6.25%), and were held at 16 inches from the subject. In order to preserve attentiveness, the subjects were allowed to begin reading letters 2 or 3 lines above their demonstrated Snellen capability. The choice (between the amblyopic and dominant eye) of first eye to be tested was randomized with a coin toss to prevent familiarity bias. The fellow eye was occluded by the clinician during testing.

The same administrator (MAC) performed the test on all subjects. Since the test was performed in various locations, a light meter was used to ensure that the proper illumination of 31 foot-candles (range 29-34 foot-candles) was provided.

Contrast visual acuities were measured at all five contrast levels for each eye. The number of letters correctly identified was recorded and then the geometric mean contrast visual acuity was calculated at each contrast level for both the amblyopic and dominant eyes for both subgroups of amblyopia.

A one-way analysis of variance was used for statistical analysis.

RESULTS

All subjects were able to complete the contrast visual acuity test with good cooperation. Both eyes of control subjects performed very similarly in contrast acuity testing at all levels of contrast (averaging 1.9 letters difference in acuity between the two eyes). One eye of each subject was therefore randomly chosen for statistical comparison.

When compared to control eyes, the dominant fellow eyes of amblyopic subjects achieved acuities equal to or higher than that of controls. Figure 3, below plots the comparison of mean contrast visual acuity for control eyes at each contrast level against that of the amblyopic eyes for each type of amblyopia. Significant differences were noted for both subgroups of amblyopia at low contrast levels, but especially between the anisometropic subjects and controls.

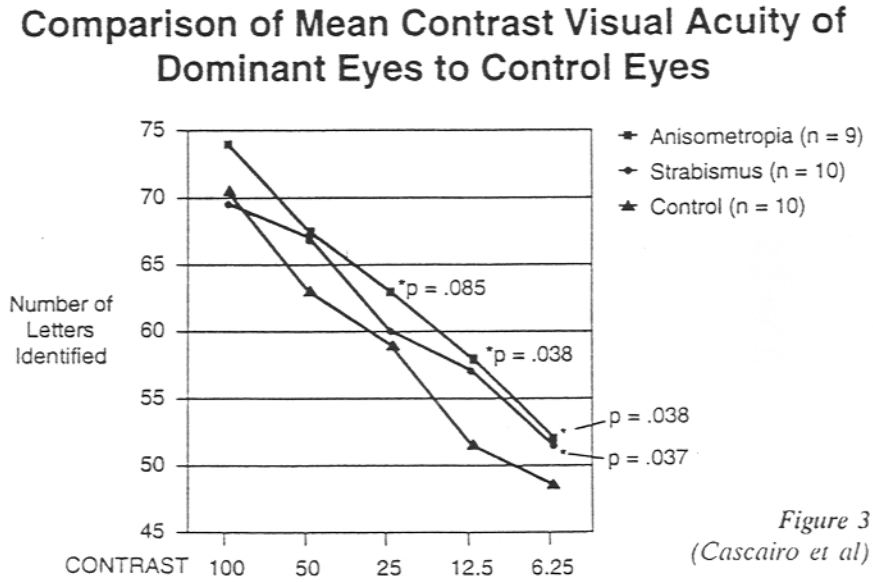

Figure 3 (Cascairo et al)

Both strabismic and anisometropic amblyopic eyes, however, demonstrated reduced contrast visual acuities when compared to their dominant fellow eyes. Figures 4 and 5 plot the mean contrast visual acuities for the amblyopic eyes against those of the dominant eyes. The reduction was statistically "significant" at all contrast levels for the anisometropic subjects, but not at any level for the strabismic subjects. The mean contrast visual acuity difference between the amblyopic and dominant eyes was calculated at each contrast level and is displayed in Figure 6 (right). Control subjects showed an increased difference at lower contrast levels, while both strabismic and anisometropic amblyopes showed decreased differences at lower levels of contrast. This tendency toward less contrast acuity deficit at lower contrast levels is also demonstrated in Figures 4 and 5 (right) as a relative decrease in the slope of the contrast acuity curve for the amblyopic eyes as compared to the slope of the curve for the dominant eyes.

In a subgroup of five amblyopes (2 anisometropic and 3 strabismic) with post-treatment Snellen visual acuity in both eyes of 20/20, no statistically "significant" difference in contrast visual acuity function between the amblyopic and dominant eyes was seen at any contrast level (see Figure 7, top, next page). The number of subjects in this subgroup was small, however, and the mean contrast visual acuity scores for the amblyopic eyes were worse at all contrast levels when compared to the dominant eyes, except at the lowest contrast level.

The contribution of residual Snellen visual acuity deficits of the amblyopic eyes to their contrast visual acuity deficits was evaluated by an approximate correction of the original curves for the amblyopic eyes (Figures 8 and 9, next page). That is, the contrast visual acuity value for the amblyopic eye of each subject was increased by any difference in Snellen acuity

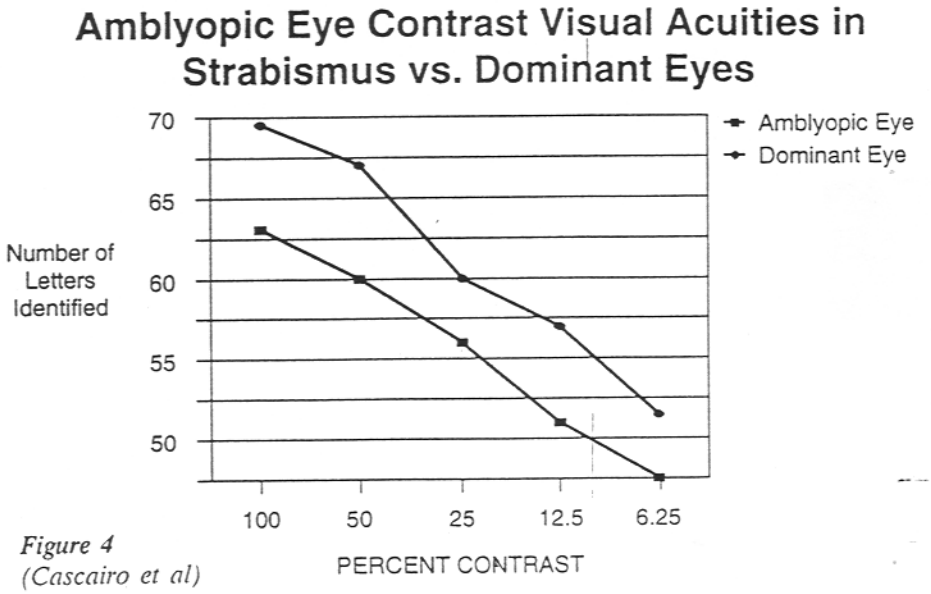

Figure 4
(Cascairo et al)

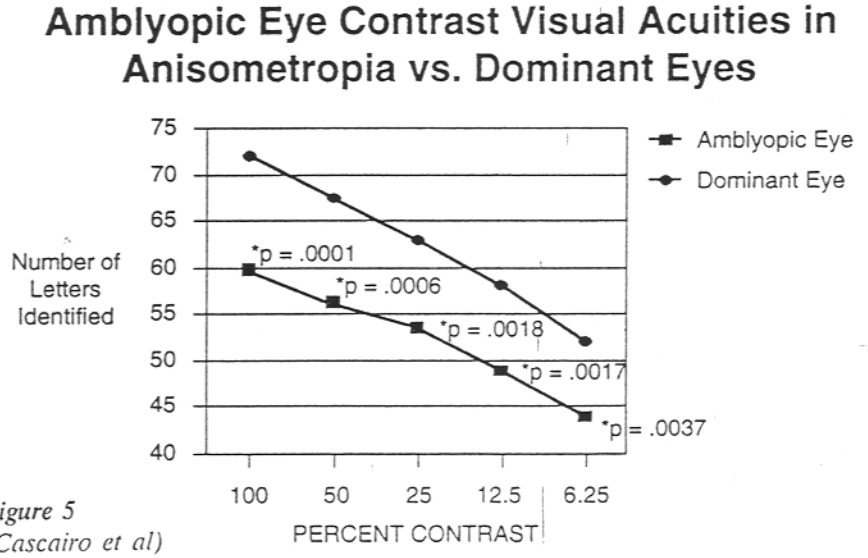

Figure 5
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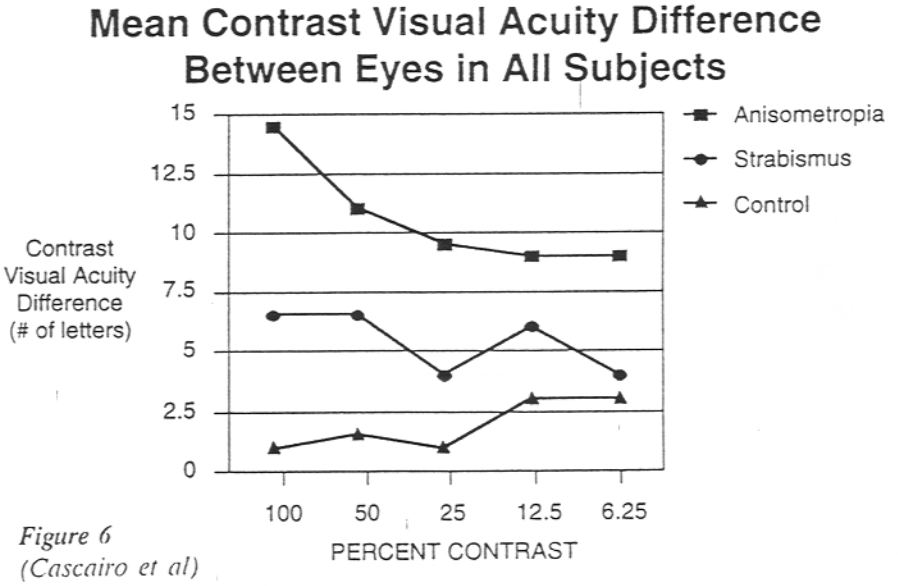

Figure 6
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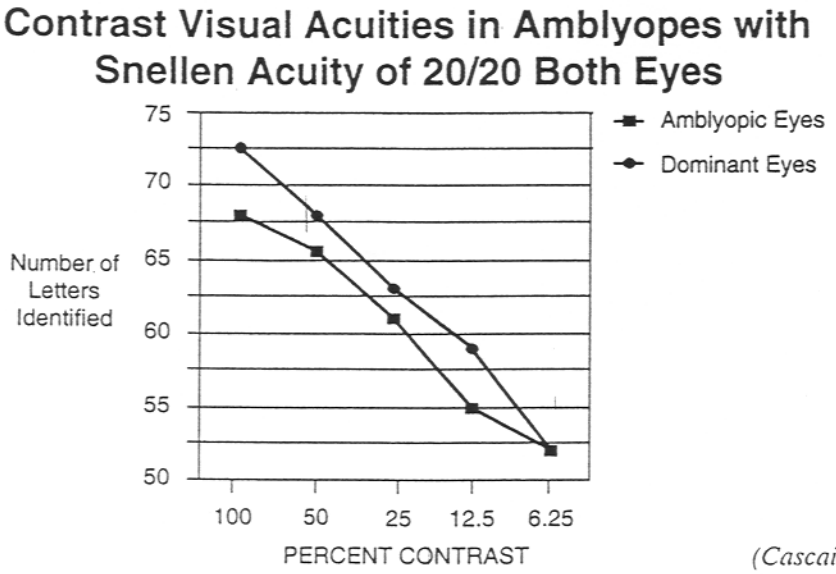

Figure 7
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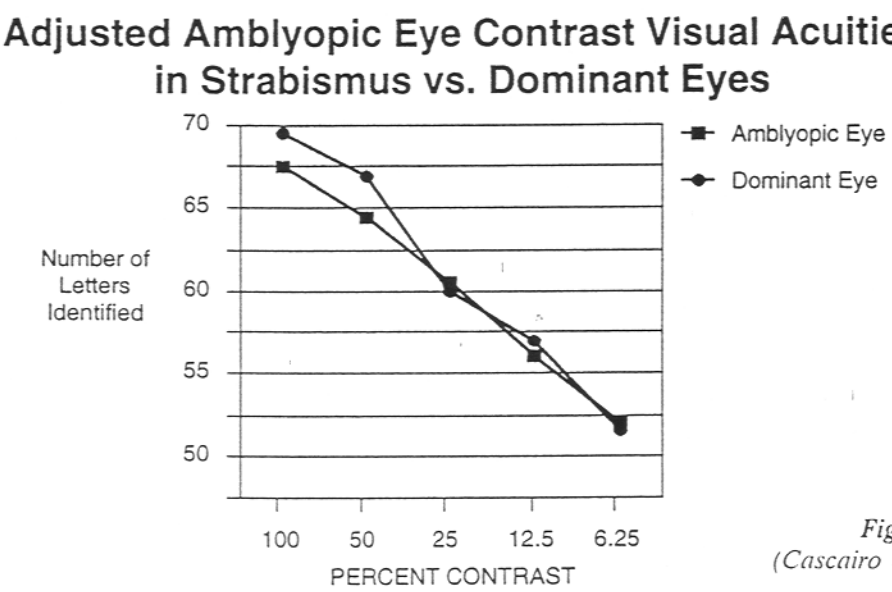

Figure 8
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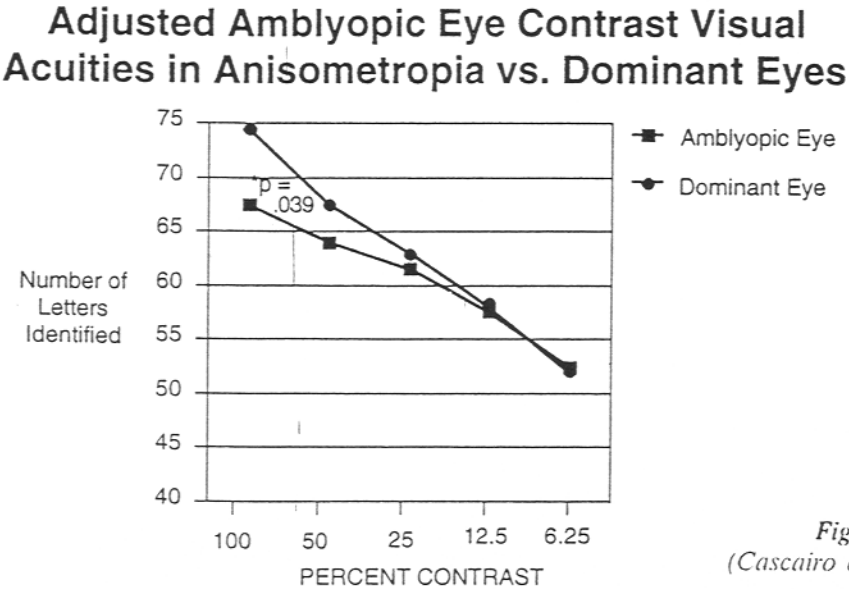

Figure 9
(Cascairo et al)

between the amblyopic and dominant eyes. The correction was only approximate due to different testing distances for the Snellen and contrast acuity testing, and because the Snellen charts were not arranged on a logarithmic scale. With the approximate correction, however, the corrected contrast acuity results for the amblyopic eyes approached those of the dominant eyes at lower contrast levels. At higher contrast levels, residual difference remained even after compensating for Snellen acuity deficits, especially in the anisometropic subjects.

DISCUSSION

Amblyopic eyes were compared with the dominant fellow eyes as controls in our study. Previous findings (14) have shown that dominant eyes of amblyopes compare favorably to control eyes in contrast sensitivity measurement. This was not the case in our study testing contrast visual acuity, as is demonstrated in Figure 2. The better contrast visual acuity function seen in dominant eyes of amblyopic subjects compared to controls is likely related to age and maturity differences. Fourteen of 19 treated amblyopic subjects in our study population retained some Snellen visual acuity deficits in the amblyopic eye. This is a finding common in other studies in which contrast sensitivity function in amblyopia is tested (6,7). As Rogers et al (3) demonstrated, the contrast sensitivity function is related to visual acuity in a linear fashion. One might, therefore, predict that eyes with residual visual acuity deficits will also demonstrate reduced contrast sensitivity function. Our results are in agreement.

Contrast visual acuity function was reduced for the amblyopic eyes in our study for both subtypes of amblyopia. Reductions in contrast visual acuity were proportional to reductions in Snellen visual acuity. The linear relationship between Snellen acuity and contrast visual acuity function

in our amblyopic subjects is demonstrated by plotting the contrast acuities of representative patients with varying endpoint visual acuities (Figures 10 and 11, right). Though the linear progression is not demonstrated as well graphically in the strabismic group at the lower Snellen acuity levels, it can be seen that the slopes of the curves are quite constant.

Our data also confirms previous reports that both strabismic and anisometropic amblyopic eyes show less contrast acuity deficits at lower contrast levels when compared to the dominant eyes. In Figures 3 and 4, (prior pages) this is demonstrated as a tendency for the curves of the amblyopic eyes to approach the curves of their fellow eyes as contrast decreases. Thus, in our population of patients, both subtypes of amblyopes demonstrated greater deficits in contrast visual acuity function when presented with the smaller optotypes (visible at higher contrast levels).

Our study results suggest that contrast visual acuity remains reduced in amblyopic eyes following treatment of the amblyopia. Both strabismic and anisometropic amblyopes appear to be affected similarly. The amblyopic eyes demonstrate greater defects in contrast visual acuity function at higher contrast levels when compared to the dominant eyes, and the defects appear to be in proportion to residual Snellen visual acuity deficits. Our population groups are too small, however, to determine true statistical differences.

The Holladay Contrast Acuity Test™ provided reproducible measurement of contrast visual acuity function in literate pediatric patients with relative ease in the clinical setting. However, the apparent variation in performance associated with age and maturity levels would make determination of normative values for the pediatric population difficult. The test succeeded in detecting differences in contrast visual acuity between the amblyopic and dominant eyes

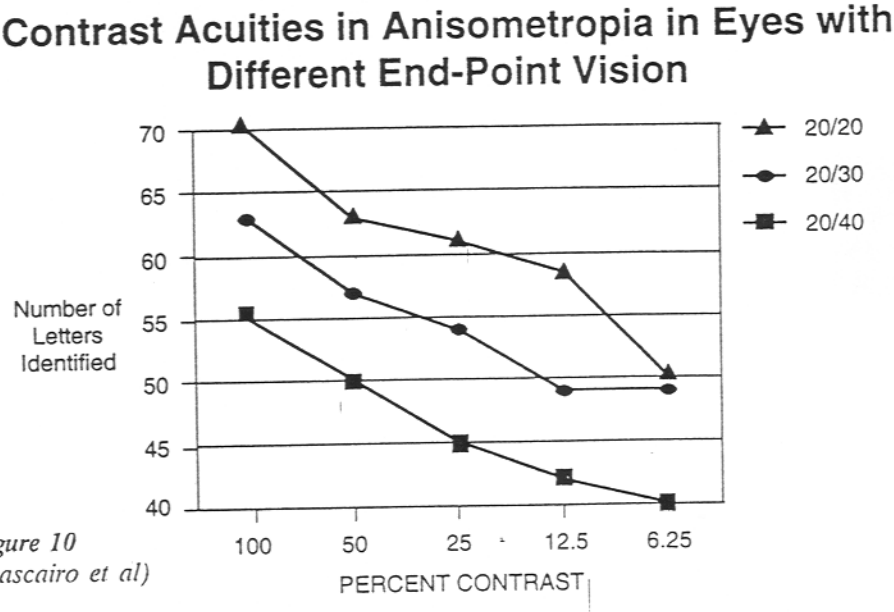

Figure 10
(Cascairo et al)

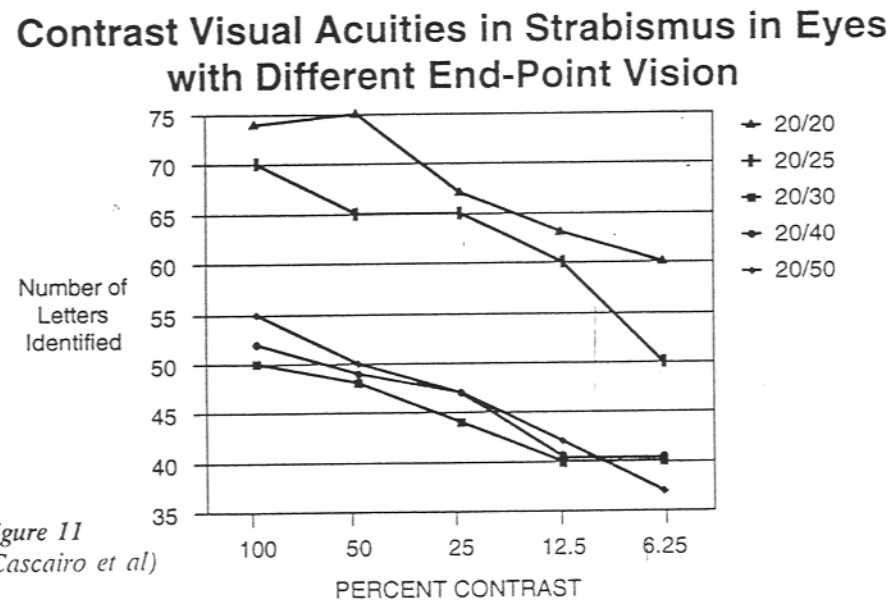

Figure 11
(Cascairo et al)

in treated amblyopia when no difference in Snellen visual acuity was apparent on measurement with conventional distance acuity charts. A future study in which distance Snellen visual acuity is measured with a chart based on a logarithmic progression of letter sizes may help to determine whether contrast visual acuity measurement is a more sensitive indicator of attaining vision equal to that of the dominant eye in the treatment of amblyopia. For instance, in our study, the five amblyopic subjects with endpoint Snellen visual acuity of 20/20 in the amblyopic eye may have demonstrated more subtle deficits in Snellen visual acuity if more detailed methods of testing were employed. Also, larger patient populations, closer age matching of subjects, and a forced-choice method of testing Snellen visual acuity would improve the ability to make comparisons in a future study.

The Holladay Contrast Acuity Test™ used in this study was developed and patented by one of the authors, Jack T. Holladay, MD, who maintains a financial interest in this product.

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Abstract in Spanish, French and German

Agudeza Visual por Contraste en Ambliopía Tratada.

RESUMEN: ***Propósito:*** *La agudeza visual por contraste fue medida en ambos ojos en niños tratados de ambliopía monocular anisometrópica o estrábica para determinar si los defectos en la agudeza visual por contraste permanecen despues de que la agudeza visual con Snellen se haya normalizado mediante el tratamiento del ojo ambliope. Tambien en los ojos ambliopes que no obtuvieron vision normal despues del tratamiento se analizó la relación entre la disminución residual de la agudeza visual con Snellen y la correspondiente disminución de la agudeza visual por contraste. Tambien los sujetos anisometropes fueron comparados con los sujetos estrábicos.*

Métodos: *Diecinueve ambliopes (10 estrábicos y 9 anisométropes) en los cuales se completó el tratamiento de la ambliopía fueron explorados para evaluar la mejor agudeza visual Snellen con corrección y la agudeza visual por contraste en ambos ojos. Fué utilisada la Prueba de Agudeza por Contraste de Holladay (Stereo Optical, Chicago) para medir la agudeza visual por contraste. Los resultados en los ojos ambliopes fue comparado con los ojos dominantes de los sujetos ambliopes, y estos resultados fueron comparados con la agudeza visual por contraste en diez sujetos control.*

Resultados: *Los ojos con ambliopía, ya sea por anisometropia o por estrabismo, mostraron una reducción de la agudeza visual por contraste comparados con los ojos compañeros dominantes aún despues de completarse el tratamiento de la ambliopía. La reducción estuvo en proporción al deficit residual post-tratamiento de agudeza visual Snellen, excepto en los niveles mas altos de contraste en los cuales los ojos ambliopes mostraron mayor reducción en la agudeza visual por contraste que la sugerida por el deficit residual de agudeza Snellen. Este patrón de mayor reducción en la agudeza visual por contraste a niveles mayores de contraste tambien fue visto en los ojos ambliopes de los pacientes en los cuales la agudeza visual Snellen post-tratamiento era de 20/20. La Prueba de Agudeza por contraste de Holladay proporcionó resultados reproducibles en los sujetos control.*

Conclusiones: *La agudeza visual por contraste tanto en ambliopes por anisometropía como por estrabismo se encontró reducida en el ojo ambliope despues de ser completado el tratamiento. Este grupo siguió un patrón de Tipo 1 (mayor pérdida a niveles mas altos de contraste) para ambos tipos de ambliopía y estuvo en proporción al defecto residual de agudeza visual Snellen en el ojo ambliope, excepto en los niveles mas altos de contraste (optotipos menores) en donde se observó una tendencia hacia una mayor reducción.*

Palabras Clave: *ambliopía, anisometrópica / ambliopía, estrabismica / ambliopía, tratamiento / agudeza visual por contraste / Prueba de Agudeza por Contraste de Holladay / estudio, prospectivo / agudeza visual, contraste.*

Acuité Visuelle mesurée par la méthode des contrastes dans l'amblyopie traitée.

Résumé: But: L'acuité visuelle mesurée par la méthode des contrastes était recherchée aux deux yeux chez des enfants avec une amblyopie monoculaire par anisométropie ou par strabisme traitée; cette mesure avait pour but de déterminer si des anomalies de l'acuité visuelle mesurée par la méthode des contrastes persistaient quand on avait obtenu par le traitement une normalisation de l'acuité visuelle de l'oeil amblyope au test de Snellen. De plus chez les yeux amblyopes qui n'ont pas une vision normale après traitement, on a recherché une relation entre les chutes résiduelles de l'acuité visuelle au test de Snellen et les chutes correspondantes de l'acuité visuelle mesurée par la méthode des contrastes. Enfin, les sujets anisométropes étaient comparés aux sujets strabiques.

Méthodes: dix neufs amblyopes (10 strabismes et 9 anisométropes) ayant terminé leur traitement pour amblyopie monoculaire étaient testés pour la meilleure acuité visuelle corrigée aux deux yeux au test de Snellen et à la méthode des contrastes. Pour mesurer l'acuité visuelle par la méthode des contrastes, on a utilisé le "Holladay Contrast Acuity Test" (Stereo Optical, Chicago). Les résultats des yeux amblyopes étaient comparés à ceux des yeux dominants chez les sujets amblyopes, et ces résultats étaient comparés aux acuités visuelles par la méthode des contrastes de dix sujets de contrôle.

Résultats: Les yeux avec amblyopie, qu'elle soit due à une anisométropie ou un strabisme, montraien à la méthode des contrastes une acuité visuelle réduite quand on la comparait aux yeux congénères dominants, même après achèvement du traitement de l'amblyopie. La réduction était proportionnelle au déficit de l'acuité vosuelle au test de Snellen persistant après traitement, excepté aux plus hauts niveaux de contraste ou les yeux amblyopes avaient une réduction des acuités visuelles par la méthode des contrastes plus grande que celle qu'on aurait pu attendre d'après les déficits résiduels de l'acuité visuelle mesurée au test de Snellen. Cet aspect d'une plus grand réduction de l'acuité visuelle à la méthode des contrastes aux niveaux plus élevés de contraste était aussi observée sur les yeux amblyopes de patients avec une acuité au test de Snellen de 20/20 après traitement. Le "Holladay Contrast Acuity Test" donne des résultats non contradictoires chez les sujets de contrôle.

Conclusions: L'acuité visuelle mesurée par la méthode des contrastes chez les amblyopes aussi bien anisométropiques que strabiques était réduite pour l'oeil amblyope après achèvement du traitement de l'amblyopie. Cette réduction était du type 1 (perte d'acuité plus grande aux niveaux de contraste plus élevés) pour les deux types d'amblyope et était proportionnelle au déficit résiduel d'acuité visuelle de l'oeil amblyope mesurée au test de Snellen, excepté aux niveaux plus élevés de contraste (optotypes plus petits) ou on observait une tendance vers une plus grande réduction.

Mots clés: Amblyopie, anisométropique / Amblyopie, strabique / Amblyopie, traitée / Acuité visuelle, contraste / Holladay Contrast Acuity Test / Etude, prospective.

Kontrastsehschärfe bei behandelter Amblyopie

Zusammenfassung: Hintergrund: Die Kontrastsehschärfe beider Augen von Kindern mit behandelter monokularer Anisometropie- oder Schielamblyopie wurde gemessen, um festzustellen, ob Defekte in der Kontrastsehschärfe verbleiben, nachdem durch Amblyopiebehandlung normale Optotypensehschärfe (Snellen) am amboyopen Auge erreicht wurde. Außerdem wurde bei amblyopen Augen, die nach Abschluß der Behandlung, keine normale Sehschärfe erreicht hatten, untersucht, ob die verbliebene Visusminderung der Minderung der Kontrastsehschärfe entsprach. Daneben wurden anisometrope Personen mit schielamblyopen Personen verglichen.

Methoden: Bei 19 amblyopen Personen (10 schielamblyope und 9 anisometrope), bei denen die Behandlung der einseitigen Amblyopie abgeschlossen war, wurde die bestkorrigierte Snellensehschärfe und die Kontrastsehschärfe beider Augen untersucht. Zur Bestimmung der Kontrastsehschärfe wurde der "Holladay Contrast Acuity Test" (Stereo Optical, Chicago) benutzt. Es erfolgte ein interokularer Vergleich und ein Vergleich mit der Kontrastsehschärfe von 10 Kontrollpersonen.

Ergebnisse: Auch nach Abschluß der Amblyopiebehandlung bestand sowohi bei den schielals auch bei den refraktionsamblyopen Augen ein Verminderung der Kontrastsehschärfe gegenüber dem nichtamblyopen Auge. Die Reduktion entsprach dem nach der Behandlung verbliebenen Snellenvisusdefekt, außer auf dem höchsten Kontrastniveau, wo amblyope Augen größere Reduktionen der Kontrastsehschärfe zeigen, als aufgrund der verbliebenen Visusminderung zu erwarten war. die stärkere Reduktion der Kontrastsehschärfe auf höherem Kontrastniveau feil auch bei amblyopen Augen von Patienten mit einem Snellenvisus von 20/20 nach Behandlung auf. Der "Holladay Contrast Acuity Test" ergab reproduzierbare Ergebnisse bei den Kontrollpersonen.

Schlußfolgerungen: Sowohl bei Anisometropie- als auch bei Schielamblyopie war die Kontrastsehschärfe des amblyopen Auges nach Abschluß der Amblyopiebehandlung vermindert. Für beide Amblyopieformen zeigte diese VErminderung ein Typ 1 Muster, (stärkerer Verlust auf höherem Kontrastniveau) und entsprach der verbliebenen Snellenvisusreduktion des amblyopen Auges, auß auf den höheren Kontraststufen (kleinere Optotypen), wo ein Trend zur stärkeren Reduktion der Kontrastsehschärfe beobachtet wurde.