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The Effects of Diffusion Blur on Snellen and Grating Acuity and Foveal Function in Amblyopia

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In order to verify that the effects of diffusion blur on Snellen and grating acuity in amblyopic eyes resemble those obtained from the peripheral or central retina in normal controls, we conducted the following experiment using a liquid crystal window (Edmund Scientific Co.) to produce diffusion blur on Snellen and grating acuity. Spatial frequencies used for a Snellen chart and Teller acuity card were 3.2, 6.5, 13.0, 26.0 cyc/cm at a working distance of 55 cm. The values of diffusive blur on central and peripheral visual acuity obtained from 20 normal healthy control eyes were compared with those values of central visual acuity in 26 amblyopic eyes. The diffusion blur had a strong negative effect on both Snellen and grating acuity in amblyopic eyes, but it had more potent effects on grating acuity ($p<0.05$). The diffusion blur values obtained from the central amblyopic retina were more compatible with those of the central retina than with those of the peripheral retina in the control group ($p>0.05$). Snellen acuity obtained from diffusion blur overestimated grating acuity in the normal central acuity group and amblyopic central acuity group. The result of this investigation demonstrated that the liquid crystal diffusion blur had a strong negative effeet on both Snellen and grating acuity and suggested that the visual function of an amblyopic retina resembled that of a normal central retina.

Key Words: Amblyopia, central retina, diffusion, liquid crystal window, peripheral retina

Foveal vision has traditionally been tested by Snellen acuity and grating acuity. The grating acuity has been advocated for special clinical situations. The grating acuity has been used to test acuity in infants and foveal vision in cataracts. Kim reported that grating acuity has been more influenced by diffusion blur (Kim *et al.* 1989). Since the dioptric blurring method has strong negative effects on only Snellen acuity (Frank and Faye, 1990), the novel diffusion blurring method of the liquid crystal window was used to compare the blurring effects of amblyopic and normal eyes. Previous studies have implied the resemblance between foveal function of amblyopic eyes and the peripheral retina of normal eyes (Von Noorden, 1996).

In order to verify whether the effects of diffusion blur on Snellen and grating acuity in amblyopic eyes resemble those obtained from the peripheral or central retinas in normal controls, we performed the following experiment using a liquid crystal window.

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MATERIALS AND METHODS

Patient

Twenty six amblyopes (female : male=13 : 13) between 5 and 10 years of age (mean: 7.3), with 20/50 (mean) corrected acuity were selected as subjects (Table 1). The consent form and study protocol were approved by the ethics committee of Severance Hospital. Informed consent for each child was obtained from at least one parent. Ten normal adults (20 eyes) between 23 and 30 years of age with 20/20 or better corrected acuity were selected for the normal control group (Table 1). The informed consent for controls was obtained from the subjects.

Methods

We used a Snellen chart and Teller acuity card in measuring central and peripheral visual acuity for control subjects and amblyopic patients. The illumination of the experiment room was kept constant at 175 lux. A liquid crystal window (Edmund Scientific Co., Barrington, NJ, U.S.A.) consists of a thin layer of material comprised of cavities (1~5 m) of nematic liquid crystal in a polymer matrix sandwiched between two electrodes of indium thin oxide-coated polyester film. When electric current is applied, the liquid crystals become regularly arranged and the light passing through the window can be varied. Diffusion blur, caused by liquid crystal windows, reduces contrast sensitivity and luminance so that visual acuity is decreased by lowering the voltage of the liquid crystal power supply. We measured the voltage at which the subjects could read the visual acuity chart through the liquid crystal window. In order to verify central Snellen acuity, the subjects and patients read the Snellen chart monocularly from 20 feet through the liquid crystal window, and the voltage at which they could define four levels of a Snellen chart (20/200, 20/100, 20/50, 20/25) was measured. The equivalent spatial frequencies for Snellen acuity of 20/200, 20/100, 20/50, 20/25 at a working distance of 6 feet were 3.2, 6.5, 13.0, 26 cyc/cm for a Teller acuity card at a working distance of 55 cm. In order to verify central grating acuity, the voltages at which subjects and patients could define four spatial frequencies of a Teller acuity card (3.2, 6.5, 13.0, 26 cyc/cm) were measured. In order to verify the peripheral visual acuity of amblyopic patients, we measured the voltages at which the patients could define four spatial frequencies of a Teller acuity card and a Snellen acuity chart occluding the macula, using an occluder (6 mm in diameter) located about 18 cm in front of the cornea.

Table 1. Characteristics of the control and amblyopic groups

	Control	Amblyopia
No	20	26
M : F	8 : 12	13 : 13
Mean Age	28	7.3
Mean V/A	20/20	20/50

Statistics

Values were expressed as mean plus or minus the standard deviation and as a range. Unless otherwise specified, data were analyzed by ANOVA with repeated measure trend.

RESULTS

Tables 2 and 3 illustrate the values of diffusion blur that were obtained from amblyopic eyes and normal adult control eyes. The diffusion blur had a strong negative effect on both the Snellen and grating acuity, but it had a more potent effect on grating acuity in amblyopic eyes and normal adult

Table 2. Voltage changes in central and peripheral Snellen visual acuity

S/F[1] (cyc/cm)	Amblyopia(c)[2] (volts)	Control(c) (volts)	Control(p)[3] (volts)
3.2	15.56±5.88	14.74±1.36	20.36±4.13
6.5	18.11±5.72	15.96±1.66	24.80±6.80
13.0	19.79±3.73	17.63±2.11	31.60±10.40
26.0	25.32±4.71	22.17±6.58	90.01±32.70

[1]S/F: spatial frequency, [2]c: central, [3]p: peripheral

Table 3. Voltage changes in central and peripheral grating visual acuity

S/F[1] (cyc/cm)	Amblyopia(c)[2] (volts)	Control(c) (volts)	Control(p)[3] (volts)
3.2	18.55±3.63	17.39±2.86	21.29±2.54
6.5	22.36±4.31	20.44±4.06	25.59±4.80
13.0	26.22±5.72	24.14±5.13	32.90±7.45
26.0	28.65±7.22	35.41±9.69	92.84± 30.21

[1]S/F: spatial frequency, [2]c: central, [3]p: peripheral

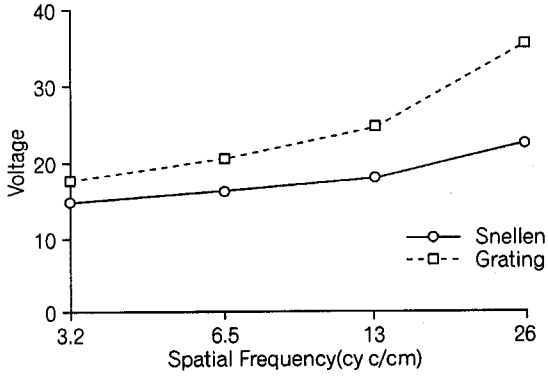

Fig. 1. Graph of central Snellen and Grating visual acuity in the Control Group. The diffusion blur had a strong negative effect on both the Snellen and grating acuity, and a more potent effect on grating acuity in the normal adult control group ($p<0.05$).

controls ($p<0.05$, Fig. 1, 2, 3). The values of diffusion blur in amblyopic eye were more compatible with those of the central retina than with those of the peripheral retina in the control group ($p>0.05$, Fig. 1, 2, 3).

DISCUSSION

The liquid crystal window offers an inexpensive and readily adjustable source of diffusion blur, as well as being a useful shutter, luminance filter and contrast attenuator. The diffusion blur produced by a liquid crystal window may provide a useful model for the intraocular scattering associated with cataract (Peter, 1990).

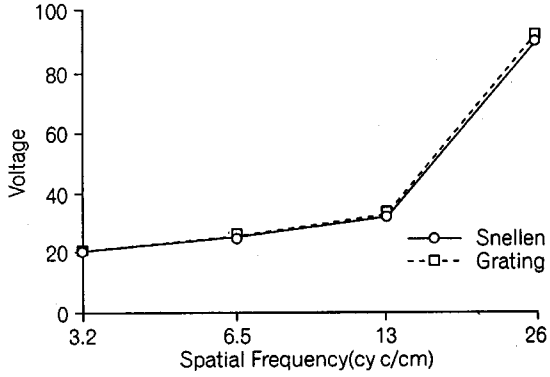

Fig. 2. Graph of peripheral Snellen and Grating visual acuity in the Control Group. The diffusion blur had a strong negative effect on both the Snellen and grating acuity in the normal adult control group ($p<0.05$).

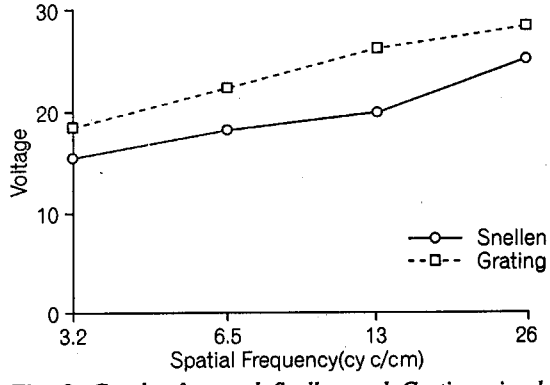

Fig. 3. Graph of central Snellen and Grating visual acuity in the Amblyopic Group. The values of diffusion blur in amblyopic eyes were more compatible with those of the central retina than with those of the peripheral retina in the control group ($p>0.05$).

Amblyopia is a disturbance of spatial or formed vision that develops early in life, usually in association with strabismus, anisometropia, and severe refractive error (Dennis, 1990). Amblyopia induces physiologic and anatomic change in the visual cortex, but there is no change in the retina. There have been many reports about the function of amblyopic central vision. Miller reported that amblyopic fovea behaved like the peripheral portion (Von Noorden, 1996). Thomas showed that contrast sensitivity functions obtained from the foveal region of amblyopes resembled those obtained from the peripheral retina of normal eyes (Joseph, 1978; Von Noorden, 1996).

Volkers reported that two characteristics were found to be typical for amblyopia: first, that there is a discrepancy between the high-frequency cut-off ('grating acuity') and the Snellen acuity; and second, that the contrast sensitivity is strongly dependent on the width of the stimulus (Volkers *et al.* 1987). Levi reported that the positional uncertainty in anisometropic amblyopia is consistent with the reduced sensitivity of the spatial filters (Levi *et al.* 1987). Moseley reported that no differences were found between amblyopes' ability to detect the grating acuity and to accurately discriminate target orientation (horizontal or vertical) (Moseley *et al.* 1987). White reported that grating acuity deteriorates less rapidly with eccentricity than does Snellen acuity (White and Loshin, 1989)

Frank reported that the dioptric blur had a strong negative effect on Snellen acuity, but had little effect on grating acuity (Frank and Faye, 1990). This study demonstrated that the diffusion blur produced by a liquid crystal window had a strong negative effect on both the Snellen and grating acuity in amblyopic eyes and normal adult controls, and that it had a more potent effect on grating acuity. The contrast of the Snellen chart was 95% and that of the grating chart was 80%. The difference in contrast between the Snellen and grating charts was a factor which affected the result that grating acuity was more influenced by diffusion blur (Kim *et al.* 1989).

The diffusion blur values obtained from amblyopic retinas were more compatible with those of the central retina than with those of the peripheral retina in the adult control group. This result showed that the visual function obtained from the foveal region of amblyopes resembled those from the central retina of normal eyes. Because the patients were very young, we were unable to obtain the values of diffusion blur compared with the normal peripheral retina. Therefore, we were unable to compare directly the values of diffusion blur from amblyopic retina with those of a child's normal peripheral retina. Our results may have been influenced by two factors: the control group was composed of normal adults and the patients had relatively good visual acuity (mean 20/50). According to increasing spatial frequency, the visual function of an amblyopic retina resembles that of a normal central retina.

The results of this investigation demonstrated that liquid crystal diffusion blur had a strong negative effect on both Snellen and grating acuity, suggesting that the visual function of an amblyopic retina resembled that of a normal central retina.

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