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Optical Defocus: Differential Effects on Size and Contrast Letter Recognition Thresholds
(Reprint)

By

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The purpose of this study was to determine if optical defocus produces a greater reduction in visual acuity or small-letter contrast sensitivity. Letter charts were used to measure visual acuity and small-letter contrast sensitivity (20/25 Snellen equivalent) as a function of optical defocus. Letter size (acuity) and contrast (contrast sensitivity) were varied in equal logarithmic steps to make the task the same for the two types of measurements.

Both visual acuity and contrast sensitivity declined with optical defocus, but the effect was far greater in the contrast domain. However, measurement variability also was greater for contrast sensitivity. After correction for this variability, measurement in the contrast domain still proved to be a more sensitive (1.75) index of optical defocus.

Small-letter contrast sensitivity is a powerful technique for detecting subtle amounts of optical defocus. This adjunctive approach may be useful when there are small changes in resolution that are not detected measures of visual acuity. Potential applications include evaluating the course of vision in refractive surgery, classification of cataracts, detection of corneal or macular edema, and detection of visual loss in the aging eye. Evaluation of candidates for occupational requiring unique visual abilities also may be enhanced by measuring resolution in the contrast domain.

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Optical Defocus: Differential Effects on Size and Contrast Letter Recognition Thresholds

Jeff Rabin

Purpose. To determine if optical defocus produces a greater reduction in visual acuity or small-letter contrast sensitivity.

Methods. Letter charts were used to measure visual acuity and small-letter contrast sensitivity (20/25 Snellen equivalent) as a function of optical defocus. Letter size (acuity) and contrast (contrast sensitivity) were varied in equal logarithmic steps to make the task the same for the two types of measurement.

Results. Both visual acuity and contrast sensitivity declined with optical defocus, but the effect was far greater in the contrast domain. However, measurement variability also was greater for contrast sensitivity. After correction for this variability, measurement in the contrast domain still proved to be a more sensitive (1.75×) index of optical defocus.

Conclusions. Small-letter contrast sensitivity is a powerful technique for detecting subtle amounts of optical defocus. This adjunctive approach may be useful when there are small changes in resolution that are not detected by standard measures of visual acuity. Potential applications include evaluating the course of vision in refractive surgery, classification of cataracts, detection of corneal or macular edema, and detection of visual loss in the aging eye. Evaluation of candidates for occupations requiring unique visual abilities also may be enhanced by measuring resolution in the contrast domain. Invest Ophthalmol Vis Sci. 1994;35:646–648.

The ability to detect, discriminate, and recognize visual detail is dependent on the quality of the retinal image.[1] Optical defocus selectively attenuates the contrast of higher spatial frequencies leading to a reduction in visual acuity—the smallest resolvable detail at maximum stimulus contrast.[1–4] The relationship between visual acuity and defocus forms the basis of subjective refraction. Optimization of visual acuity is also the goal of surgery designed to correct refractive error and opacities of the ocular media. Notwithstanding the utility of visual acuity for disclosing the effects of defocus, blurring the retinal image also reduces the contrast of higher spatial frequencies leading to a reduction in contrast sensitivity.[1,2,5,6] In terms of the contrast sensitivity function, defocus shifts the descending limb of the contrast sensitivity function downward, and consequently, to the left. The translation downward along the contrast dimension is quantified as a loss of contrast sensitivity, and the shift leftward along the spatial frequency axis represents the reduction in visual acuity. Because of the steepness of the contrast sensitivity function near the spatial frequency cutoff, a blur-induced loss of acuity involves a relatively larger reduction in contrast sensitivity. This suggests that measurement of high frequency sensitivity loss may provide a more sensitive index of blur than visual acuity. This assumption was confirmed in the current study.

METHODS

Visual acuity and contrast sensitivity were measured with letter charts displayed on a high-resolution video monitor. Luminance and contrast, spatial, and temporal presentation were controlled by computer. The visual acuity and contrast sensitivity charts were patterned after the work of Bailey and Lovie[7] and Pelli et al.[8] Acuity charts consisted of high-contrast (93%) black letters on a white background. Each line of the

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chart included five letters, and, from top to bottom, decreased in size by a constant factor (0.1 log unit). The same principles were used to design the letter contrast charts, but size was held constant (20/25 Snellen equivalent) while contrast was varied, by line, in approximately 0.1 log steps. The same letters were used on all charts, but letter sequences were varied from trial to trial to discourage learning effects. Scoring was conducted by letter with a precision of 0.02 log units.[9] Measurements were obtained with different levels of optical defocus (0 to +1.25 diopters) from eight normal subjects (aged 20 to 38 years; mean = 26 years). Each subject was refracted optimally for the viewing distance and tested monocularly on the acuity and contrast tasks at each level of defocus. In accordance with the Declaration of Helsinki, informed consent was obtained from subjects after the protocol was approved by our institutional review committee.

RESULTS AND DISCUSSION

Main results are depicted in Figure 1. Mean (±1 SE) visual acuity and contrast sensitivity are plotted as a function of optical defocus. By plotting these variables on equal log axes, the magnitude of the defocus effect can be compared directly across the two conditions. It is clear that both acuity and contrast sensitivity decline with increasing optical defocus, a finding that has been well established previously. However, the magnitude of this effect is far greater in the contrast domain. A 1.25 D defocus causes a 3× reduction in visual acuity, but a 16× reduction in small letter contrast sensitivity.

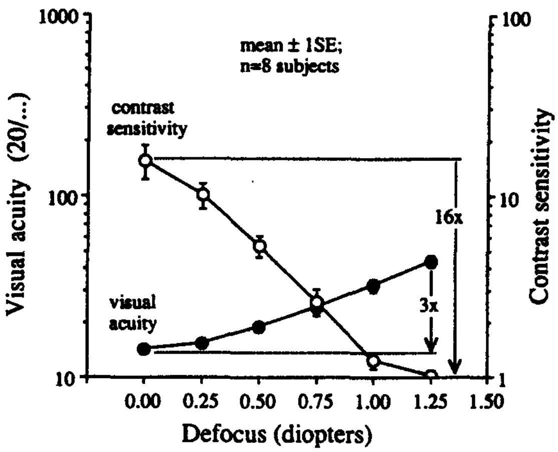

FIGURE 1. Mean (±1 SE) visual acuity and contrast sensitivity (20/25 letter size) are plotted against optical defocus. Values are shown on equal log axes which span a 100× change in visual threshold. The vertical arrows show that 1.25 D of optical defocus reduces visual acuity 3×, but contrast sensitivity 16×.

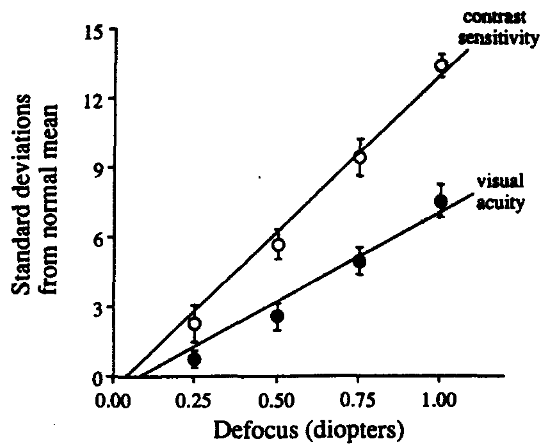

FIGURE 2. The average number of standard deviations from the normal mean (no defocus) is plotted against defocus for visual acuity and contrast sensitivity. Each function is linear with the ratio of the slopes being 1.75.

Whereas each 0.25 D defocus reduces acuity by an average of one line on the acuity chart, sensitivity is reduced three lines per 0.25 D on the contrast threshold chart.

Despite the greater efficacy of defocus on small letter contrast sensitivity, the utility of this approach depends critically on measurement variability. A larger effect does not ensure greater test sensitivity if the measurement is inherently more variable, as was the case for contrast sensitivity. To standardize measurements with respect to variability, the difference between each visual threshold and the mean threshold with no defocus was divided by the standard deviation of the measurement. This simple transformation, which specifies the deviation from the expected mean in standard units, facilitates direct comparison of acuity and contrast sensitivity results. Figure 2 shows the average number of standard deviations from the mean (at 0 D) plotted against optical defocus for visual acuity and contrast sensitivity. Despite correction for greater variability, measurement in the contrast domain still proved to be a (1.75×) more powerful tool for disclosing small amounts of optical defocus.

Several conditions are characterized by small changes in visual resolution that may be undetected by conventional measures of visual acuity. Evaluation of these conditions could be enhanced by measuring small-letter contrast sensitivity. Potential applications include evaluating the course of vision in refractive surgery, presurgical classification of cataract patients, and detection of contact-lens–induced corneal edema, and subclinical macular edema. Neural and media-induced visual loss in the aging eye also may be better disclosed by careful measurement of small letter contrast sensitivity. Evaluation of potential candidates for occupations requiring unique visual abilities, such as space and aviation, may also be enhanced by measuring resolution in the contrast domain. We are exploring the utility of small-letter contrast sensitivity for application in clinical and research environments.

Key Words

visual acuity, contrast sensitivity, defocus, blur, vision testing

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