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Effect of Supplementary Lenses on logMAR Visual Acuity

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ABSTRACT

Background: While previous studies have examined the effect of supplementary plus lenses on visual resolution, albeit sometimes using sub-optimal techniques, the effect of overminusing an accommodating patient (adding additional minus lens power) is less clear. This study assessed distance logMAR visual acuity (VA) through plus and minus lenses added to the optimal refractive correction.

Methods: The study was performed on 20 subjects. After determining the distance refractive correction, supplementary spherical lenses ranging from +1.00 to -1.00D (in 0.12D steps) were introduced in random order, and logMAR resolution VA was measured through these lenses using Landolt C optotypes at a viewing distance of 4m.

Results: As expected, +1.00 and +0.75D lenses produced a significant reduction in VA. However, no significant change was observed for lenses ranging from +0.50 to -1.00D. The mean VA for this range of lenses was -0.14 logMAR (SD=0.10). Within the range from plano to +1.00D, a significant positive linear correlation was observed between VA and supplementary lens power, described by the function logMAR VA = 0.36F – 0.19 (where F = lens power).

Conclusion: In accommodating individuals, the effect of supplementary lens power between +1.00 and -1.00D is predictable. Plus lenses produce a linear increase in logMAR VA, with 1D of defocus producing a loss of approximately 3 lines of logMAR acuity, while no significant change in VA was found when minus lenses were added. Previous findings on the effect of fogging lenses as a check for induced hyperopia may have over-estimated the expected reduction in VA.

Keywords: accommodation, hyperopia, minimum angle of resolution, refraction, visual acuity

Introduction

Visual acuity (VA) may be the most frequently measured parameter in clinical optometric practice. The effect of optical blur on this function plays a significant role within the routine eye examination. For example, the standard endpoint in the determination of refractive error is the maximum plus lens that provides the optimum VA.[1] Similarly, unaided VA provides the practitioner with an initial assessment of the uncorrected refractive error. While a number of previous studies have reported the relationship between blur and visual acuity,[2-6] many have used sub-optimal methods to assess VA. For instance, many early investigations used the Snellen acuity system.[2,6,7] This introduces difficulties when only part of a line is read, non-standardization of spacing between letters, as well as issues regarding statistical analysis. Another problem with this chart is the basement effect, whereby the subject has already reached the bottom line on the chart, and therefore any additional improvement cannot be measured. It is also well established that some optotypes are easier to read than others, thereby introducing another source of variability when recognition acuity is being assessed.[8]

Johnson and Casson[9] examined the effect of plus lenses on logMAR acuity (using Landolt C optotypes) at different luminance levels in a group of just four subjects. The logMAR chart overcomes many of the limitations described above when using a Snellen acuity chart.[8] The authors observed that VA decreased sharply for the first 2D of blur, and then more gradually for lenses between +2.00 and +8.00D. They noted that without blurring lenses, the average VA was "slightly better than 20/20 (6/6)," although the exact value was not provided. Radhakrishnan et al. reported that minus lenses produced a smaller decline in VA (technically a smaller increase in logMAR) in cyclopleged myopic eyes when compared with the equivalent plus lens. However, these authors found no significant difference between the effect of equal amounts of plus or minus lenses on logMAR VA in cyclopleged nonmyopic eyes (ranging between -0.25 and +1.25D; mean = +0.62D).[10]

The effect of supplementary minus lenses (to induce hyperopia) on visual resolution in accommodating individuals is less well documented. For example, Borish and Benjamin[11] stated that "most hyperopes do not suffer depreciation of distant vision," although they did not include any evidence to support this claim. By introducing supplementary minus lenses, the resulting minification will condense the letter into a smaller space, thereby making it appear to be of higher contrast. This accounts for an optotype appearing "smaller and darker" when the patient is rendered hyperopic. One might think that this minification could actually reduce the achieved level of VA. Indeed, some practitioners use this observation to justify not pushing the patient to achieve their optimal VA during a subjective refraction, but instead stop at a sub-optimal level (frequently 6/6 or 20/20) on the basis that this will avoid over-minusing the patient.

Accordingly, the aim of the present study was to examine the effect of both supplementary plus and minus lenses (added over the refractive correction) on logMAR VA. In order to avoid a basement effect, the chart was calibrated to allow the presentation of targets as small as -0.40 logMAR (equivalent to 6/2.4). Additionally, lenses were introduced in ±0.12D steps. This interval, which is smaller than has been used in previous studies, is expected to yield more reliable results.[12]

Methods

The study was performed on 20 visually-normal subjects between 21 and 26 years of age. All had best-corrected visual acuity of less than 0.0 logMAR, and none had strabismus or manifest ocular disease. The protocol followed the tenets of the Declaration of Helsinki, and informed consent was obtained from all subjects after an explanation of the nature and possible consequences of the study. The protocol was approved by the Institutional Review Board at the SUNY State College of Optometry. Initially, the optimal distance refractive correction was determined for the right eye using retinoscopy and standard subjective refraction (including Jackson Cross Cylinder) through a Reichert phoropter (model number 11625B–Reichert Inc., Buffalo, NY) to achieve a maximum plus to best VA refraction.[1] The left eye was occluded throughout the subjective refraction procedure. Supplementary spherical lenses ranging from +1.00 to -1.00D (in 0.12D steps) were introduced into the phoropter over this refractive correction in random order, and logMAR VA was measured through these lenses using Landolt C optotypes at a viewing distance of 4m. The gap in the Landolt C was presented in four possible directions, namely up, down, right and left. In all cases, subjects were encouraged to guess the orientation of the gap in the optotype, and the test ended

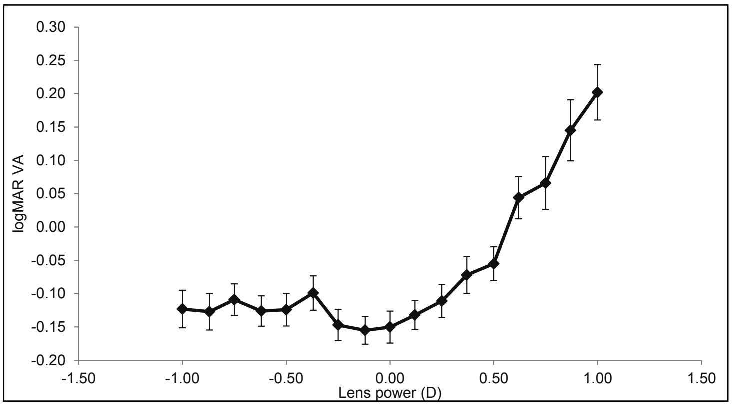

Figure 1. *Effect of supplementary lenses on logMAR VA. Error bars indicate ± 1SEM (N=20).*

when the subject could no longer identify any of the target orientations within a particular line. To allow a greater range of responses, the computerized acuity chart [presented using TestChart Pro 2000 (Thomson Software Solutions, Welham Green, Herts, U.K.)] on a 17-inch flat panel LCD monitor (Dell Corp, Round Rock, Texas) was calibrated for a distance of 2m (even though it was positioned 4m away from the subject) to allow the presentation of targets as small as -0.40 logMAR (equivalent to 6/2.4). Screen luminance measured using a Spectra Pritchard photometer (Model 1980A–Kollmorgen Corp; Burbank, CA) was 143 cd/m2, and the contrast scale on the software was set to the highest level (denoted 100%).

Results

The mean spherical equivalent refractive error for the group was -3.04D (SD = ±2.92D; range -0.25 to -9.12D). The effect of supplementary lenses on logMAR VA is shown in Figure 1. Analysis of variance indicated that VA varied significantly with lens power ($F=14.13$; $df=16,323$; $p<0.0001$). Post-hoc analysis using the Tukey test demonstrated no significant change for lenses between +0.50 and -1.00D. The mean VA for this range of lenses was -0.14 logMAR (SD=0.10), which is equivalent to a Snellen fraction of 6/4.3 (20/14.3). Within the range from plano to +1.00D, a significant positive linear correlation was observed between logMAR VA and supplementary lens power ($r=0.63$, $p<0.0001$), having a regression equation of logMAR VA = 0.36F − 0.19 (where F = lens power). Fitting these data (for lenses between plano and +1.00) with a second- or third-order polynomial function produced minimal improvement in fit.

Discussion

In healthy, visually-normal, accommodating individuals, the effect of supplementary lenses between +1.00 and -1.00D on resolution VA is predictable. Plus lenses produce a positive linear increase in logMAR VA, while minus lenses do not produce any significant change. Accordingly, there is no support for the proposal that the practitioner should not seek optimal acuity because they may end up over-minusing the patient. Rather, clinicians should always seek to achieve the best possible level of VA when refracting a patient. There is no justification for stopping short of this magnitude unless desired by the patient.

The mean best-corrected VA recorded in the present study was -0.14 logMAR (equivalent to 6/4.3). This is almost identical to the mean of -0.13 logMAR reported by Elliott et al.[13] for individuals between 18 and 24 years of age. Indeed, Elliott et al. noted that in normal, healthy eyes, mean VA was never greater than 0.0 logMAR for subjects up to 80 years of age. These authors pointed out that earlier studies frequently used projector charts (having relatively low luminance and contrast) which often did not include many optotypes smaller than 6/6. Indeed, it has been well documented that 6/6 should not be regarded as normal VA for a healthy eye. As long ago as 1898, Tscherning wrote that good eyes have approximately 6/3 visual acuity, and if an eye has only 6/6 we can be sure that it has easily detectable problems.[14] Significantly, Velasco e Cruz pointed out that Snellen's calculations were in error since he incorrectly used a full grating cycle (equivalent to the width of two bars) as the basis for the width of a black line in an optotype.[15] Therefore, 6/6 (20/20) acuity should not be regarded as optimal, ideal, or even average acuity in a healthy eye.

It should be noted that the mean VA measured here through the +0.50 and +1.00 supplementary lenses was -0.06 logMAR (equivalent to 6/5) and +0.20 logMAR (equivalent to 6/10), respectively (Figure 1). These values represent better levels of acuity than has been reported previously under blurred conditions. However, many of these earlier studies appear to have underestimated the optimal level of VA. For example, Bennett and Rabbetts[4] stated that if a patient's best VA is 6/6, then the addition of +0.50 and +1.00 lenses will blur the acuity to 6/9 and 6/18, respectively. Similarly, Hirsch6 reported that 0.50 and 1.00D of myopia produced average VA of 6/7.5 and 6/19.5, respectively. It is not possible to use Hirsch's data to interpolate the expected level of acuity for an emmetropic subject as inserting zero into the regression equations provided would give an expected VA of 6/0, which the author notes is of course impossible. Therefore, in an optimally corrected patient (i.e., better than 6/6), the effect of fogging lenses (frequently used as a screening test for hyperopia or to ensure that the patient has not been over-minused at the end of the refractive examination[1]) will not reduce VA to the degree reported previously. The results of the present study support the rule of thumb proposed by Blendowske, namely that 1D of defocus will produce a loss of approximately 3 lines of logMAR acuity.[5]

An important difference between the methodology of the present investigation and many previous studies is that resolution acuity was tested here; subjects had to locate the orientation of a critical element, in this case the gap in a Landolt C. Since oblique orientations were not tested, subjects had a 1 in 4 chance of guessing the correct direction of the gap. Most previous investigations examined recognition acuity, where the observer was required to identify an object. In the latter case, the number of alternatives will be higher, with less likelihood of guessing correctly. This may at least partially explain the improved acuity observed under blurred conditions found in the present study when compared with earlier findings. However, the linear function observed here for plus lenses (i.e., logMAR VA = 0.36F − 0.19, where F = plus lens power) is very similar to the finding of logMAR VA = 0.36F − 0.28 for cyclopleged myopic subjects reported by Rahhakrishnan et al.10 The latter investigation was performed over a larger range of lenses (plano to +3.00). However, the specific type of VA test used, i.e., whether resolution or recognition acuity, was not recorded in their paper. Similarly, Poulere et al.[16] observed that the introduction of a +2.00D spherical lens produced a mean increase in logMAR VA for myopic subjects of 0.66 and 0.77 when letter or Landolt C targets were used, respectively, while Smith noted that refractive error of 0.30D would produce a change of 1 line of logMAR acuity.[3] Interestingly, Poulere et al. suggested that the finding of a smaller reduction in acuity with letter optotypes, when compared with Landolt Cs, might imply that the spatial characteristics of letters were differently affected by blur, thereby making them more easily identifiable. Landolt Cs will appear as circles when blurred, whereas some letters retain sufficient characteristics to be still identifiable when defocused.

A limitation of this study is that the refractive correction was not determined under cycloplegia. This was omitted to allow the testing of VA through supplementary minus lenses with concurrent accommodation. However, the absence of a cycloplegic refraction could mean that latent hyperopia (or pseudomyopia) was missed. With an entirely myopic population having best corrected VA better than 6/6, the likelihood of substantial errors in the measured refractive error seems small. Therefore, the finding that additional minus lenses do not improve VA seems valid. Additionally, pupil size was neither controlled nor monitored. However, Atchison et al.[17] observed that when viewing

0.0 logMAR letters through either 3, 4, or 6mm pupils, the limits at which blur first became noticeable were ±0.33D, ±0.30D, and ±0.28D, respectively. This finding indicates that within this range of pupil diameters, the effect of pupil size on the perception of blur when viewing small targets is minimal. Further, the VA was assessed immediately after the introduction of plus lenses. Had the subjects been given the opportunity to adapt to the presence of blur over time, then their visual resolution is likely to have improved.[18-20]

Conclusion

The results of the present investigation demonstrate that plus lenses produce a positive linear increase in logMAR VA while minus lenses do not produce any significant change. However, previous findings of the effect of fogging lenses to check for induced hyperopia may have overestimated the reduction in VA.

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