Comparison of Low-Contrast Visual Acuity Between Eye Black and Maxsight Tinted Contact Lenses

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Objectives: Athletes who participate in outdoor activities seek products to reduce glare and improve contrast. This study compares performance of low-contrast visual acuity (VA) in bright outdoor conditions between the Maxsight Amber contact lens (CLs) and clear CLs with and without Eye Black grease.

Methods: Seventeen subjects were fitted with clear CLs, clear lenses with Eye Black grease, Maxsight lenses with Eye Black grease, and Maxsight lenses alone. With each modality, the subject demonstrated low-contrast VA assessed and completed a questionnaire. At the end of testing, subjects completed a questionnaire to survey the performance of each modality.

Results: The average low-contrast VA with clear CLs was 20/18.4, which improved to 20/17 with the addition of Eye Black grease (P=0.132). Significant improvement in low-contrast VA was seen with the Maxsight CLs to 20/15.4 ($P<0.05$), although it was not further improved with the addition of Eye Black grease. The results of the questionnaire showed a preference of the Maxsight CLs throughout the study for low-contrast VA.

Conclusions: Although Eye Black grease has its place in sport and some sporting environments, the benefit in contrast acuity is insignificant. The better performance of the amber Maxsight lenses in this study demonstrates a visual performance benefit in bright sunlight.

Key Words: Contrast sensitivity—Visual acuity—Eye black grease—Tinted contact lens.

(*Eye & Contact Lens* 2011;37: 147–152)

Athletes who participate in outdoor sports and recreational activities are exposed to illuminance ranges from 1,000 to 10,000 foot-lamberts.[1] Sunlight exposure saturates the retina and reduces finer levels of contrast sensitivity.[2] Visible light is responsible for glare that can cause significant interference with an athlete's ability to see the visual details critical for successful performance. For example, direct glare from the sun is evident in a blue sky because it affects the visibility of a lofted ball. Reflected glare is exceptionally troubling for athletes when the sun is reflected off surfaces such as water, snow, pavement, and sand. These surfaces reflect horizontally polarized light that can produce substantial glare. Dark filters aid in recovery of contrast sensitivity and dark adaptation after photoreceptor saturation.[3] The ability of filters to reduce glare and improve contrast may enhance the ability to discern crucial details and judge depth in bright outdoor conditions.

It has long been recognized that, to be successful in sports, an athlete must use a variety of visual skills. Researchers and clinicians have sought to determine the specific vision skills that correlate to success in sports. The vision skills identified as critical include static and dynamic visual acuities (VAs), contrast sensitivity, distance stereopsis, accommodative-vergence facility, span of perception, central eye–hand reaction and response speeds, and peripheral eye–hand response speed.[1] Athletes have demonstrated better visual abilities than do nonathletes and top athletes—those who are most successful–often demonstrate visual abilities that are superior to lower-level or less successful athletes.[4–8] Eye care providers may endeavor to improve any of these vision skills to contribute to success in sport by recommending the use of optical aids such as contact lenses (CLs) and sun eyewear.[1,9]

In addition to sun eyewear, Eye Black has been used for at least six decades.[10] For many years, Eye Black was available as a grease, frequently placed along the inferior orbital rim in an elongated oval shape (Fig. 1). In addition to the use of grease, Eye Black stickers in the shape of the typical Eye Black grease application are available (Fig. 2). In theory, Eye Black is used to decrease glare caused by reflections off the skin of the inferior orbital rim. This glare is believed to degrade visual image quality, thereby decreasing visual performance.[11] For years, athletes have used Eye Black with minimal evidence supporting its efficacy. DeBroff and Pahk[11] found that Eye Black grease improved contrast sensitivity in direct outdoor sunlight compared with Eye Black stickers and to a control of petroleum jelly applied on the inferior orbital rim.

In some sports, sun eyewear can be impractical because of frame discomfort, fit, or sports performance concerns. There is considerable interest in the potential advantages of CLs containing tints that are engineered for the visual demands of baseball and other sports, commonly referred to as performance tints. However, the major disadvantage of tinted CLs is that they are more cumbersome than eyewear to change or remove if the environmental conditions change.

Nike (Beaverton, OR) Maxsight lenses were commercially available performance-tinted CLs with two tint options, Grey–Green and Amber. The Grey–Green tint was designed for outdoor activities, such as trail running, mountain biking, water sports, and golf. The Amber tint was designed for high-speed ball sports where a ball must be tracked against the background of the playing field or sky, such as soccer, tennis, and baseball. Nike Maxsight lenses

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Disclosure: All contact lens materials were supplied at no charge from Nike, Inc. (Beaverton, OR).

The authors have no funding or conflicts of interest to disclose.

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Accepted December 20, 2010.

DOI: 10.1097/ICL.0b013e31820c6e09

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FIG. 1. Two subjects wearing the Maxsight Amber contact lenses (CLs) and the Eye Black grease.

claimed to offer enhanced visual comfort by reducing brightness and glare throughout the full visual field, while also improving contrast recognition by selectively filtering short-wavelength light.[12] Because the Amber tint filters a substantial portion of the short wavelength light (Fig. 3), a reduction in chromatic aberration may be responsible for improved image clarity with these lenses.

Tinted CLs may improve or degrade the contrast sensitivity function (CSF) under different conditions. Measurement of CSF has been recommended in athletes because many sports involve visual discrimination tasks in suboptimal lighting because of environmental variability.[1,6,7,13] The effect of yellow-range tints on contrast sensitivity has been studied extensively, and there has been mixed success in quantifying the perceived improvements in contrast sensitivity.[3,14–20] A recent study found that Maxsight lenses significantly improved CSF in collegiate and professional football athletes.[21] Another study confirmed that Maxsight CLs improve contrast discrimination and speed of visual recovery in bright sunlight when compared with clear lenses.[22] Maxsight lenses also provided better contrast discrimination when alternating between bright and shaded target conditions. It should be noted that contrast sensitivity may be degraded in CL wearers if the lens fit is not optimal, even when VA seems acceptable.[23–26]

This study compares performance on low-contrast VA in bright outdoor conditions between the Maxsight Amber CL, a clear CL, and Eye Black grease. The study compares performance with a combination of Eye Black and both CL modalities. To control for the feeling of wearing a CL, a clear CL serves as a control for the Maxsight CL. Because artificial lighting conditions are far below the intensity (in candelas per square meter) of natural sunlight, the hypothesis was that purported improvements in visual performance would be revealed in the natural environment. A number of sport situations contain subtle visual information with varying contrast conditions; therefore, low-contrast VA was chosen for visual performance testing.

FIG. 2. Eye Black Stickers. Available at: http://images.bacharach.com/300/97568.JPG.

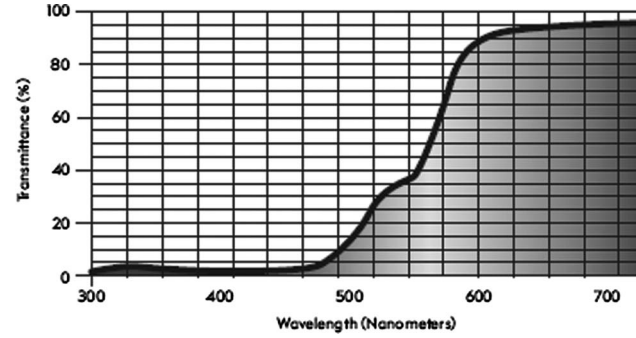

FIG. 3. Spectral transmission curve for the Nike MAXSIGHT Amber-tinted CL.

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MATERIALS AND METHODS

Subjects

An Institutional Review Board proposal for the use of human subjects in research was submitted and approved. Seventeen subjects (9 men, 8 women), ages 22–29 years, were recruited from the Pacific University College of Optometry student body to participate in the study. All subjects signed an Informed Consent Form at the time of the initial screening. Subjects were compensated for participating in the study with a pass to the Nike employee store located in Beaverton, Oregon; however, the subjects were not informed of the connection between Nike and the lenses being assessed in the study.

Subjects were required to pass a vision screening for participation in the study. Binocular VAs were measured under normal room illumination with a 100% contrast Bailey–Lovie VA chart at 6 m. Minimum binocular VA of 20/20 was required with habitual refractive compensation. The habitual refractive compensation was measured by lensometry if the subject wore spectacles or ascertained from the product container or prescription if the subject was a CL wearer. Anterior segment health was assessed with a biomicroscope to ensure that there was no pathologic condition that would contraindicate soft CL wear.

Materials

Subjects were fitted with Bausch and Lomb (B&L; Rochester, NY) Optima 38 clear CLs, and Nike Maxsight Amber CLs with 50% visible light transmission (VLT). Easton (Van Nuys, CA) Sports Eye Black was applied along the inferior orbital rim in an elongated oval pattern, as typically applied for sport use. The VLT value represents the luminous transmittance level (Fig. 3 for spectral transmission curve). The Maxsight CLs were all commercially tinted Optima 38 lenses. All CLs were spherical and demonstrated an equivalent base curve of 8.8 mm and a diameter of 14.3 mm. If the subject demonstrated a spectacle correction for astigmatism, a spherical equivalent was determined mathematically, and the corresponding CLs were fitted. Plano lenses were used for subjects with no habitual refractive correction, B&L provided plano Optima 38 lenses for this study. The fit of the experimental CLs was assessed with a biomicroscope to assure an acceptable fit. Visual acuity was reassessed with each CLs modality to ensure that the subject achieved VA of 20/20 or better.

Procedures

Environmental Conditions

All testing was performed between 10:00 am and 3:00 pm on August 13 through 17, 2007, at Pacific University in Forest Grove, Oregon. Weather conditions were bright and sunny, varying from no clouds to thinly scattered high clouds. Testing was postponed if clouds covered the sun. The subjects were seated with the sun directly behind them; the chart position was adjusted to be in direct sunlight.

The testing conditions were set up to maximize the exposure to direct sunlight. To increase overall luminance of the test areas for bright sunlight, white cotton sheets were used to cover the ground between the subject and chart. The sheets also formed a uniform backdrop for each test area. Subjects sat in a chair facing a 10% contrast Bailey–Lovie chart at 4 m; the chart was placed in the top center of a 7-ft. by 7-ft. white backdrop (Fig. 4).

Fitting and Education

Data collection took approximately 30 minutes to complete for each subject. To minimize differences in sunlight levels during data collection, the most efficient testing sequence was used for all subjects, as follows: (1) Clear Optima 38 lenses; (2) Clear Optima 38 lenses with eye black; (3) Nike MAXSIGHT Amber tinted CLs with Eye Black; (4) Nike MAXSIGHT Amber tinted CLs with no Eye Black.

Low-Contrast Visual Acuity

Low-contrast VA was assessed binocularly at 4 m with several different 10% contrast Bailey–Lovie VA charts. Different versions of the VA chart were used for each modality to eliminate memorization by the subject. For each test modality, the subject would be walked to the outdoor setup, and the following instructions were read:

''Call out the lowest line of letters you can see. Please do not squint or shield your eyes.''

Guessing was encouraged if the subject was hesitant. Visual acuity was recorded in LogMar units.

Questionnaire

After each modality was completed, the subject was asked to fill out a questionnaire (Appendix A). At the end of all modality testing, an overall questionnaire comparing the different modalities was completed (Appendix B). These questionnaires were employed to determine subjective perceptions of performance and comfort for each of the modalities.

Statistical Analysis

Visual acuity in logMAR units was described with means and SDs and null hypotheses tested using a within-subjects analysis of variance (ANOVA), and post hoc Bonferroni adjusted least significant differences (*t*-tests) were reported (SPSS v18, IBM Inc., Somers, NY). The subjective questionnaires using Likert scale data were tabulated for the postmodality questions. The final questions presented after all conditions were experienced were described with medians and 25th and 75th percentiles and null

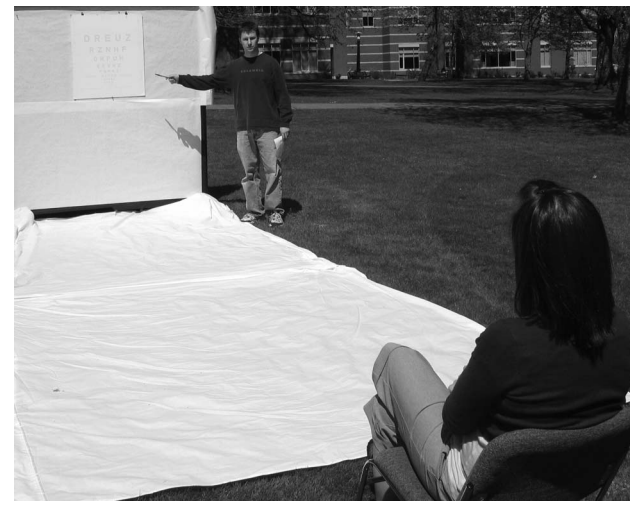

FIG. 4. Data collection testing conditions.

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TABLE 1. *Low-Contrast Visual Acuities*[a]

	Maxsight	Maxsight eye black	Clear CL	Clear CL eye black
Avg LogMar VA	−0.11	−0.11	−0.04	−0.07
SD	0.053	0.066	0.072	0.065
Snellen average	20/15.4	20/15.4	20/18.4	20/17
Min	20/17.4	20/18	20/21.7	20/19.7
Max	20/13.7	20/13.3	20/15.5	20/14.6

[a]Significance *P* values are Bonferroni adjusted.

CL, contact lens.

hypotheses tested with Wilcoxon matched pair analyses and Bonferroni adjusted.

RESULTS

Visual Acuity

The results of low-contrast VAs measured in bright conditions with each modality are summarized in Table 1.

All visual performance data were analyzed using within-subjects ANOVA with post hoc *t*-tests with Bonferroni adjustments ($F(3,48)$, $df=14.13$, $P<0.001$; the Mauchly test for sphericity 3.75, $P=0.59$) (Table 2). There was a significant difference ($P<0.05$) in low-contrast VA between the following: (1) the Maxsight CL and the clear CL; (2) the Maxsight CL with Eye Black and the clear CL; (3) the Maxsight CL with Eye Black and the clear CL with Eye Black. There was no significant difference in low-contrast VA between the following: (1) the Maxsight CL and the Maxsight CL combined with Eye Black; (2) the clear CL and the clear CL with Eye Black.

Subjective Questionnaire

The effect of condition on comfort was significant ($F=56.5$ [$df=3.48$], $P<0.001$). The comfort and performance scores were significantly correlated with each other ($r=0.90$, $P<0.001$). Because we collected the postmodality information, we have included it, though our inferential statistics are based on the final judgment because that is the point when subjects experienced all conditions. We believe their relative opinions changed as a function of seeing the new conditions and could only make accurate judgments for comparison after experiencing all conditions.

Table 3 presents the results of the Wilcoxon matched pairs test for perceived comfort and performance at the end of the session after all conditions were presented. Maxsight and Maxsight with Eye Black were not different from each other in either perceived comfort or performance. Both Maxsight conditions were significantly greater than both clear contacts and clear contacts with Eye Black. Considering the Bonferroni correction, clear contacts were not significantly different from clear contacts with Eye Black.

TABLE 2. *Paired Comparisons of Conditions on Mean Visual Acuity (logMAR)*

	Mean (SD)	Maxsight −0.112	Maxsight eye black −0.112	Clear CL −0.037	Clear CL eye black −0.071
Maxsight	−0.112(0.053)		*P*=0.999	*P*=0.003	*P*=0.036
Maxsight eye black	−0.112(0.066)	*P*=0.999		*P*=0.001	*P*=0.017
Clear CL	−0.037(0.072)	*P*=0.003	*P*=0.001		*P*=0.132
Clear CL eye black	−0.071(0.065)	*P*=0.036	*P*=0.017	*P*=0.132	

CL, contact lens.

TABLE 3. *Paired Comparisons of the Final Perceived Comfort and Performance Scores from a Single Question Likert Scale Where 1 Was Most Desirable and 7 Was Least Desirable*

		Maxsight	Maxsight eye black	Clear CL	Clear CL eye black
Comfort	Median (25%,75%)	1(1,2)	1(1,2.5)	6(5,7)	5(4,5.5)
Maxsight	1(1,2)		*P*=0.414	*P*=0.001[a]	*P*=0.001[a]
Maxsight eye black	1(1,2.5)	*P*=0.414		*P*=0.001[a]	*P*=0.001[a]
Clear CL	6(5,7)	*P*=0.001[a]	*P*=0.001[a]		*P*=0.009
Clear CL eye black	5(4,5.5)	*P*=0.001[a]	*P*=0.001[a]	*P*=0.009	
Performance		2(1,2.5)	2(1,2.5)	6(3,6.5)	5(3.5,6)
Maxsight	2(1,2.5)		*P*=0.999	*P*=0.002[a]	*P*=0.001[a]
Maxsight eye black	2(1,2.5	*P*=0.999		*P*=0.002[a]	*P*=0.001[a]
Clear CL	6(3,6.5)	*P*=0.002[a]	*P*=0.002[a]		*P*=0.085
Clear CL eye black	5(3.5,6)	*P*=0.001[a]	*P*=0.001[a]	*P*=0.085	

[a]Denotes statistical significance at $P < 0.05$ with a Bonferroni adjustment (0.05/5 = 0.0083). *P* values in the table are unadjusted. Median and 25th and 75th percentiles are reported.

CL, contact lens.

DISCUSSION

We used clear CLs as the control for our subjects and to represent no effort in improving the contrast sensitivity of the subject. The use of clear CLs, rather than no CLs, maintained a consistent CL fit comfort level. The average VA level achieved when viewing a 10% contrast chart with clear CLs was 20/18.4, which we consider the baseline for our subject group.

With Eye Black grease applied along both inferior orbital rims, the subjects demonstrated an average VA on the 10% Bailey–Lovie contrast chart of 20/17. In this study, the improvement was not a significantly better Snellen letter acuity compared with the clear CLs control. Although the trend is similar, this finding does not corroborate previous findings showing that Eye Black grease improves contrast sensitivity in natural sunlight.[11] Subjects wearing the Maxsight CLs showed an improved low-contrast VA of 20/15.4. This is a significant ($P<0.05$) improvement over the clear CLs. This result confirms the Porisch findings in a study of athletes with the same amber CLs.[21] The Maxsight CLs were also significantly better than clear CLs combined with Eye Black going from 20/17 to 20/15.

When the subjects wore both the Maxsight CLs and the Eye Black, an improvement in low-contrast VA was seen over the clear CLs, but it was equivalent to the Maxsight CLs alone. The level of acuity was equivalent to 20/15.4. It is likely that low-contrast discrimination was at its highest level with the Maxsight CLs and that the Eye Black demonstrated no additive effect.

Wearing Eye Black grease did not show improvement in low-contrast VA, where Maxsight CLs affords a more significant improvement. The potential benefits of Eye Black include the following: it is easily accessible, because it is over the counter and often available from other athletes on a team; it is disposable; it requires less long-term maintenance; it is less expensive than CLs; and CLs do not need to be worn. The drawbacks of Eye Black include the following: It requires proper application to receive the maximum benefit; it can smear easily; it may clog facial pores. An

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athlete may choose amber tinted CLs over Eye Black grease for the following reasons: CL wearers already can correct refractive error and improve low-contrast VA with one modality; the lenses are always applied correctly to achieve improved low-contrast discrimination; because CLs have the tint throughout the lens, there is full coverage of the athlete's visual field, eliminating off-axis light leakage or glare; there is minimal risk of lens dislocation during competition. The drawbacks of the Maxsight lenses are that they currently are not commercially available, and those without need for refractive correction would need to wear CLs. There are companies that will custom tint CLs to match the Maxsight parameters or there are ''do-it-yourself'' tinting systems available for this purpose.

Subjective Questionnaire

The subjective questionnaires completed by the subjects after each modality use provides insightful information not necessarily revealed in the objective findings. When analyzing the individual modalities, all four modalities demonstrated similar perceived levels of comfort and visual performance. This was expected because each modality is a comfortable product. The Eye Black grease should not degrade vision nor should a properly fit CLs.

After all conditions were presented, amber Maxsight CLs were perceived as significantly superior over clear CLs regardless of the presence of Eye Black. The Maxsight CLs were ranked as the more superior condition. This was closely followed by the Maxsight CLs with Eye Black. There was no statistically significant change when adding Eye Black to Maxsight. Both of these modalities were judged as significantly superior to the clear CLs and the clear CLs with Eye Black. The perceived benefit of the Maxsight CLs may be because of the 50% VLT and the reduced chromatic aberration.[12] Both visual aspects have been reported to increase visual performance and comfort in a previous study.[22] Eye Black grease slightly increased low-contrast VA compared with clear lenses alone, but it was not perceived to show the same visual performance as the Maxsight CLs when trying to see in a high glare environment.

The final subjective questionnaire administered at the end of all conditions regarding superior visual comfort and visual performance was not consistent with the scores reported after each modality. The authors recognize the lack of randomization in the testing protocol. There is a confounding between order of presentation and the effect of modality. Subjective impressions can change as a function of experience with the conditions. We present descriptive statistics for the subjective questions that were asked after each modality, but we reserve the inferential statistics for the final judgment after all modalities were experienced. An alternative explanation to our findings is that subjective judgment is best for the most recent modalities presented. We view this as unlikely as the VA and subjective orders were not consistent with this hypothesis. However, the fact that all clear CL modalities were always first and amber always last does not allow us to eliminate that the findings may be because of a bias toward the amber tinted CLs based purely on order of presentation.

Although Eye Black grease has its place in sport and some sporting environments, the benefit in low-contrast acuity is insignificant. The better performance of the amber Maxsight lenses in this study demonstrates a possible visual performance benefit in bright sunlight. However, the limitations of this study include a small sample size and a lack of sport-specific visual tasks. The results of this study can assist eye care practitioners in providing the evidence-based recommendations for athletic patients.

ACKNOWLEDGMENTS

The authors thank Nike, Inc., for providing the CLs and subject compensation to facilitate this study. They thank Drs. John R. Hayes and Karl Citek for assistance with statistical analysis. F.C.H. and G.B.E. frequently provide consultation services to Nike, including research measuring performance with prototypes of the Maxsight lenses. However, F.C.H. and G.B.E. have no financial relationship involving the products tested or discussed in this article.

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APPENDIX A: INTRATEST SURVEY

Comparison of Contrast Sensitivity With Eye Glare and Nike MaxSight Contacts

Amber Eye-Black Clear

Subject #_____ Date:_/_/_

Please circle the number that best fits your experience/opinion during today's testing.

	Strongly agree						Strongly disagree
Comfort							
The eye glare product is comfortable	1	2	3	4	5	6	7
Vision							
Does not obstruct or distort vision	1	2	3	4	5	6	7
Provides exceptional *visual* comfort	1	2	3	4	5	6	7
Reduces the effect of bright sun on my eyes (squinting, tearing, etc.)	1	2	3	4	5	6	7
Enhances visibility when first looking at the chart	1	2	3	4	5	6	7
Product reduces the effect of stray light on my vision	1	2	3	4	5	6	7
Overall performance							
Overall, the product performed very well	1	2	3	4	5	6	7

APPENDIX B: POST TEST SURVEY

Comparison of Contrast Sensitivity With Eye Glare and Nike MaxSight Contacts

Post test Survey

Subject #_____ Date:_/_/_

Please rate the following when comparing the clear, Amber Contact Lenses and Eye-Black Grease

Over all visual *comfort*issuperior (superior=relaxed, no glare or squinting)							
	Strongly agree						Strongly disagree
Clear	1	2	3	4	5	6	7
Amber	1	2	3	4	5	6	7
Eye-Black w/ Clear	1	2	3	4	5	6	7
Eye-Black w/ Amber	1	2	3	4	5	6	7
Overall visual *performance* is superior (superior = clear, efficient target visibility)							
Clear	1	2	3	4	5	6	7
Amber	1	2	3	4	5	6	7
Eye-Black w/Clear	1	2	3	4	5	6	7
Eye-Black w/Amber	1	2	3	4	5	6	7
Additional comments:							

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