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The effect of tints on distance stereoacuity under varying retinal illuminations

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Background: Stereopsis is the accurate awareness of relative depth necessary for efficient hand–eye coordination and navigation. A popular brand of sunglasses claims to enhance depth perception.

Aim: This study set out to investigate the effect of tinted lenses on distance stereoacuity under varying retinal illumination.

Setting: This study was set at the Discipline of Optometry, University of KwaZulu-Natal.

Methods: A pretest–post-test research design was used. Forty participants were recruited using convenience sampling. The Howard–Dolman apparatus was used to measure distance stereoacuity with different tints of a popular sporting brand under varying retinal illumination. The tinted lenses and their respective transmission values used included persimmon (61%), light grey (38%), G30 (30%) and black iridium (10%). The placebo comprised of a white lens (100% transmission). Habitual distance stereoacuity was measured with no lens as the control. Retinal illumination was varied with neutral density filters to simulate mesopic and scotopic conditions. The Friedman and paired *t*-tests were used to analyse the data.

Results: The mean stereoacuity for each lens was significantly different across the three retinal illumination levels ($p < 0.05$). A statistically significant difference ($p = 0.012$) was found with only the light grey tint under scotopic conditions when compared to the habitual stereoacuity. However, clinically significant differences were noted with the persimmon, light grey and black iridium tints. Overall, poorer stereoacuity was noted in mesopic and scotopic conditions compared to photopic for all five lenses.

Conclusion: Tinted lenses used had no statistically significant effect on distance stereoacuity but clinically significant changes were noted. However, the change in retinal illumination adversely affected distance stereoacuity.

Keywords: distance stereopsis; spectacle tints; retinal illumination.

Introduction

Stereopsis is the fusion of horizontal retinal image disparity which gives rise to the perception of relative depth and distance.[1] Even though not essential for the perception of depth, stereopsis allows for the accurate judgement of distances between two objects which complements efficient hand–eye coordination and navigation, particularly at intermediate distances.[2,3,4] Stereoacuity, the clinical measurement of stereopsis, is expressed in seconds of arc (arcsec) and represents the smallest horizontal retinal image disparity resulting in the perception of depth.[5] The lower the stereoacuity, the better the stereopsis. Stereoacuity is often measured in a clinical setting and has applications in the assessment of binocular vision including screening for amblyopia, aniseikonia and anisometropia.[6] Stereopsis is affected by many factors including anisometropia, high ametropia, reduced visual acuity, sensory and/or motor fusion dysfunctions and retinal illumination.[7,8]

Retinal illumination can be altered with tinted lenses.[9,10] Tinted lenses reduce the transmission of certain wavelengths of light, and therefore protect against harmful radiation; enhance contrast sensitivity and colour perception; and alleviate photosensitivity.[1] Many tinted lenses are also used to reduce light scatter.[11,12] Tinted lenses are being used more frequently for everyday tasks and are available in a variety of colours.[13] Particularly, people involved in outdoor activities such as drivers, pilots and sportsmen use tinted lenses more often. Sportsmen commonly use tinted lenses to enhance visual performance including visual acuity and contrast sensitivity.[14,15] A popular brand of sunglasses comprising of the tints persimmon, black iridium and G30 is claimed to enhance depth perception.[16] However, no research studies are available to validate this claim.

Most of the previous studies[6,17,18,19] are limited by their exclusive focus on near stereoacuity. As tinted lenses are used for both professional and recreational activities performed at intermediate and distant viewing distances, it is important to investigate the effect of the tinted lenses on distance stereoacuity. Furthermore, tinted lenses may be worn under different illumination levels. Therefore, the aim of this study was to investigate the effect of Oakley tinted lenses on distance stereoacuity under varying retinal illumination levels.

Methods

The study employed an experimental pretest–post-test research design and was conducted at the University of KwaZulu-Natal, Westville campus. Study participants (n = 40) were selected using convenience sampling. Participants were aged between 18 and 28 years, of either gender and of any race, with unaided monocular and binocular visual acuities of 6/6. Participants with ocular or systemic illnesses, strabismus or uncompensated heterophorias were excluded.

The Howard–Dolman apparatus is probably the gold standard for distance and near stereopsis and was used to measure distance stereoacuity.[20,21] Each participant was aligned at eye level with their chin and forehead securely against the rests to eliminate monocular cues to depth.[22] Participants were instructed to align the movable test rod, by pulling on strings, such that it appeared adjacent to the fixed rod in the horizontal plane. The separation (disparity) between the two rods in millimetres was incorporated in a mathematical formula, mentioned below, to determine the stereoacuity in arcsec[8,11]:

$$\eta = \left(\frac{\text{interpupillary distance } (\text{mm}) \times \text{ object seperation } (\text{mm}) \times 206265}{\text{fixation distance } (\text{mm})^2} \right), \quad \text{[Eqn 1]}$$

Distance stereoacuity was measured with five lenses which included a white plano CR39 lens and four plano-tinted plutonite (lens material of this brand of sunglasses) lenses. The four tints with their respective transmission values displayed in brackets included persimmon (61%), light grey (38%), G30 (30%) and black iridium (10%). The white CR39 lens, with 100% transmission, served as the placebo. Habitual stereoacuity was measured with no lens which served as the control.

Stereoacuity was assessed under photopic (normal room illumination), mesopic and scotopic conditions simulated using neutral density filters (NDFs). Neutral density filters decrease the mean illumination but have no effect on the physical contrast of the stimuli.[19] The 1.2 NDF (6.3% transmission) and the 1.5 NDF (3% transmission) were used to simulate mesopic (moderate light levels) and scotopic conditions (very low light levels), respectively. Thus, stereoacuity for each participant was assessed at three different illumination levels starting with no lens (control) followed by measurements with the white lens (placebo) and the four tinted lenses. The five lenses were randomly presented, in the same illumination level, to minimise any learning effects.[18] Furthermore, stereoacuity was assessed by the same clinician to ensure standardisation where the average of three measurements was computed and recorded as the mean stereoacuity.

Data were captured and analysed with the Statistical Package for Social Sciences (SPSS) version 22. The Shapiro–Wilk's test and graphical inspection of the distance stereoacuity histograms were used to assess normality of the data. The Friedman test, for repeated measures, was used to assess differences in mean stereoacuity with each lens at the three illumination levels. The independent sample t-test was used to assess gender differences in habitual stereoacuity. Paired sample t-tests were used to assess stereoacuity differences between the control and each of the five lenses. Significance was set at the 95% confidence interval with a p-value of ≤ 0.05 considered as statistically significant. The data are presented with means and the standard deviation (SD) in parentheses wherever applicable.

Ethical considerations

Data collection commenced once ethical approval was obtained (SHSEC 029/14) and tenets of the Declaration of Helsinki were adhered to. Informed consent was obtained from all participants.

Results

Forty participants comprising of 25 females and 15 males aged between 18 and 28 years (mean of 21.35 ± 2.27 years) were included. The mean habitual stereoacuity, with the standard deviation in brackets, in photopic, mesopic and scotopic conditions, were 11.29 (8.37), 22.44 (18.34) and 19.80 (15.86) arcsec, respectively. The habitual stereoacuity was significantly different at the three illumination levels ($\chi^2 = 12.636$, $p = 0.002$) where better stereoacuity was noted in photopic compared to mesopic and scotopic conditions. A similar trend was seen for each tinted lens where the mean stereoacuity measurements were significantly different in the three illumination conditions (G30 $\chi^2 = 10.205$, $p = 0.006$; persimmon $\chi^2 = 9.600$, $p = 0.008$; light grey $\chi^2 = 11.962$, $p = 0.003$; black iridium $\chi^2 = 10.706$, $p = 0.005$). At all three illumination levels, the white lens produced slightly higher (2–5 arcsec) stereoacuity measurements as compared to the habitual stereoacuity although these differences were insignificant (photopic $p = 0.32$; mesopic $p = 0.23$; scotopic $p = 0.23$). Male participants showed insignificantly better habitual stereoacuity compared to females under photopic (10.66 [7.51] vs. 11.66 [8.97] arcsec), mesopic (19.62 [15.67] vs. 24.13 [19.89] arcsec) and scotopic conditions (16.81 [14.06] vs. 21.59 [16.86] arcsec) ($p > 0.05$).

Figure 1 shows the mean stereoacuity at distance under photopic conditions with no lens (control) versus the five tinted lenses. The tinted lenses are arranged in order of decreasing transmission values. All five lenses produced

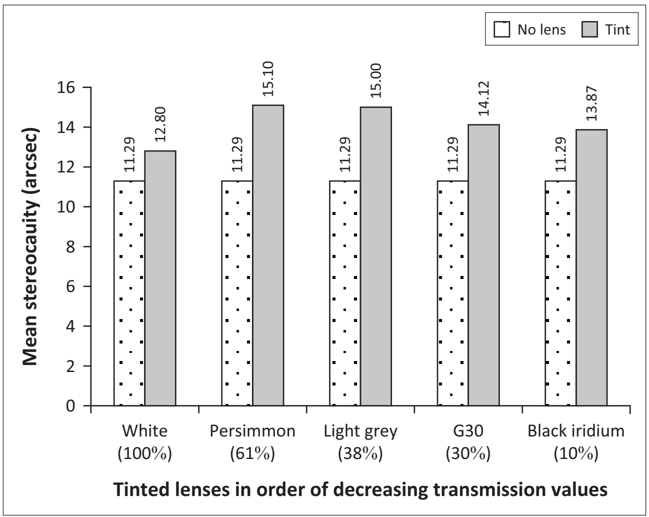

FIGURE 1: Mean distance stereoacuity under photopic conditions with no lens versus the tinted lenses.

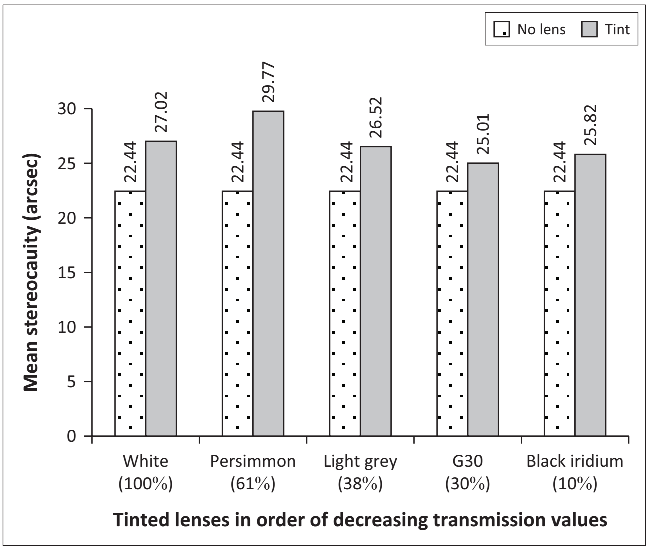

FIGURE 2: Mean distance stereoacuity under mesopic conditions with no lens versus the tinted lenses.

higher mean stereoacuity measurements, indicating a decline in stereopsis, versus the control. However, the change in stereoacuity for each of the five lenses compared to the control was statistically insignificant ($p > 0.05$). The greatest change of almost 4 arcsec was seen with the persimmon and light grey tints.

Figure 2 illustrates the mean stereoacuity at distance under mesopic conditions with no lens (control) versus the five tinted lenses. Compared to photopic conditions, the habitual stereoacuity had almost doubled. Similar to photopic conditions, higher stereoacuity measurements were noted with all five tinted lenses even in mesopic conditions which again were not significantly different from the control ($p > 0.05$). The greatest change in stereoacuity, corresponding to almost 8 arcsec, was noted with the persimmon tint. Interestingly, the G30 and black iridium lenses produced smaller stereoacuity changes compared to the white lens.

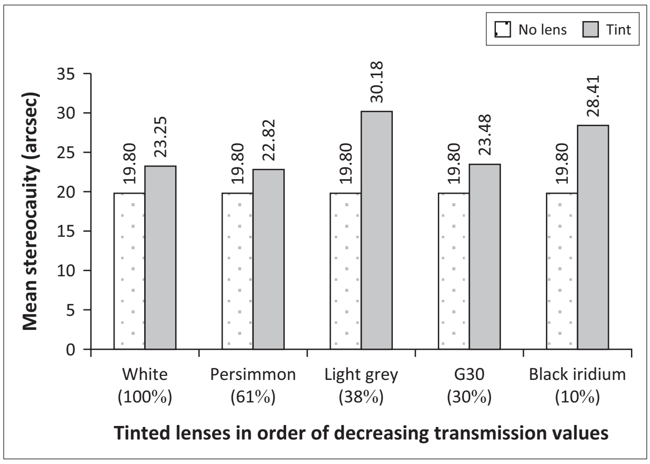

FIGURE 3: Mean distance stereoacuity under scotopic conditions with no lens versus tinted lenses.

Figure 3 illustrates the mean stereoacuity at distance under scotopic conditions with no lens (control) versus the five lenses. The habitual mean stereoacuity was higher in scotopic conditions compared to photopic but lower than that in mesopic conditions. Compared to the control, all five lenses produced higher mean stereoacuity measurements with the differences ranging between 3.02 and 10.38 arcsec. With the exception of light grey, the change in mean stereoacuity noted with each lens compared to the control was statistically insignificant ($p > 0.05$). As compared to the control, light grey produced the greatest change in stereoacuity of almost 10 arcsec ($p = 0.012$).

Discussion

Under photopic conditions, the mean habitual distance stereoacuity was 11.29 (8.37) arcsec, which is in line with the expected distance stereoacuity of 14 arcsec or less when measured with the Howard–Dolman instrument.[11] In both mesopic and scotopic conditions, the mean habitual distance stereoacuity was lower compared to photopic conditions. Two independent mechanisms are responsible for depth: one that is sensitive to luminance contrast and the other that is sensitive to chromatic contrast.[23] Luminance contrast refers to the difference in brightness of two or more objects and would have been the primary influence on stereopsis as illumination was changed from photopic to mesopic and then to scotopic conditions with the aid of NDFs. As the illumination decreased, the stereoacuity was found to increase implying a reduction in distance stereoacuity compared to that under photopic conditions. Furthermore, the notable change in mean stereoacuity measurements of each lens (range between 8 and 15 arcsec) under the different lighting conditions confirms that stereoacuity is dependent on illumination.[19] This is in line with previous studies which have noted that stereopsis is present but reduced when retinal illumination levels are decreased.[18,19,24]

The influence of luminance contrast on stereopsis may be related to the duplicity theory of vision.[19,25,26] Cones, maximally functional under photopic conditions, which are involved in the resolution of detail and colour, hence allow for better stereopsis. On the other hand rods, which are maximally functional under scotopic conditions and have poor spatial resolution, hence affect stereoacuity negatively. Interestingly, stereoacuity measured under mesopic conditions exhibited a greater reduction in stereopsis compared to both photopic and scotopic conditions except with the light grey and black iridium tints. Under mesopic conditions, both cones and rods may be functional although not at their optimal. As rod activity may be inhibited by cone activity, this may have resulted in poorer stereopsis than that found under both photopic and scotopic conditions.[26] Pupil size is another consideration when assessing stereopsis. Lovasik and Szymkiw[17] found that pupil sizes less than 2.5 mm cause a significant drop in stereoacuity. In this study, even though pupil size was not measured, NDFs used to alter retinal illumination could have had an effect on the pupil size, that is, an increase in pupil size with reduced illumination levels and hence increased stereopsis.

Chromatic contrast is created by a difference in the wavelength of light reflected by two or more objects, which was created by comparing the effect of tints of varying transmission values on stereoacuity. While the change in illumination had a significant effect on stereoacuity, the change in transmission value within each illumination level did not have a statistically significant effect on stereoacuity when compared to the control and the various tinted lenses. This supports the theory that luminance contrast has a greater effect on stereoacuity than chromatic contrast.[23] All lenses (transmission values ranging from 10% to 100%) resulted in poorer stereoacuity as compared to the control under all three illumination levels but the change was only significant for light grey (38% transmission level) in scotopic conditions where the mean stereoacuity was 10.38 arcsec higher than the control. Hence, a change in the transmission levels of lenses does not have a statistically significant effect on stereoacuity.

Interestingly, the persimmon and light grey tints which had the higher transmission levels (61% and 38%, respectively) compared to the other two tints resulted in a greater reduction in stereopsis under both photopic and mesopic conditions. This brings into question whether the colour composition of the tint may have had an effect on stereoacuity independent of its transmission level. Chromatic contrast is reported to have poor stereoacuity, is less sensitive to contrast, has a smaller disparity range and has a poorer ability to encode stereoscopically defined shapes.[18,19,20,21,22,23] It was noted that persimmon (orange) and G30 (rose pink) absorb shorter wavelengths more than longer wavelengths. Rods tend to be more sensitive to the shorter wavelengths, while cones are more sensitive to longer wavelengths,[19,25,26] which may account for stereoacuity differences among different tints for varying illuminations. The light grey and black iridium, on the other hand, based on their grey colour may be expected to behave in a similar way to a neutral density filter and therefore absorb different wavelengths equally, and thus not change stereoacuity significantly.

No previous studies of the effect of tinted lenses on distance stereoacuity were found to allow for comparison to the results of this study. Mehta et al.[18] investigated the effect of five different levels of illumination simulated with NDF filters and tinted lenses (pink, blue, brown, grey, yellow green, green, all of Grade B depth) on stereoacuity as measured by the Titmus Fly stereotest at near stereoacuity. It was found, as in this study, that there was a significant decline in stereopsis as the level of illumination decreased but near stereoacuity was decreased with tinted lenses. Mehta et al.[18] attributed their findings to luminance and chromatic contrast.

In this study, the NDFs were introduced binocularly as this would be representative of 'real-world situations' when using tinted lenses. However, stereopsis is expected to be affected more when there is a monocular change in illumination often when using NDFs between 1.4 and 1.7.[6,17,19] This implies that binocular illumination may need to be severely reduced before a significant change in stereoacuity is noted which may account for statistically insignificant changes recorded in this study, particularly with the lenses of varying transmission levels. Furthermore, high spatial frequency targets are affected more by changes in mean illumination than low spatial frequency targets.[19] Insignificant changes in stereopsis found in this study may be related to the design of the Howard–Dolman apparatus, being a local stereopsis test with a test rod that can be considered as a low spatial frequency target.[11]

In clinical research, in addition to analysing data for statistical significance, clinically significant differences should also be considered. In stereopsis tests, clinical measurements of stereoacuity are calculated in logarithmic (log) steps. Under photopic conditions, the stereoacuity of the control was 11.29 arcsec with one log step higher, being 14.21 arcsec. A 2.92 arcsec difference may therefore be considered as clinically significant. Both the persimmon and the light grey tints produced clinically significantly poorer stereoacuity under photopic conditions. Similarly, under mesopic conditions a difference of 5.81 arcsec compared to the control could be considered as clinically significant. The mean stereoacuity with the persimmon tint changed by 8 arcsec and may therefore be considered as clinically poorer stereoacuity. Poorer stereoacuity, which was clinically significant, was also recorded with the light grey and black iridium tints under scotopic conditions (a difference of more than 5.13 arcsec compared to the control).

When considering the neuroanatomical aspects of stereopsis, it is evident that the phenomenon of stereopsis is not entirely physiological as there are limitations of the perception of stereoscopic depth occurring within a defined range of disparities. A stimulus to disparity creates a psychic experience, and hence, there are often variations found when comparing individuals' responses to clinical tests.[7,11] Stereopsis can also be described as either patent or qualitative. Patent or obligatory stereopsis is always of the same character and is compulsory to disparate retinal images. Qualitative stereopsis has larger disparities and is more susceptible to alteration of its character by changes in the external environment.[7] Binocular parallax and monocular cues to depth play a major role in the appreciation of stereopsis, especially at distance. In this study, binocular parallax and monocular cues to depth were both eliminated under the testing conditions. It would therefore be clinically valuable to assess distance stereopsis in a real environment in which these cues are present and under varying environmental illumination levels. In this way, the effect of tinted lenses on stereopsis in a real environment can be assessed. Furthermore, a greater variety of lenses (in terms of transmission values and colour compositions) can be tested on subjects including those with refractive errors. However, this study did not assess depth perception which may involve other aspects like monocular cues to depth and not just retinal disparity.

Conclusion

Good stereopsis is essential in sporting activities as they often involve complex visual tasks and hand–eye coordination. It is expected that the tinted sunglasses as marketed by a popular sporting brand would be used primarily by individuals in sporting codes like cricket, bowling and cycling in which stereopsis, particularly at distance, would be an important visual factor to enhance sporting performance. This study has not been able to verify the claim that some of the tints are able to enhance stereopsis as they were found to actually reduce stereoacuity, particularly under varying illumination. Some of the sporting codes like cricket may be played under varying illumination levels as well. Reduced illumination levels in conjunction with the tinted lenses were found to actually reduce stereoacuity, and this should be considered when prescribing tinted lenses.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

N.R. and R.H. were involved in the conceptualisation, data analysis and manuscript preparation, while all other authors were involved in the data collection.

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Data availability statement

Data sharing is not applicable to this article.

Disclaimer

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References

1. Grosvenor TP. Primary care optometry. 5th ed. New York: Professional Press Books, 2007; p. 79–80.
2. Bauer S, Dietz K, Kolling G, Hart G, Schiefer U. The relevance of stereopsis for motorists: A pilot study. Graef Arch Clin Exp. 2001;239:400–406. https://doi.org/10.1007/s004170100273
3. Wong BPH, Woods RL. Stereo-acuity at distance and near. Optom Vis Sci. 2002;79:771–778. https://doi.org/10.1097/00006324-200212000-00009
4. Suttle CM, Melmoth DR, Finlay AL, Sloper JJ, Grant S. Eye-hand coordination skills in children with and without amblyopia. Invest Ophthalmol Vis Sci. 2011;52:1851–1864. https://doi.org/10.1167/iovs.10-6341
5. Romano P, Romano J, Puklin J. Stereo acuity development in children with normal binocular vision. Am J Ophthalmol. 1975;79:966–971. https://doi.org/10.1016/0002-9394(75)90679-0
6. Chang YH, Lee JB, Kim NS, Lee DW, Chang JH, Han SH. The effects of interocular differences in retinal illuminance on vision and binocularity. Graef Arch Clin Exp. 2006;244:1083–1088. https://doi.org/10.1007/s00417-005-0196-z
7. Ogle K. The optical space sense. In: Davson H, editor. Davson's visual optics and the optical space sense. New York: Academic Press Inc., 1962; p. 209–417.
8. Saladin JJ. Stereopsis from a performance perspective. Optom Vis Sci. 2005;82:186–205. https://doi.org/10.1097/01.OPX.0000156320.71949.9D
9. Heuer DK, Anderson DR, Feuer WJ, Gressel MG. The influence of decreased retinal illumination on automated perimetric threshold measurements. Am J Ophthalmol. 1989;108:643–650. https://doi.org/10.1016/0002-9394(89)90855-6
10. Wolffsohn JS, Cochrane AL, Khoo H, Yoshimitsu Y, Wu S. Contrast is enhanced by yellow lenses because of selective reduction of short-wavelength light. Optom Vis Sci. 2000;77:73–81. https://doi.org/10.1097/00006324-200002000-00011
11. Benjamin WJ. Borish's clinical refraction. St Louis, MI: Butterworth Heinemann; 2006.
12. Eperjesi F, Fowler CW, Evans BJW. Do tinted lenses or filters improve visual performance in low vision? A review of the literature. Ophthal Physiol Opt. 2002;22:68–77. https://doi.org/10.1046/j.1475-1313.2002.00004.x
13. De Fez MD, Luque MJ, Viqueira V. Enhancement of contrast sensitivity and losses of chromatic discrimination with tinted lenses. Optom Vis Sci. 2002; 79:590–597. https://doi.org/10.1097/00006324-200209000-00010
14. Porisch E. Football players' contrast sensitivity comparison when wearing amber sporttinted or clear contact lenses. Optometry. 2007;78:232–235. https://doi.org/10.1016/j.optm.2006.11.014
15. Zimmerman AB, Lust KL, Bullimore MA. Visual acuity and contrast sensitivity for sports vision. Eye Contact Lens. 2011;37:153–159. https://doi.org/10.1097/ICL.0b013e31820d12f4
16. Oakley sunglass lens tint guide [homepage on the Internet]. [cited 2019 Feb 11] Available from: www.oakleyforum.com/threads/excel-file-of-comprehensive-list-of-oakley-lenses-lens-transmission-cacatman.78840/.
17. Lovasik JV, Szymkiw M. Effects of aniseikonia, anisometropia, accommodation, retinal illuminance and pupil size on stereopsis. Invest Ophthalmol Vis Sci 1985;26: 741–750.
18. Mehta M, Ramkissoon P, Bhagwanjee AM. A comparison of the effect of reduced illumination and tinted lenses on stereopsis at near. S Afr Optom. 2007;66:3–11.
19. Reynaud A, Zhou J, Hess RF. Stereopsis and mean luminance. J Vision. 2013;13: 1–11. https://doi.org/10.1167/13.11.1
20. Reading RW. Binocular vision: Foundations and applications. Boston, MA: Butterworth Publishers, 1983; p. 25–43.
21. Cooper J. Stereopsis. In: Eskridge JB, Amos JF, Bartlett JD, editors. Eskridge, Amos & Bartlett's clinical procedures in optometry. New York: J B Lippincott Company, 1991; p. 121–134.
22. Steinman SB, Steinman BA, Garzia, RP. Foundations of binocular vision: A clinical perspective. New York: McGraw-Hill Professional; 2000.
23. Simmons DR, Kingdom FAA. Interactions between chromatic-and luminance-contrast sensitive stereopsis mechanisms. Vision Res. 2002;42:1535–1545. https://doi.org/10.1016/S0042-6989(02)00080-9
24. Livingstone MS, Hubel DH. Stereopsis and positional acuity under dark adaptation. Vision Res. 1994;34:799–802. https://doi.org/10.1016/0042-6989(94)90217-8
25. Stabell B, Stabell U. Duplicity theory of vision – From Newton to the present. New York: Cambridge University Press, 2009; p. 6–70.
26. Weale RA. The duplicity theory of vision. Edridge-Green lecture delivered at the Royal College of Surgeons of England on 28th March 1959. Ann R Coll Surg Engl. 1961;28;1:16–35.