CHROMATICITY SHIFTS ASSOCIATED WITH O2AMP™ CHROMA ENHANCING LENSES

by

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ABSTRACT

Background: The Hemo-Iso and Oxy-Iso glasses (produced by the O2AMP™) are currently marketed as lenses to aid in "bruise finding" and to amplify vein recognition in hospital settings. It is postulated that the Oxy-Iso lenses shift the color transmission of visible wavelengths that are hard to discriminate with the naked eye. Intuitively, the design principle of the Hemo-Iso glasses predicts a shift of the chromaticity coordinates of colors away from the red spectrum towards the green spectrum to aid in bruise identification. While the Oxy-Iso Vein lenses shift the spectrum away from the green towards the color spectrum for vein identification. This study measured the shift in the chromaticity coordinates of color caps comprising the FM-100 hue arrangement tests caused by these two marketed chroma enhancing lenses. Methods: The chromaticity coordinates of every other hue cap comprising the FM-100 arrangement test were measured without and with both the Oxy-Iso and Hemo-Iso lenses using the Minolta CS-100A Chromometer. All tests were conducted under standard lighting approximating the Illuminant C light source. Chromaticity coordinates for each cap were plotted on the CIE-xy chromaticity diagram. Ellipses were fit to the resulting hue contours to extract geometric indices that characterized the shifts of the hue contours of the FM-100 without and with the lenses. Results: The chromaticity coordinates for the FM-100 that were plotted on the CIE-chromaticity diagram. This plot showed a shift toward the red and green color spectrum when comparing measurements first without and then with the O2AMP™ lenses. Conclusions: The results of this study indicate that the Hemo-Iso lenses will shift the color spectrum toward shorter wavelengths while the Oxy-Iso lenses will shift the color spectrum to the longer wavelengths. Clinical applications of where these lenses can be useful will be discussed.

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CHAPTER 1

INTRODUCTION

The most widely accepted theory to explain how humans detect and identify colors is the Trichromatic Color Theory which was first proposed by Thomas Young and Hermann Helmholtz[1]. This theory states there are three receptors in the eye, called cones, that have a distinct spectral sensitivity and so initiate a unique physiological response when various wavelengths of light enter the eye resulting in perceived colors in human vision[1]. As such, if one of these receptors are absent or not functioning properly, it will result in a deficiency in color detection. On the contrary, it is possible to shift the color spectrum so that light entering the eye stimulates these receptors in a way to make certain structures or anatomical features more visible to the naked eye[2]. This can be beneficial to professions that need to identify a variety of colors correctly in a short amount of time such as pilots, policeman and medical professionals. For instance, a nurse whom can easily identify a vein and insert an IV on the first try would have a higher rate of success compared to a colleague who has trouble finding a vein to insert the IV. As such, multiple lenses have been designed to achieve this visual advantage including the Hemo-Iso and Oxy-Iso glasses.

The Hemo-Iso and Oxy-Iso glasses (produced by O2AMP™) are currently marketed as lenses that can shift the color spectrum to aid in "bruise finding" and to amplify vein recognition in hospital settings. The Hemo-Iso glasses were designed to create a shift of the chromaticity coordinates of colors away from the red spectrum towards the green spectrum to aid in bruise identification. Likewise, the Oxy-Iso Vein lenses were designed to shift the spectrum away from the green towards the color spectrum for vein identification. Despite a similar study performed by Clark and Byers (2016) in which the authors used similar lenses made by O2AMP™, no study has shown if the Hemo-Iso and Oxy-Iso glasses lenses do in fact shift the chromaticity coordinates of colors enough to be significant.

This study aims to determine the exact amount of chromaticity shift of colors when using the Hemo-Iso and Oxy-Iso glasses. To achieve this objective, the respective lenses were placed in front of a chronometer pointed at Farnsworth-Munsell 100 (FM-100) color caps. The chromaticity coordinates produced be the chronometer were then recorded and plotted on the CIE 1931 color space to produce chromaticity diagrams.

Perception of color can be hard to explain based on the variety of color and the limitation of language. As such, a chromaticity diagram is a way to describe any color using three key metrics called tristimulus values[4]. These values represented by variables X, Y, and Z are defined in reference to the color sensitivities of the three cone receptors of the human eye[4]. The variable X represents a combination of human cone receptor responses, the variable Y defines the luminance of a color source and the variable Z represents the S cone response which typically is more sensitive to blue colors. These variables define a region that is the CIE color plot[4]. Within the CIE color plot there are certain test lines which are used by hue tests and arrangement tests, such as the FM-100 caps, to assess if the participant has a color discrimination deficiency.

The FM-100 hue test consists of 100 differently colored caps that the participant should arrange in the correct order of similar hues when viewed under a standard reference light source such as the Illuminant C light source. Using a chronometer, the color coordinates of these caps can be plotted on the CIE 1931 color space to produce chromaticity diagrams. Hence, the FM-100 hue test represents an objective method to determine if the hue from any of the caps appear shifted when viewed through a filter such as the Hemo-Iso and Oxy-Iso glasses. This study aims to determine and analyze the color coordinate shifts created by the Hemo-Iso and Oxy-Iso glasses using the FM-100 arrangement test which in turn alters the human perception of colors making certain structures or anatomical features more visible to the naked eye.

CHAPTER 2

METHODS

A method similar to the one used by Clark and Byers (2016), was used in this study. Every second cap of the FM-100 color arrangement test was measured using the Minolta CS-100A chronometer. All testing was performed in standard lighting using the Illuminant C light source from the DayLight^{TM} light source. Testing was performed once with the Hemo-Iso lenses and repeated using the Oxy-Iso lenses. The chronometer was adjusted to a tripod at a fixed distance to ensure that the center of each color cap was viewed by the chronometer. A +7.00 diopter lens was place over the objective lens of the chromometer to account for the working distance of the color disc. Chromaticity coordinates of the FM-100 were plotted on the CIE chromaticity diagram without a filter and with each respective filter and a best-fit ellipse was fit to the coordinates using the least-squares minimization method using MatLab^{TM}. The parameters where derived from the best fit ellipse to the chromaticity coordinates are as follows:

i) Vertical Ratio: The ratio of the major vertical axis of the best fit ellipse with each filter to the major vertical axis of the best fit ellipse without filter. The smaller the number the greater the "contraction" of the ellipse along its major vertical axis.

ii) Horizontal Ratio: The ratio of the major horizontal axis of the best fit ellipse with Oxy-Iso and Oxy-heme filter to the major horizontal axis of the best fit ellipse without filter. The smaller the number represents a greater "contraction" of the ellipse along its major horizontal axis.

iii) Central Coordinates of Fitted Ellipse: The geometric center of the best fit ellipse with Oxy-Iso and Oxy-heme filter compared to the geometric center of the best fit ellipse without any filter. The position of the geometric centers reflects the overall shift of the best fit ellipse.

iv) Tilt of Fitted Ellipse Relative to the X-axis: The tilt of the best fit ellipse relative to the x-axis with Oxy-Iso and Oxy-heme filter compared to the tilt of the best fit ellipse relative to the x-axis without any filter. The tilt of each ellipse reflects the overall shift of the best fit ellipse.

CHAPTER 3

RESULTS

The parameters of the best fit ellipses shown in Table 1, Table 2, and Table 3 demonstrate how the Oxy-Iso and Oxy-heme filters shift the color coordinates relative to the best fit ellipse when no filter was used. Figure 1 and Figure 2 show the best fit ellipse of the color coordinates using the Oxy-Iso filter and Heme-Iso filter compared to when no filter was used. These color coordinate shifts are summarized below.

Vertical ratio: For both the best fit ellipses of the Oxy-Iso and Oxy-heme filters, the vertical ratio of less than one indicates there was a decrease in the excitation purity between the chromaticity along the vertical axis.

Horizontal ratio: For the best fit ellipse of the Oxy-Iso filter, a horizontal ratio larger than one indicates an increase in the relative differences in excitation purity along the horizontal axis. For the best fit ellipses of the Heme-Iso filter, a horizontal ratio less than one indicates a decrease in the relative differences in excitation purity along the horizontal axis.

Central coordinates of fitted ellipse: The geometric center of the best fit ellipse of the Oxy-Iso filter is greatly shifted to a lesser value along the Y axis and is slightly shifted to a larger value along the X axis. This shift indicates a general shift of the color coordinates towards the purple and red portions of the CIE color plot compared to no when no filter was used. The geometric center of the best fit ellipse of the Heme-Iso filter is drastically shifted to a greater value along the Y axis and is slightly shifted to a lesser value along the X axis. This shift indicates a general shift of color coordinates towards the green and blue portions of the CIE color plot compared to when no filter was used.

Tilt of Fitted Ellipse Relative to the X-axis: The best fit ellipse of the Oxy-Iso filter was found to have a less tilt in respect to the x-axis compared to the best fit ellipse with no filter. This indicates a general shift of the color coordinates towards the purple and red portions of the CIE color plot compared to no when no filter was used. The best fit ellipse of the Heme-Iso filter was found to have a much greater tilt in respect to the x-axis compared to the best fit ellipse with no filter. This indicates a general shift of the color coordinates towards the green and blue portions of the CIE color plot compared to when no filter was used.

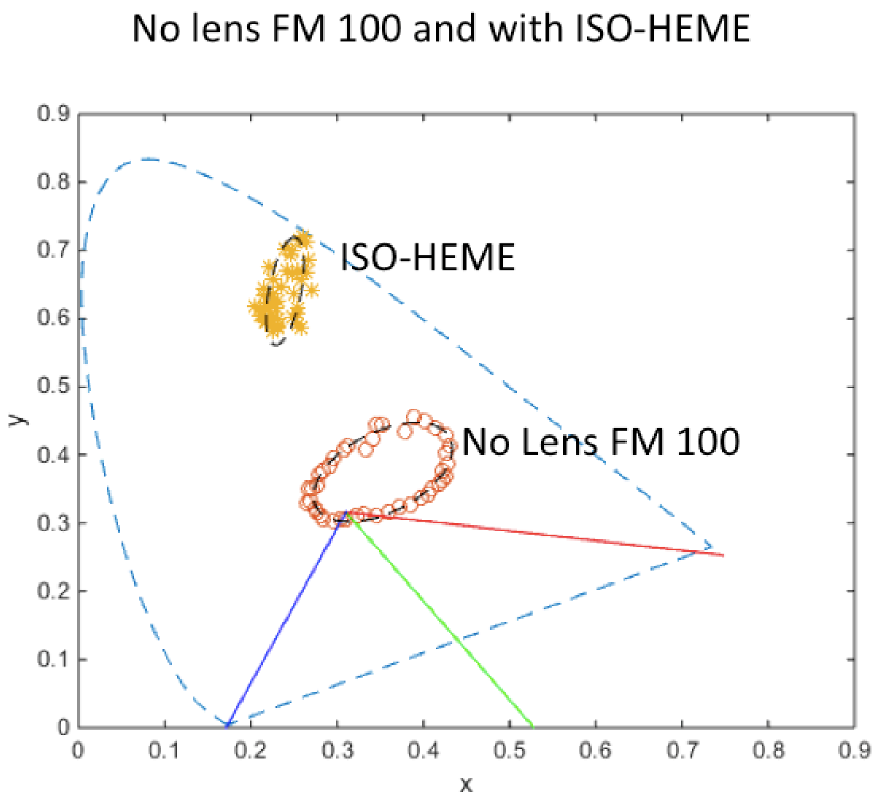

Figure 1. CIE-xy Chromaticity diagram with chromaticity coordinates of FM-100 color cap set with the Oxy-Iso filter and without a filter. Solid Lines represent the major color confusion lines.

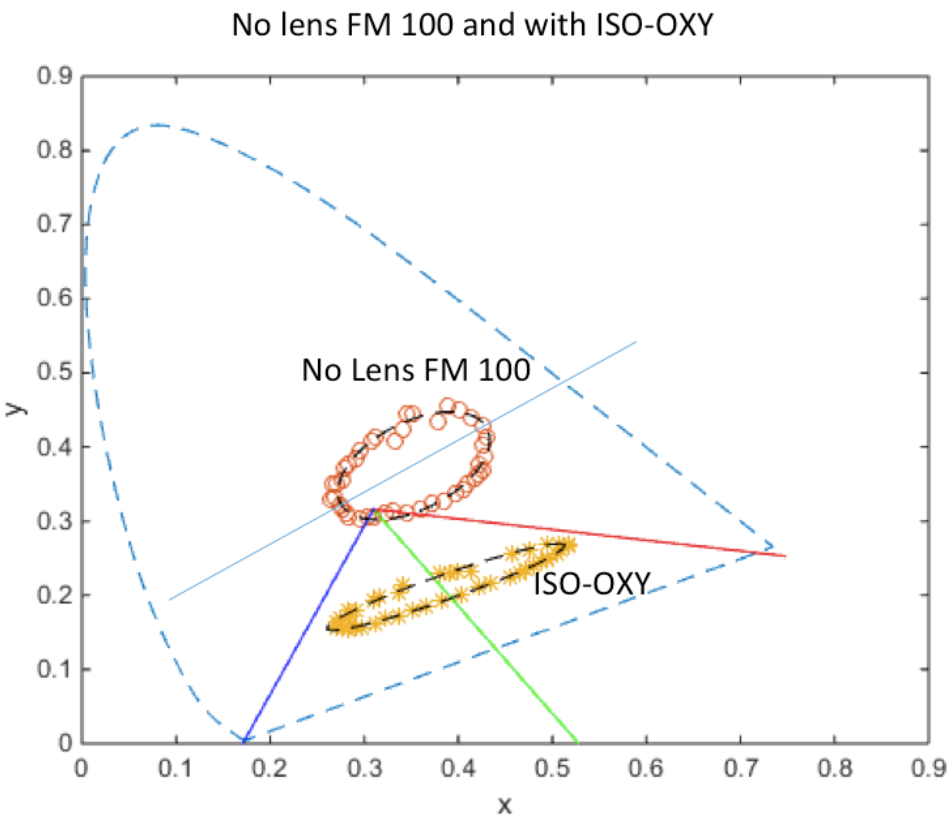

Figure 2. CIE-xy Chromaticity diagram with chromaticity coordinates of FM-100 color cap set with the Oxy-Iso filter and without a filter. Solid Lines represent the major color confusion lines.

	Vertical Ratio	Horizontal Ratio
FM-100 with the Hemo-Iso Lens	0.345	1.468
FM-100 with the Oxy-Iso Lens	0.291	0.851

Table 1: Vertical and horizontal ratios of the best fit ellipse for the Hemo-Iso lens and the Oxy-Iso lens compared to the best fit ellipse with no filter.

	X	Y
FM-100 center with no lens	0.353	0.375
FM-100 center with the Hemo-Iso Lens	0.239	0.640
FM-100 center with the Oxy-Iso Lens	0.387	0.211

Table 2: Coordinates for the center of the best fit ellipse with no lens, Hemo-Iso lens and the Oxy-Iso lens.

	Radians	Degrees
FM-100 tilt with no lens	0.679	38.926
FM-100 tilt with the Hemo-Iso Lens	1.428	81.791
FM-100 tilt with the Oxy-Iso Lens	0.421	24.097

Table 3: Relative tilts of the best fit ellipse with no lens, Hemo-Iso lens and the Oxy-Iso lens.

CHAPTER 4

DISCUSSION

This study measured the shift in the chromaticity coordinates of color caps comprising the FM-100 hue arrangement tests caused by these two marketed chroma enhancing lenses. The results of this study indicate that the Hemo-Iso lenses will shift the color spectrum toward shorter wavelengths while the Oxy-Iso lenses will shift the color spectrum to the longer wavelengths. The spectated clinical applications of where these lenses can be used will be discussed; however, testing of this must be done in future studies. The results from this study showed best demonstrated in Figure 1 and 2. The center best of fit for the normal (clear lens) was 0.375 along the Y-axis. While the Hemo-Iso lens shifted the Y-axis central value to 0.640, meaning it shifted all the plates to the green spectrum. On the other hand, Oxy-Iso lens was 0.211 along the Y-axis; meaning, that the read values of all the Farmsworth-100 were shifted away from the green spectrum. The hypothesis for this study was to objectively prove this shift; so, other studies can research the true clinical implications of these lenses knowing the science behind the lenses is accurate.

In 2010 Diaconu set out to understand the reason why through certain colored filters dichromats report improvement in their ability to see colors. It Is not by using tinted lenses they can suddenly see colors, but Diaconu theorized and tested that even though the red filter only red color perception remains, a red filter does not improve the protanopia red-green perception, but it does improve the ability of the protanope to detect long length light.[2] He believes improvement is brought about by the means of the luminance mechanism. Essentially that is what these lenses aim to do, except without the color deficiency, but rather note stubble variations in color in a particular color spectrum.

The design goal from these shifts in color was based on the principle of the Hemo-Iso glasses predicts a shift of the chromaticity coordinates of colors away from the red spectrum towards the green spectrum to aid in bruise identification. Bruising is a rather green spectrum identification and to be able to subtly tell differences in bruising with this lens may help in the medical field. While the Oxy-Iso Vein lenses shift the spectrum away from the green towards the color spectrum for vein identification. This could aid medical field in efficiency of finding veins for injections, IVs and drawing blood.

There are a few ways to improve upon the testing method used. The testing could be repeated several times, and idealistically testing should be done with a flat non-curved lens as opposed to the lens given in the frame for this study.

Despite the shortcomings, Oxy-Iso and Heme-Iso lenses do appropriately shift the color spectrum in the direction that could influence the ability to detect subtle differences in bruising and veins. The medical impacts of these lenses can be further researched in other clinical studies.

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