A BICHROME INTERPRETATION OF STEREOPSIS: DOES CHROMATCITY AFFECT STEREOACUITY TESTING?

By

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ABSTRACT

Background: The purpose of this study is to determine the validity of the bichrome circles in screening for decreased stereoacuities. *Methods:* The validity will be determined via a Wilcoxson Signed Rank Test using JMP 5.0 software by SAS analysis of the results of the bichrome circles to the "gold standard" of stereoacuity testing, the stereo fly Wirt rings. Stereoacuities of seventy subjects of normal binocular status were measured with both the bichrome circles and the stereo fly Wirt rings. *Results:* It was found that the mean stereoacuity as measured with the bichrome circles was greater than the mean as measured with the stereo fly Wirt rings. *Conclusion:* The stereoacuities of subjects found with the bichrome circles were not correlated with the stereoacuities found with the "gold standard" stereo fly Wirt rings.

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A COMPARISON OF THE BICRHOME STEREO CIRCLES TO THE STEREO FLY WIRT RINGS

Abstract

Background: The purpose of this study is to determine the validity of the bichrome circles in screening for decreased stereoacuities. *Methods:* The validity will be determined via a Wilcoxson Signed Rank Test using JMP 5.0 software by SAS analysis of the results of the bichrome circles to the "gold standard" of stereoacuity testing, the stereo fly Wirt rings. Stereoacuities of seventy subjects of normal binocular status were measured with both the bichrome circles and the stereo fly Wirt rings. *Results:* It was found that the mean stereoacuity as measured with the bichrome circles was greater than the mean as measured with the stereo fly Wirt rings. *Conclusion:* The stereoacuities of subjects found with the bichrome circles were not correlated with the stereoacuities found with the "gold standard" stereo fly Wirt rings.

Introduction

It is imperative for the practicing optometrist to incorporate a measure of screening and/or the evaluation for binocular anomalies within their practice. [1] To determine the status of a binocular system, one must measure a patient's stereoacuity, or stereopsis. This can be defined as "a binocular perception of depth, or three-dimensional space". [2] Determining abnormal binocular vision and possible amblyopia is essential for the overall health and well being of the patient's visual system. Many studies have been conducted to determine standards for the testing of this critical visual attribute.[3, 4]

The Stereo Fly Wirt Rings have been the "gold standard" of stereoacuity screenings in the optometric community, presented by the Stereo Optical Company in 1949. [5] This commonly used device uses polarized lenses and Wirt Rings, and is otherwise known as the Graded Circle Test. The test consists of nine figures, each decreasing in visual angles from eight hundred seconds to forty seconds of arc. This procedure measures fine/threshold depth perception. According to the instructions of the manufacturer, it can be determined that the patient has a binocular anomaly if the stereopsis measurement is greater than the smallest visual angle presented: forty seconds

of arc. The Bichrome Circles, introduced by Synthetic Optics Incorporated in 2001, also has an analogous testing procedure for stereoacuity screening. This also consists of nine figures, each decreasing in visual angle from eight hundred seconds to forty seconds. Testing glasses consisting of one red lens and one green lens are used in lieu of the polarized lenses of the Wirt Rings.

A study performed by Hatch and Richman[6] compared the available polarized stereopsis testing mechanisms versus nonpolarized Stereopsis tests. Their results showed "no significant difference in stereopsis levels between the various tests, and that polarized-free tests were highly correlated with the polarized comparison tests." This study is integrated into our own experiment, being that the Bichrome Circles are also nonpolarized. However, the above study does not take into consideration the effect of chromaticity on measured stereoacuity.

It has also been determined that the chromaticity of stimuli affects acuity levels. Chromatic aberration is a direct result of "the fact that the refractive index of a material varies slightly with the wavelength".[7] Chromatic aberration creates a difference in refraction of different colors, thus producing images that are not focused in the same plane, but actually images with one color blurred while the other is focused. As shorter wavelengths are refracted more than longer wavelengths, it is thereby deduced that green colors are refracted more than red colors. If a stimulus contained only the colors red and green, it can be assumed that these wavelengths would not produce identical acuities. Therefore, stereoacuities measured with such stimuli, such as the bichrome Circles, might prove to produce different results than the standard stereoacuity tests available. We feel it necessary to investigate the validity of this "tool" using normal test subjects in order to assess its usefulness on screening for patients with actual binocular problems.

We hypothesize that in normal binocular subjects, the use of nonpolarized, chromatic lenses and chromatic stimuli in the Bichrome Circles will give the <u>same results</u> as the standard stereopsis screening tool, the Stereo Fly Wirt Rings.

Although we are only performing our study at near distances (approximately forty centimeters), these results will also prove to be valid at far distances (approximately five hundred and eighteen centimeters, the distance-habitual). This is supported by a recent study done by Wong, et al.[8] This study showed that stereoacuity was not different at distance and near under normal viewing conditions when presented with a polarized Random Dot display.

Previous studies have determined at what age a stereoacuity measurement could be assessed with a minimum of confounding factors. In a study performed by Ciner et. al.[3], it was found that stereoacuities approach adult levels at twenty-four months of age. In addition, it was also found that normal stereopsis and stereoacuity improves "significantly" between age four and five and a half years, and reaches an adult-like level at this point, as determined by Tomac and Altay. [9] Measurements of stereoacuities taken before these age thresholds would be found to be variable, questionable or even invalid, as stereovision would still be in the development stage. On the other hand, it was found in a study conducted by Zaroff et. al.[10] that stereo deficiencies become more pronounced with age, specifically after age sixty. These studies prove that it is best to determine stereoacuity between the ages of five and a half years old to sixty years old. Due to the constraints on our subjects determined by their admission in the Michigan College of Optometry program, our subjects were limited to these confinements. We addressed this confounding factor in our questionnaire by asking for the age of the subject, and any conclusions drawn from the age factor are to be implicated within our discussion.

In addition to distances measured and age, stereoacuities can be affected by many other variables, each addressed below in Methods.

Rationale

We are predicting the stereoacuity measurements of the Bichrome Circles will be clinically significant and correlated with the "gold standard" Stereo Fly Wirt Dots results. This information would be invaluable to the optometric community, as it would demonstrate the Bichrome Circles as a useful screening tool for the standard optometric examination.

Methods

Seventy-four were recruited for this investigation, accounting for twenty-six males and forty-eight females. Their ages ranged from twenty to thirty-six years old. Subjects ranged in race, but the majority came from middle-class backgrounds. All participants were students at the Michigan College of Optometry at Ferris State University, and were not compensated for their time. A Human Subjects Application was obtained and approved from Ferris State University, and each subject was required to sign an informed consent request. Each subject was randomly assigned a number that was used for the remainder of the experiment in order to protect their identity.

Each subject completed a questionnaire, which was used to categorize all confounding data at the completion of the study. A copy of the questionnaire is included in Appendix B. Both the Stereo Optical Company Stereo Fly Wirt Rings and the Synthetic Optics Incorporated bichrome Random Dot Circles were used to measure stereoacuity. Subjects wore their current prescriptions while performing both testing procedures. Subjects were given thirty seconds in which to complete the each test. Both tests were performed according to manufacturer instructions. (See Appendix A & B)

To allow for a double-blind study, the experimenters did not conduct the testing procedures themselves, but rather selected experimenters who had no knowledge of the testing hypothesis. These experimenters were to perform only one test, selected randomly, on each subject. Once completed, the next experimenter would also randomly select which test was next administered to the subject. In both procedures, the highest Stereoacuity was determined by the smallest visual angle of the Wirt Rings or bichrome Circles seen and recorded.

Environmental conditions were controlled to be as identical as possible with each patient; Lighting conditions were not varied (a standard 60W bulb was aimed directly onto the Stereo Test from a distance of three feet), along with full exam room lighting. Time of day was controlled within 8 a.m. to 5 p.m. Subjects were not allowed to move their heads or the test during the measurement to prevent an increase in stereoacuity from parallax motion. Visual acuities were measured via the Snellen Visual Acuity chart at forty centimeters (sixteen inches). Color Vision was assessed using the Farnsworth desaturated-15 color test. Patients were assumed to have stable binocular systems based

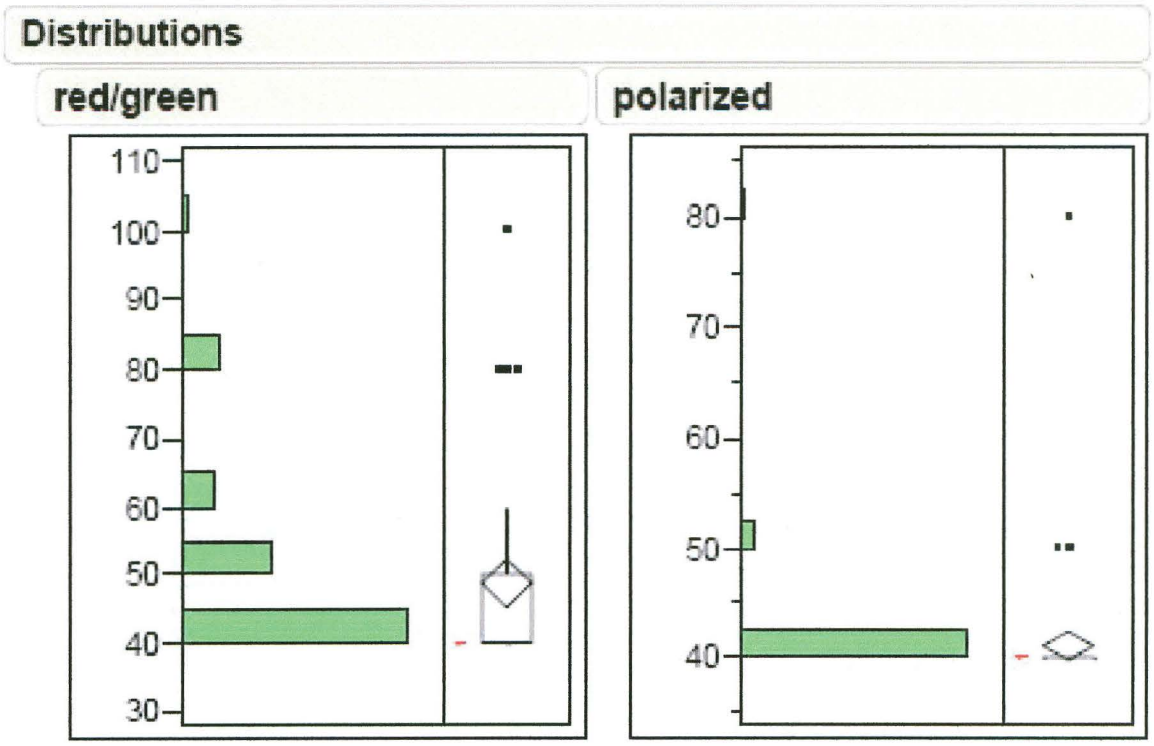
on information provided in the questionnaires. These factors were used to control for confounding factors within the testing procedure. Patient information was compiled and analyzed only after all data had been collected. Subjects were to be excluded from the results if they exhibited binocular anomalies as measured by the above screening methods. These binocular anomalies include a horizontal or vertical tropia of any magnitude, an exophoria >6 prism diopters, an esophoria >0 prism diopters, an accommodative facility of 5 cycles or less within 30 seconds, any deviation from the Fixation Disparity Curve 1, or +/-1 diopters from Donder's expected norms of accommodative amplitude (18.5D-0.30age). [11]

Nonparametric data from this study was analyzed via the Wilcoxson Signed Rank Test using JMP 5.0 software by SAS, which was successively used to calculate its significance via the Paired t-test.

Results

It was found that of the seventy-four subjects, four of the subjects needed to be excluded from our statistics as their results were significantly skewed. This may imply that they had underlying binocular defects missed by our exclusion criteria, as explained further below. The mean (x) of the stereoacuity measured by the Stereo Fly Wirt Rings of the remaining seventy subjects was 41.142857 (seconds of arc), with a standard deviation (σ) of 5.2593208. The mean of the bichrome circles was 48.857143 (seconds of arc), with a standard deviation (σ) of 13.888047. In addition, the bichrome circle stereoacuities were 100% either the same as the stereoacuities measured by the Wirt rings or worse. A Wilcoxson Signed Rank test showed a signed rank of -189 at a $t < 0.0001$. A paired t-test showed a value of -5.0138.

Figure 1. Distributions of Individual Stereoacuity Tests



Quantiles

100.0%	maximum	100.00
99.5%		100.00
97.5%		84.50
90.0%		80.00
75.0%	quartile	50.00
50.0%	median	40.00
25.0%	quartile	40.00
10.0%		40.00
2.5%		40.00
0.5%		40.00
0.0%	minimum	40.00

Moments

Mean	48.857143
Std Dev	13.888047
Std Err Mean	1.6599391
upper 95% Mean	52.168631
lower 95% Mean	45.545655
N	70

Quantiles

100.0%	maximum	80.000
99.5%		80.000
97.5%		56.750
90.0%		40.000
75.0%	quartile	40.000
50.0%	median	40.000
25.0%	quartile	40.000
10.0%		40.000
2.5%		40.000
0.5%		40.000
0.0%	minimum	40.000

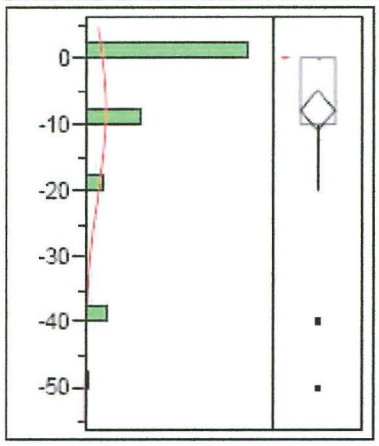
Moments

Mean	41.142857
Std Dev	5.2593208
Std Err Mean	0.6286091
upper 95% Mean	42.396898
lower 95% Mean	39.888816
N	70

Figure 2. Comparison of Stereoacuity Tests

Distributions

F3



Normal(-7.7143,12.873)

Quantiles

100.0%	maximum	0.00
99.5%		0.00
97.5%		0.00
90.0%		0.00
75.0%	quartile	0.00
50.0%	median	0.00
25.0%	quartile	-10.00
10.0%		-38.00
2.5%		-42.25
0.5%		-50.00
0.0%	minimum	-50.00

Moments

Mean	-7.714286
Std Dev	12.873006
Std Err Mean	1.5386185
upper 95% Mean	-4.644826
lower 95% Mean	-10.78375
N	70

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	Mu	-7.7143	-10.7837	-4.6448
Dispersion	Sigma	12.8730	11.0375	15.4464

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.639832	0.0000

Test Mean=value

Hypothesized Value	0	
Actual Estimate	-7.7143	
df	69	
Std Dev	12.873	
	t Test	Signed-Rank
Test Statistic	-5.0138	-189
Prob > |t|	<.0001	0.000
Prob > t	1.0000	1.000
Prob < t	<.0001	0.000

Discussion

According to the statistics used to analyze our measurements, it was found that the stereoacuities measured with the bichrome circles were not significantly correlated with the standard measure of the Stereo Fly Wirt Rings. In other words, the data did not support the null hypothesis; specifically, the bichrome circles do not give the same results as the "gold standard" Wirt rings and are not an acceptable screening method of stereoacuity levels as compared with the standard measure. Although the testing

procedure worked for some patients, many could not use stereopsis during the exam (i.e. they could not see depth within the circles). If used in a standard optometric exam, this screening measure would indicate to the practitioner that the patient did not have fusion (stereopsis). Unfortunately, if the practitioner had used the standard stereoacuity screening device, the Wirt Rings, the patient most likely would have passed the procedure with the normal stereoacuity reading of forty seconds. It was found that the Stereo Fly Wirt Ring measurements had a mean of 41.142857 seconds of stereoacuity. This number indicates that of the seventy subjects measured, the majority had stereoacuity levels of forty seconds of arc. Of those same subjects measured with the bichrome circles, results show that the mean stereoacuities were much less than the forty seconds of arc, specifically a mean of 48.857143. This proves the measurements of the bichrome circles are not correlated with the measurements of the Wirt Rings.

It can be deduced from previous findings that the different results of the bichrome circles in measuring stereoacuities could be due to the chromatic nature of the procedure. As explained earlier, the separate wavelengths of the testing stimulus could have negatively affected the measurements provided by this method. This theory could be tested in the future by repeating a similar study of this nature more thoroughly, or by conducting studies that more accurately demonstrate how chromaticity affects stereopsis. The number of possibilities and the variety of these suggested studies are outside the realm of this discussion.

In addition, due to the deviations of four outlying subjects, we did not include their values in our statistics. Although we attempted to minimize the confounding variables in our experimental design, there still could be many at play in the results. It could be that some of the students actually did have binocular problems that have never been diagnosed in the past, or that they were never informed of. Due to time constraints in this study, the experimenters could not test for binocular deficiencies. This left only the patient's subjective memory as the indicator of their actual binocular status. One way to minimize this would be to increase the length of the study to allow for testing of these deficiencies.

The patients might also have had underlying color deficiencies that were not indicated by our preliminary color screening tests. This would also confound our data. One way to minimize this facet in future testing would be to test color vision using more comprehensive color vision tests, such as the Farnsworth-Munsell 100 Hue Test. Refractive error could also have skewed the results, whereas a high myope could more easily complete the bichrome test, while a high hyperope could not perform the test at all. This could be eliminated in further testing by using a study sample of only high hyperopes, or only high myopes. Guessing could also be a large confounding variable, thereby providing inaccurate results of the patient's true depth perception in either measure. This factor could not be accounted for in succeeding studies, but would most likely average out between the two testing procedures, as both would be equally affected.

In contrast to the findings in this study, it could have been found that the results were highly significant. This would indicate that the bichrome Circles are indeed as valid as the standard Wirt Rings, and could be used as a screening tool for binocular anomalies as measured with stereopsis. This result could occur if the chromaticity actually had no effect on the measured stereopsis. Unfortunately, the data in our study proves otherwise. In addition, the results may have established a negative correlation, indicating that the bichrome Circles were actually more accurate than the standard Wirt Rings when screening for binocular anomalies. The indication from this result would be that the chromaticity of the bichrome Circles was actually enhancing the measurement of the patient's stereopsis. This information would also be invalid to the optometric profession, as it would provide another clue to how binocular depth perception occurs in the visual pathway. This result would definitely be more favorably to Synthetic Optics, Inc., for this test could now replace the standard of stereopsis testing used for fifty years! With either of these results, further testing would need to be done to determine if the bichrome circles accurately measured stereopsis in patients with every type of binocular anomaly, color deficiency, or any other confounding variable. Once these results are determined, one could accurately assess whether the bichrome circles could be used efficiently in standard optometric screenings or examinations.

Conclusion

This study concluded that the bichrome circles do not give the same results as the standard stereopsis screening measure, the Stereo Fly Wirt Rings. Studies suggest that this finding is due to the chromatic nature of the bichrome circles. This information is invaluable to the optometric community, as these tests may yield misleading information of a subject's stereoacuity in general optometric examinations.

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APPENDIX A

STEREOACUITY EVALUATION FORM

STEREOACUITY EVALUATION FORM

Subject #: _____

Habitual Visual Acuity (Snellen acuity @ **40cm**)

OD 20/_____
OS 20/_____
OU 20/_____

Color Vision Screening (Farnsworth De-saturated panel D-15)

****See attached scoring sheet OD: Pass Fail OS: Pass Fail

Binocularity Assessment

Phoria @ near: _____ (cover test @ 40cm)
Fixation Disparity: _____ (Saladin card @ 40cm)
Accommodative Amplitude: _____D_____ (Push-up test)
Accommodative Facility: cycles /30 seconds (+/-2.00D lens flipper test)

Stereoacuity Assessment

Stereoacuity Test #1: _____seconds of arc

Stereo Fly Wirt Rings **Bichrome Random Dot Stereo Circles**

Stereoacuity Test #2: _____seconds of arc

Stereo Fly Wirt Rings **Bichrome Random Dot Stereo Circles**

APPENDIX B

STEREOACUITY EVALUATION QUESTIONNAIRE

STEREOACUITY EVALUATION QUESTIONNAIRE

Subject #: _____

Have you been seen by an eye care professional before? Y N

If so, were there any remarkable findings (i.e. any diseases of the eye, cataracts, birth abnormalities, glaucoma, etc.)? _____

_____

Do you currently wear glasses? Y N

If so, for how long have you owned these glasses? _____

Do you currently wear contacts? Y N

If so, for how long have you owned these contacts? _____

If you have your contacts in today, how long have you had them in? _____

Do you have any medical problems? _____

_____

Are you on any medications? _____

Have you ever had any trauma or surgery to your eye(s)? Y N

If so, please explain. _____

Have you ever been diagnosed with a color vision deficiency? Y N

Do you have any types of problems with daily activities concerning color vision (i.e. difficulty with traffic lights/signs, using a computer, etc.)? Y N

If so, please explain. _____

_____

Have you every been diagnosed with a difficulty in binocularity? Y N

If so, please explain. _____

Do you ever have difficulty with reading? Y N

Have you ever been told that one of your eyes turns in/out? Y N

Do you ever see double? Y N

Do you ever have to "work" to see something? Y N

Do you ever have headaches? Y N

If so, how often do they occur? _____

Does anything help the headaches? _____

Do you notice the headaches are present during any certain activity? _____

_____

Would you classify the headaches as migraines? Y N

Do you have any important ocular, vision, or general health history not mentioned above?

If so, please explain. _____

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COLLEGE OF ARTS & SCIENCES
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TO: Dr. Daniel Wrubel
From: C. Meinholdt, HSRC Chair
Re: HSRC Application #041103 (Title: A comparison of the bichrome random dot stereo circles to the stereo fly wirt rings)
Date: January 5th, 2005

The Ferris State University Human Subjects Research Committee (HSRC) has reviewed your project, "A comparison of the bichrome random dot stereo circles to the stereo fly wirt rings" and approved it under the category of *expedited* (2D) on December 17th, 2004.

Your application has been assigned a project number (#041104) which you may wish to refer to in future applications involving the same research procedure. Also, project approvals are now receiving an expiration date one year from the date of approval. As such, you may collect data according to procedures in your application until December 16th, 2005.

Best wishes for a successful research endeavor and please let me know if I can be of future assistance.