5-2001

Comparison of fixation disparity measurement technique utilizing physiological diplopia quantified by the laser disparometer and the Sheedy disparometer

Mark A. Hanson
Pacific University

Recommended Citation

Hanson, Mark A., "Comparison of fixation disparity measurement technique utilizing physiological diplopia quantified by the laser disparometer and the Sheedy disparometer" (2001). *College of Optometry*. 1374.
https://commons.pacificu.edu/opt/1374

Comparison of fixation disparity measurement technique utilizing physiological diplopia quantified by the laser disparometer and the Sheedy disparometer

Abstract

This study explored a new technique for measuring fixation disparity. The concept quantified superimposition of physiologically diplopic images to determine alignment of the subjects' visual axis and fixation disparity. Fifteen subjects were tested using the new Laser Disparometer and the Sheedy Disparometer. Results showed a 0.88 correlation between the two methods and no significant difference between mean fixation disparity measurements. Future studies are needed with larger sample size to increase statistical support for the Laser Disparometer.

Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Darin Paulson

Keywords

fixation disparity, laser disparometer, physiological diplopia, sheedy disparometer

Subject Categories

Optometry

COMPARISON OF FIXATION DISPARITY MEASUREMENT TECHNIQUE UTILIZING PHYSIOLOGICAL DIPLOPIA QUANTIFIED BY THE LASER DISPAROMETER AND THE SHEEDY DISPAROMETER.

By

Mark A. Hanson

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
for the degree of
Doctor of Optometry
May 2001

Advisor:
Darin Paulson O.D.

Author

Mark A. Hanson

Advisor

Darin Paulson O.D.

Biography of Author.

Mark Hanson attended Viterbo College, Lacrosse, Wisconsin from fall semester of 1992 until spring of 1997 where he graduated with a B.S. in the field of biology. He began studies at Pacific University College of Optometry, Forest Grove, Oregon in the fall of 1997 and will graduate in spring of 2001 with a Doctor of Optometry degree. Future plans include practicing full scope optometry in the Midwest.

Abstract:

This study explored a new technique for measuring fixation disparity. The concept quantified superimposition of physiologically diplopic images to determine alignment of the subjects' visual axis and fixation disparity. Fifteen subjects were tested using the new Laser Disparometer and the Sheedy Disparometer. Results showed a 0.88 correlation between the two methods and no significant difference between mean fixation disparity measurements. Future studies are needed with larger sample size to increase statistical support for the Laser Disparometer.

Keywords:

Fixation disparity

Laser Disparometer

Physiological diplopia

Sheedy Disparometer

Acknowledgments

I would like to thank Darin Paulson O.D. for advising this study and always treating me and my ideas with respect and professionalism. I thank the physics department at Strain Hall, Pacific University for allowing me to use the machine shop facilities while constructing the Laser Disparometer. I thank Hannu Laukkanen O.D., FAAO for supplying the digital images of the device that are included in this paper as well as donating the material needed to construct the projection screen. I thank Bradley Coffey O.D., FAAO for contributing components and ideas necessary for the development and construction of the LED target system. Finally, I must thank my wife, Julie, who has worked so hard helping to put me through school and for the sacrifices she made while making room for the Laser Disparometer in our budget.

Introduction:

Many devices have been developed to measure fixation disparity. The most commonly used devices include the Sheedy disparometer and the Wesson fixation Disparity Card that are dichoptic in nature and rely on nonius test lines as targets[1]. Most fixation disparity measuring devices have variations in the size and position of nonius test-lines, the location of the binocular fusion lock, and accommodative control. Conflicting studies are common as a result of these variations[2]. The method explored in this study does not rely on nonius line targets and may more closely simulate natural viewing conditions than most commonly used fixation disparity measuring devices. Having a disparity test that uses real world targets will hopefully increase the ability of fixation disparity testing to predict symptomatic patients in a clinical environment.

The concept of this study quantifies physiological diplopia and utilizes simultaneous perception and accommodative control to identify where in space the visual axis are aimed. This method may improve the accuracy of fixation disparity measurement by the introduction of a kinetic stimulus element. Studies have shown that stimulus motion increases disparity sensativity[3]. The ability to quantify these components of the visual system will allow for fixation disparity measurement. The hypothesis for this study states that if a device can be constructed capable of accurately measuring visual axis alignment utilizing awareness of physiological diplopia, with appropriate accommodative control, fixation disparity can be measured and a positive correlation will exist with measurements taken by the Sheedy Disparometer.

Materials and Methods:

Overview

In order to accomplish the requisite outcome several features were incorporated into the design of the device. First, the device had to be capable of eliciting awareness of physiological diplopia. To do this a target was necessary that could hold accommodation at the desired plane while allowing the subject to be aware of images projected on a screen 1.0 meter behind the accommodative plane. The projected images were required to be strong enough to elicit awareness of physiological diplopia but not strong enough to easily distract accommodation. The projected images were to be dichoptic and each respective eye would view the opposite projected image. Polarized glasses and a screen capable of carrying polarization were incorporated into experimental design to accomplish this. Finally, the device had to be capable of measuring the position of the projected kinetic images with extreme accuracy when the subject reported superimposition of the images.

Design:

The device was designed to mount in place of the phoropter on the equipment stand (figure 2). It was placed above the head of the subject with two battery powered polarized Class IIIb lasers mounted on turrets capable of rotation in the X and Z axis. The lasers were polarized and projected an image of a 30mm circle with a 2mm dot in the center. The intensity of the laser beam was adjusted to optimize cancellation by placing neutral density filters (T=0.75) in carriers in front of the lasers (item C, figure 1). The laser images were projected 1.0 meter away on a curved screen with a 1.0-meter radius (figure 2). The screen was covered with 3M sticky backed polarization carrying projection materials and curved to optimize polarization. The center of rotation of the turrets (Z axis), shown in figure 1, is placed directly over the center of rotation of each eyeball and adjusted to accommodate the subject's pupillary distance. Rotation of each turret around the Z-axis by turning the horizontal adjustment knobs (item b, figure1) caused the projected laser image to be moved along horizontal axis. Thumbscrew adjustments (item D, figure 1) aligned the lasers vertically along the horizontal axis and were added solely for zeroing the device.

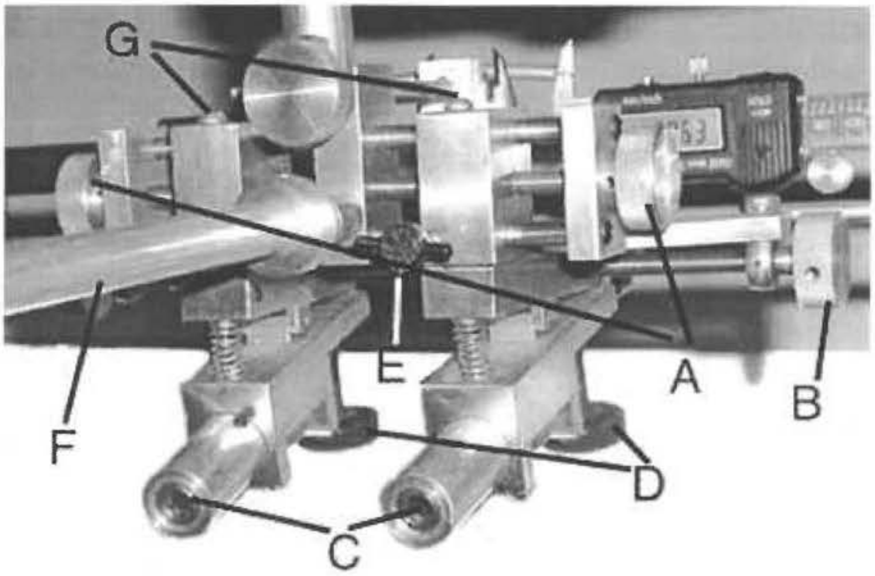

Figure 1. The Laser Disparometer. (A) Pupillary distance adjustment knobs. (B) Horizontal laser turret rotation knob. (C) Neutral density filter holders (attached directly to front of lasers). (D) Vertical laser adjustment knob. (E) OS carriage lock nut (OD carriage lock blocked in this photo by the near point rod). (F) Near point rod.

Target:

The accommodative target was designed to hold accommodation closely at the plane of regard. The target consisted of a 5 digit LED providing a 20/80 demand at 40 cm. The 5 digit numerical LED was battery powered and controlled by integrated circuits that randomly changed the digits at one-second intervals as the subject was asked to call each of the digits. The target was capable of displaying any combination of 1 to 5 digits as well as altering the rate and amount of time each digit was displayed. This feature was added in order to change the cognitive load thus stabilizing accommodation. Depending on the population being tested the subject could be asked to simply call out or add any combination of numbers. For this study all five digits were displayed at 1-second intervals and the subject was asked to call them in order from left to right. The target hung from a 40 cm near point rod with a 50 cm x 30 cm rectangular supporting frame attached to the near point rod in the center of the top part of the frame. This target configuration enabled the support for the target to rise from the bottom of the framework thereby eliminating any visual interference that would be unavoidable if the target came directly down from the near point rod (figure 2).

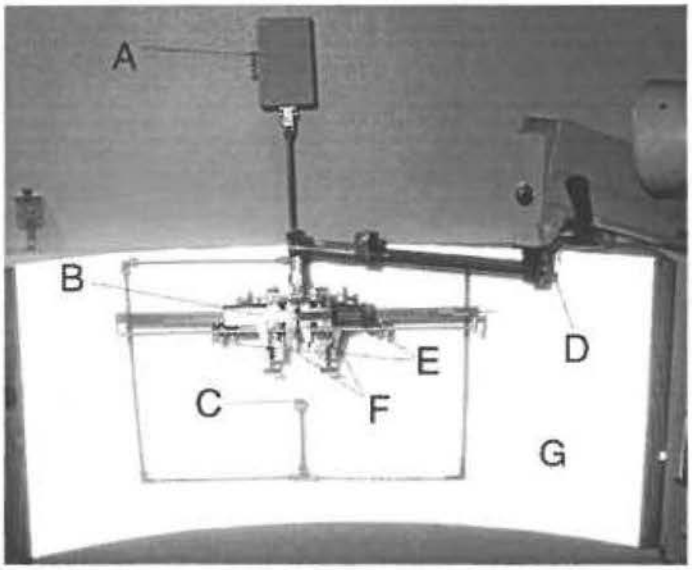

Figure 2. The Laser Disparometer setup on equipment stand with accommodative target in place. (A) Accommodative target control box. (B) Measuring calipers. (C) Target LED. (D) Equipment stand arm. (E) Horizontal laser turret rotation knobs. (F) Point of contact between turret extensions and measuring blades of caliper. (G) Projection screen.

Measuring Capabilities:

Two 6 inch calipers were mounted in opposing fashion 10.0 cm behind the center of rotation of the turrets (figure 4). An extension of the turret contacted movable blades on the digital calipers forcing movement of the caliper blades as the turret moved. Slop in the system was taken up by springs mounted from the non-movable portion of the caliper to the movable blade that contacted the turret extension. The factory specified accuracy of the calipers was +/- 0.01 mm. With the caliper mounted 10.0 cm behind the turret and the projection screen mounted 1.0 meter in front of center of rotation, prism diopters could be read directly from the calipers as accurately as 0.01 prism diopters. As the calipers are digital they can be zeroed at any position. For this study the calipers were zeroed at the exact center of the LED. The nature of the design caused any positive values to be eso and negative values to be exo. Values of zero equal ortho fixation disparity.

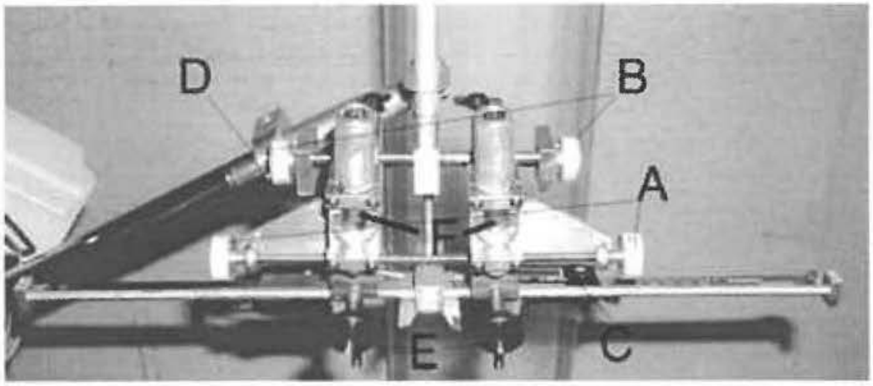

Figure 3. Bottom view of Laser Disparometer showing mounted laser pointers. (A) Horizontal laser turret rotation knobs. (B) Pupillary adjustment knobs. (C) Measuring calipers. (D) Arm of equipment stand. (E) Vertical laser adjustment knobs. (F) Laser pointers.

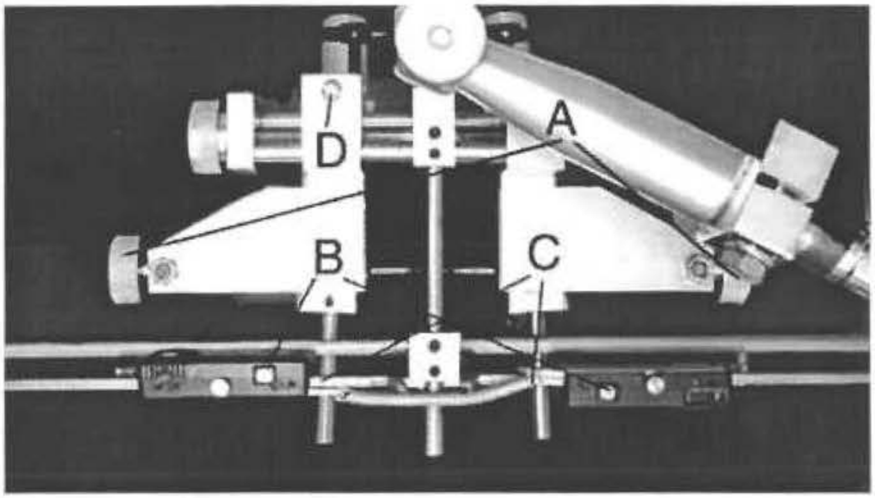

Figure 4. Top view of Laser Disparometer showing point of rotation of laser turret and point of contact between turret extension and measuring blade of calipers. Notice that from the center of rotation of the laser turrets to the interface of the turret extensions and the measuring blade is 10 cm. This is the feature that allows prism diopters to be read directly from the calipers when set to millimeters (assuming the lasers are projected to a screen 1 meter away). (A) Horizontal laser turret adjustment knobs. (B) Top view of digital measuring calipers. (C) Interface of measuring blade of caliper and turret extension.

Fabrication:

Fabrication of the device was carried out by an experienced machinist using industry standard tolerances and equipment. The device was constructed from machined aluminum and brass. The lasers pointers were purchased at *Sam Goody* and came with interchangeable image projection adapters.

Comparison with Sheedy Disparometer:

A comparison was made with results obtained from Laser Disparometer and the Sheedy Disparometer to establish validity of the results. The Sheedy was chosen as a control for several reasons. First, it was unknown what lighting would be necessary for optimal cancellation of the laser images on the screen. Studies have shown that illumination changes do not cause any significant difference with test results obtained from the Sheedy[4]. Once appropriate lighting was established, it was kept constant for all testing with the Laser Disparometer as well as with the Sheedy Disparometer. Second, the Sheedy Disparometer requires a mechanical change to alter disparity. This was desirable because of the kinetic element in the Laser method. It was felt that a moving stimuli was more appropriate even though the movement was only during changes of disparity demand. Finally, the Sheedy disparometer has well-established normative data and is one of the two most common methods used for measuring fixation disparity[1].

Test Protocol:

15 Test subjects consisting of optometry students and doctors of optometry were selected. Each subject was determined to have normal binocular function by history and was fully corrected for ammetropia. The subject was placed in the examiners chair and the headrest was adjusted placing the subjects eyes 1 meter from the screen. Next the device was aligned directly above the center of rotation of the subject's eyes and the pupillary distance on the device was set to match that of the subject. The LED target was supported from the device 40 cm from the center of eyeball rotation at eye level. The subject focused on the LED and called out the digits as they changed randomly.

Polarized laser images were projected on a screen 1.0 meter in front of the center of rotation of the eyeballs. The subject wore polarized glasses enabling only the opposite laser image to be seen by each eye while the LED is seen by both eyes. Initially the device was zeroed out on the center of the LED (ortho position) by adjusting the horizontal and vertical laser adjustment knobs. After the lasers were aligned with the center of the target they were adjusted slightly above the target so as not to be obstructed by the target itself during testing and moved to an extreme position in the eso direction. The lasers were then rotated in the exo direction in a smooth motion while the subject continued to focus on the LED. It was paramount that the subject maintains clear and constant focus on the LED while also maintaining awareness of where the laser images are and when they were superimposed. The first endpoint was reached when superimposition of the laser images was observed as the lasers were moved in the exo direction. At this point the digital calipers were read and the lasers continued to be in the exo direction moved until diplopia was noted again. The lasers were then moved in the eso direction until superimposition was reported again and the fixation disparity was bracketed.

Results:

Table 1 shows data collected using the Laser Disparometer and the Sheedy Disparometer. Fixation disparity is the average of the bracketed responses (read in hundredths of millimeters off the digital calipers) for each eye converted to arc minutes and added together.

Table 1. Fixation disparity data collected using Laser Disparometer and Sheedy Disparometer. Positive values indicate eso fixation disparity and negative values indicate exo fixation disparity.

Subject	Laser	Sheedy
1	-6	-3
	-6	-3
2	7.91	9
	8.69	8
3	-2.04	2
	-1.03	0
4	-1.36	-2
	-2.98	-2
5	-4.4	-3
	-6.34	-5
6	-10.63	-11
	-6.6	-9
7	7.1	1
	5.78	4
8	-0.58	1
	-0.79	1
9	-4.5	-1
	-3.09	-2
10	1.94	0
	-0.47	2
11	1.52	-1
	1.78	3
12	-1.47	0
	0.31	0
13	5.5	3
	7.7	2
14	7.44	4
	8.06	4
15	-8.59	-5
	-7.54	-8

Table 2. Analysis of exo fixation disparity data from table 1.

t-Test: Two-Sample Assuming Unequal Variances

	Laser	Sheedy
Mean	-5.67arc min	-4.5arc min
Variance	6.07	10.4
Observations	6	6
Standard Error	1.00	1.31
Standard Deviation	2.46	3.22

Table 3. Analysis of eso fixation disparity from table 1.

t-Test: Two-Sample Assuming Unequal Variances

	Laser	Sheedy
Mean	5.25arc min	3.25arc min
Variance	10.43	7.88
Observations	6	6
Standard Error	1.32	1.15
Standard Deviation	3.23	2.81

Table 4. Analysis of data from table 1 within 2 arc minutes of ortho as measured by both devices.

t-Test: Two-Sample Assuming Unequal Variances

	Laser	Sheedy
Mean	-0.93arc min	0.67arc min
Variance	0.27	0.33
Observations	3	3
Standard Error	0.30	0.33
Standard Deviation	0.52	0.57

Table 5. Pooled data from table 1 analyzed without separating eso from exo fixation disparity.

	Laser	**Sheedy**
Total measurements	30	30
Sum	-10.68	-11
Average	-0.36	-0.37
Variance	31.21	19.96
Correlation = 0.88		

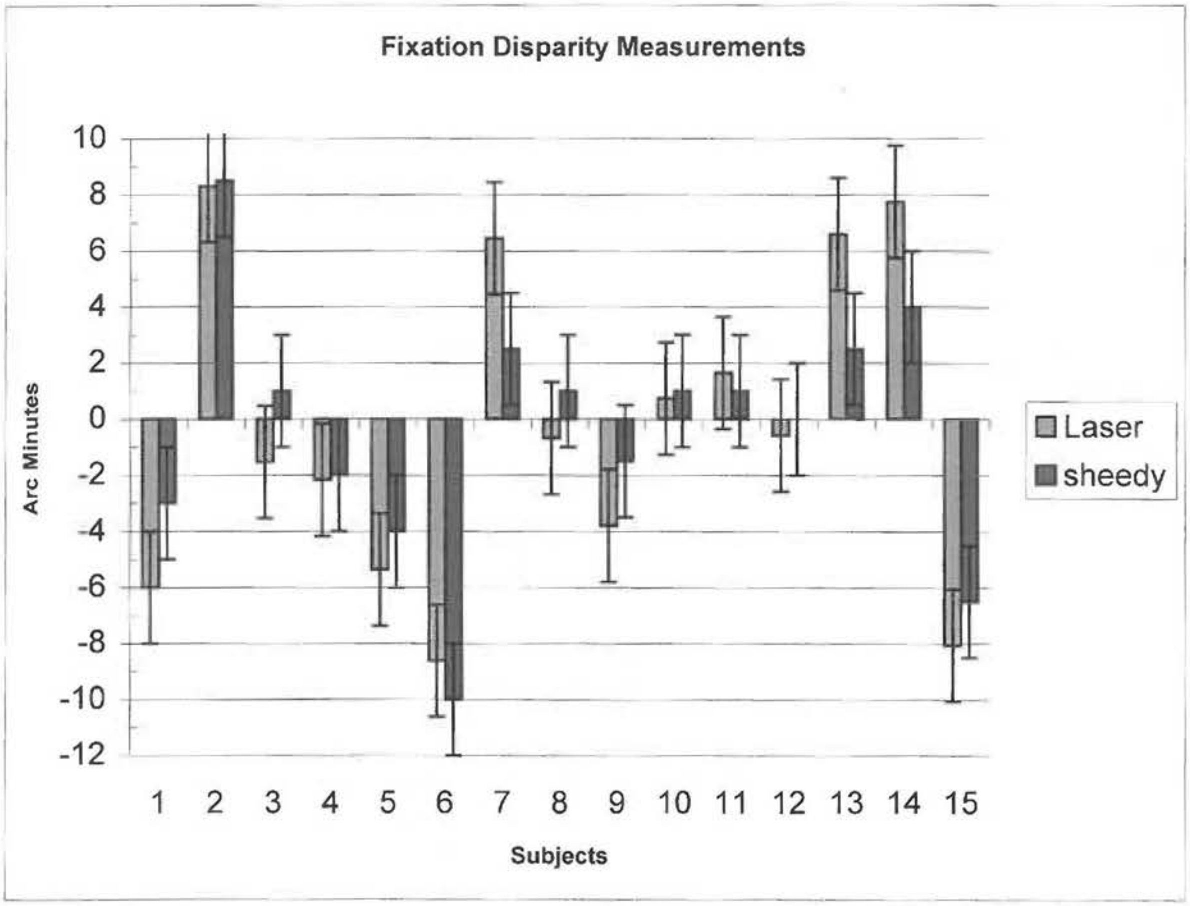

Figure 5. Comparison of fixation disparity measurements of 15 subjects taken by Laser Disparometer versus the Sheedy Disparometer. Error bars indicate standard deviation.

Discussion:

The results support the hypothesis that the laser method is capable of measuring fixation disparity and shows a high correlation (0.88) between the two methods. Results show the Laser Disparometer to be more variable than the Sheedy Disparometer when data is pooled. Studies have shown that measurements analyzed with pooled data comparing eso and exo fixation disparities have led to spurious results[5]. As such, exo and eso fixation disparity measurements were analyzed separately. Results revealed a sample variance of 6.07 and standard deviation of 2.46 for the Laser Disparometer and a higher sample variance of 10.4 and standard deviation of 3.22 for the Sheedy Disparometer when measuring exo fixation disparity. For eso fixation disparity the Laser Disparometer shows a higher sample variance of 10.43 and standard deviation of 3.22 while the Sheedy has a sample variance of 7.88 and a standard deviation of 2.80.

Fluctuating accommodative control among the subjects is felt to be the largest contributor of variance as results are highly dependant upon stable accommodation and small amounts of accommodative fluctuation result in sizeable errors. As the Laser Disparometer is new, none of the subjects have had experience performing the test and familiarity with the test did not contribute to variance reduction. Studies have shown that familiarity with the Sheedy Disparometer reduced fluctuation and unstability[6]. Future studies will incorporate a test-retest element into experimental design to monitor test performance based on familiarity with the testing method.

Another contributor to higher variance with the Laser Disparometer is the subject's ability to easily vary head position. In this study the headrest was adjusted to support the back of the subjects head. This prevented any backward movement of the head but did not prohibit forward or lateral movement. Any forward movement of the head would cause the Laser Disparometer to measure artificially more eso. If the subjects head was initially setup too far back the data collected would read artificially more exo. Future studies should consider using a chin and forehead rest to control variance secondary to head movement. It is unknown at this time why the laser method appears to be less variable when measuring exo fixation disparity and more variable when measuring eso fixation disparity. Future studies with more subjects are necessary to identify if this trend is real.

Figure 5 shows how the laser method compares to the Sheedy. Of the 15 subjects, 6 showed exo fixation disparity measured by both the Laser and Sheedy method, 6 were found eso with both methods, 2 had opposing fixation disparities, and 1 subject was ortho with Sheedy Disparometer and exo with the Laser Disparometer. In 5 of the 6 exo subjects, the Laser Disparometer measured more exo fixation disparity. Statistically the exo disparity mean measurements were not significantly different P=0.50. Of the 6 that showed eso fixation disparity with both devices, 4 were found to be more eso when measured with the Laser Disparometer. Again the difference of the means of eso fixation disparity measurements were not significant P=0.28. A study with a larger sample size is necessary to establish more reliable statistical support and to determine if the Laser Disparometer really measures more exo and more eso as compared to Sheedy Disparometer measurements.

Only 2 of the fifteen subjects showed fixation disparity in opposite directions. In both instances the measurements taken by either device were within 2 arc minutes of ortho which was within the standard of error for either device.

Subjective responses were nearly the same for every subject. All subjects initially felt that they would be unable to give accurate responses with the Laser Disparometer because they didn't feel they were aware of exactly when superimposition of the projected images occurred. All subjects also felt that the kinetic images in the laser method made identifying the point of superimposition easier. One subject felt that the moving images made the test easier than the Sheedy. This subject had the most variable responses with the Sheedy and the least variable responses with the Laser method.

This study was successful in developing a new method of measuring fixation disparity. However this study failed to establish norms that make the Laser Disparometer a clinically useful tool for measuring fixation disparity. Other studies are necessary with more subjects and greater variable control to strengthen and further identify statistical trends. Future studies with this device should include methods of quantifying error based on analysis of head movement. A more restrictive mechanism should be put into place hold the subjects head during testing. After error produced by misaligned head position and unintentional head movement are quantified a determination can be made as to how much head restriction is necessary for accurate and clinically relevant testing.

Another element that should be explored is if the method really needs to utilize dichoptics. The original intent was for the subject to only see one image in each eye thus enhancing the perception of superimposition and eliminating confusion. After conducting this study the necessity of dichoptics are questioned for several reasons. First, it was difficult to maintain adequate polarization and subjects actually reported increased confusion if the images were not cancelled completely. Second, one of the ultimate goals of this method was to closely simulate natural viewing conditions. The addition of dichoptics reduces the similarity to natural viewing condition. Third, it is hypothesized that the method will work without dichoptics. The major difference that the subject will experience is the perception of 2 targets for each eye due to physiological diplopia and the end point will be measured when the subject reports the perception of three images rather than 1 superimposed image. Finally, eliminating dichoptics will allow for accurate measurement of fixation disparity in oblique positions of gaze without concern for cancellation. This information is of interest to the behavioral and sports optometrist.

The device was found the have a weakness in the method used to rotate the lasers along the x-axis. The device was constructed to move the lasers by turning knobs on either side of the device. As the knobs were rotated, fine threaded bolts drove the turrets either in or out causing horizontal movement of the projected laser images. The fine threaded nature of the bolts caused rotation of the lasers to be slow, cumbersome, and less even than it should be. After this study it was felt that the threaded component could be eliminated and adjustment could be made by adding a system where the lasers were adjusted by sliding levers rather than turning knobs.

Once the aforementioned weaknesses of this study are remedied and statistical support is established, future studies will then be able to concentrate on the effect of changing the target. The LED target has value in this phase of the experiment but ultimately it is hoped that natural targets, such as reading material and other naturally occurring near point demands, will be incorporated into the testing scenario. It may be impossible to perfectly mimic natural viewing conditions in a clinical environment, but providing real world targets will come closer to simulating natural conditions than nonius lines or LED's.

References:

1. Goss DA, Patel J. *Comparison of fixation disparity curve variables measured with the Sheedy Disparometer and the Wesson Fixation Disparity Card.* Optom Vis Sci 1995 Aug;72(8):580-8.

2. Van Haeringen R, McClurg P, Cameron KD. *Comparison of Wesson and modified Sheedy fixation disparity tests. Do fixation disparity measures relate to normal binocular status?* Ophthalmic Physiol Opt 1986;6(4):397-400.

3. Eifuku S, Wurtz RH. *Response to motion in extrastriate area MSTl: disparity sensativity.* J Neurophysiol 1999 Nov;82(5):2462-75.

4. Wildsoet CF, Cameron KD. *The effect of illumination and foveal fusion lock on clinical fixation disparity measurements with the Sheedy Disparometer.* Ophthalmic Physiol Opt 1985;5(2):171-8.

5. Dittermore D, Crum J, Kirschen D. *Comparison of fixation disparity measurement obtained with the Wesson Fixation Disparity Card and the Sheedy Disparometer.* Optom Vis Sci 1993 May;70(5):414-20.

6. Pickwell LD, Gilchrist JM, Hesler J. *Comparison of associated heterophoria measurements using the Mallett test for near vision and the Sheedy Disparometer.* Ophthalmic Physiol Opt 1988;8(1):19-25.