AN INVESTIGATION OF THE "ESOPHORIC SHIFT" AND ITS RELATIONSHIP TO PARAMETERS OF THE FIXATION DISPARITY CURVE

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ABSTRACT

M. H. Birnbaum, O.D., investigated the presence of the esophoric shift and determined that it occurred in approximately 20% of the subjects he evaluated. He attributed the esophoric shift to the visually stressful conditions of nearpoint viewing. The purpose of this study was to attempt to replicate his findings and to correlate the reported esophoric shift with fixation disparity curve parameters. Based on our study of 50 subjects, the findings of Birnbaum were replicated and a moderate correlation between fixation disparity curve type and the esophoric shift was found. Using analysis of variance, the relationship between curve type and esophoric shift was investigated. Analysis of variance demonstrated that the eso shift occurred significantly more often among Type II, III and IV curves as opposed to Type I curves. Additionally, multiple regression analysis revealed that fixation disparity curve type, together with the x-intercept, were of value in predicting those subjects who manifested the esophoric shift.

KEY WORDS

esophoric shift, visual stress, fixation disparity, stress- induced visual dysfunction

More than a half century ago, A. M. Skeffington, O.D.,[1] proposed a model of vision based on the concept of nearpoint visual stress. It stated that the visual demand of nearpoint tasks, especially evident in reading, results in a stressful situation for the human visual system. There are cultural and psychological demands to reading and comprehending material. There are also physical demands caused by immobilization of the body while focusing and converging the eyes to the correct position for extended periods of time.[2] Skeffington felt that these demands significantly added to the stress experienced by individuals.

H. Selye,[3] who pioneered research in the field of stress, stated: "To understand the mechanism of stress (provides) a new approach to the treatment of illness, but it can also give us all a new way of life, a new philosophy to guide our actions in conformity with natural laws." He pointed out that stress is produced by a nonspecific agent which causes the hypothalamus to activate the adrenal glands leading to stimulation of the sympathetic nervous system ("fight-flight" response). It is known that this sympathetic arousal response has widespread physiological effects throughout the body.[3-8] Such effects include increased heart rate, blood pressure and blood flow to the muscles and heart. Respiration is made more efficient through bronchial dilation and sugar is made available, from the liver, for immediate energy production. Additionally pupillary dilation is effected as a result of the sympathetic stimulation. There is evidence which indicates that sympathetic stimulation may also result in a cycloplegic effect upon the visual accommodative system.[9,10] The actual demand of the nearpoint task requires parasympathetic stimulation to focus the eyes on the reading material. Under the constraints of sustained, stressful nearpoint activity, there appears to be a conflict, an effector system mismatch, between the sympathetic and parasympathetic systems. According to Birnbaum, the individual attempts to overcome the lag of accommodation through excess accommodative efforts.[10,11] Therefore, in order to maintain a focused target, the eyes overconverge (via accommodative convergence) to a location closer than the actual position of the nearpoint demand.[11] This phenomenon, of overconvergence, has been attributed to development of functional accommodative and vergence disorders as well as myopia.[10,11] In other words, the effects of environment (the nearpoint task in this case) have been implicated as causative factors in the development of some visual dysfunctions. Birnbaum's thinking regarding this series of events in the visual system closely follows Selye's more general statement that

stress-induced altered body functions can result in bodily structural changes.[3]

The aforementioned effector system mismatch (between the parasympathetic and sympathetic input into the visual system) has been viewed by Skeffington[1] and others[2,10,11] as the fundamental nearpoint visual problem. However, this notion has been difficult to substantiate or quantify. Therefore, a question to address is, "Do the eyes actually overconverge after extended nearpoint demand?" As early as 1945, Stenhouse-Steward[12] demonstrated an increase in esophoria following a five-minute nearpoint task. In 1960, Forrest[13] reported such an increase, also after a five-minute visually stressful task. Historically, it is accepted that the near phoria finding has been stable and should not change with repeated measurement. Nevertheless, Birnbaum[14] reported a phenomenon called the esophoric shift. He found that 18 of 100 subjects manifested a progressive shift in their near von Graefe[15] phoria of at least 5 prism diopters in the eso direction. Schor and Narayan[16] have reported individuals who, because of convergence accommodation and accommodative convergence interactions (with high AC/A), manifest significant increases in "esophoria" under fused (associated phoria) conditions. These reports appear to indicate that there may be an esophoric shift associated with nearpoint demands.

The effect of nearpoint viewing on the visual system was addressed in this study of the esophoric shift phenomenon. The results may lead to implications for preventive care and management of existing and incipient stress-induced visual dysfunctions.

The first purpose of this research study was to attempt to replicate the esophoric shift reported by Birnbaum.[14] The second purpose was to investigate the relationship between this shift and the parameters of the fixation disparity curve to find out whether any of these parameters are predicative of the esophoric shift. The parameters utilized were:

1. Curve type
   Type I has been found to be associated with asymptomatic patients while types II, III and IV with symptomatic patients.[17, 18]
2. Slope
3. Y-intercept
4. X-intercept

The null hypotheses were as follows: 1. There is no esophoric shift; 2. If there is an esophoric shift, there is no correlation between certain fixation disparity parameters (curve type, slope, y-intercept and x-intercept) and the esophoric shift.

METHODS

Fifty pre-presbyopic optometry students served as subjects. Prior to testing, the refractive conditions of the subjects were determined and corrected if 20/20 visual acuity was not attainable at near under habitual conditions. Also, binocular function was assessed so that no strabismic, amblyopic, or suppressing individuals were included as subjects. All subjects had lateral disparity stereopsis of 50 seconds or better.

The near phoria testing was performed by one examiner (unaware of the results of the fixation disparity curve findings) using the von Graefe method. The procedure was patterned after the one used in Birnbaum's study.[14] Six prism diopters base-down over the right eye and 15 prism diopters base-in over the left eye were used for dissociation in the phoropter. Testing began from the base-in side. Patients were instructed to keep the lower nearpoint 20/20 target clear. Following the subject's report that alignment had been obtained, base-in prism was increased and the phoria was repeated again. A minimum of three measurements were taken; if the phoria progressively increased in the eso direction, testing was continued until three consecutive measurements that were within 2 prism diopters of each other were obtained. To avoid measurement bias, the Risley prism was covered so that the examiner was not able to read the prism amount until after alignment had been reported.

The fixation disparity testing was performed by the other examiner (blind to the results of the near phoria finding) using a disparometer. Forced-vergence fixation disparity curves were generated, in accordance with the suggested procedure of Griffin.[19] The disparometer was attached to the nearpoint rod of a phoropter. Crossed polarizing filters were used in the phoropter. The angle of fixation disparity (F, the y-intercept on the curve), was obtained when the examiner dialed in the particular vertical polarized vernier lines that created the subject's perception of the top line being exactly above the bottom line. The curve was generated by measuring the fixation disparity, minutes of arc to align the polarized targets, as increments of prism were introduced (first 3pd Bl, then 3pd BO, 6pd Bl, 6pd BO, 9pd Bl, 9pd BO, etc.). The x-intercept (the vergence demand which results in angle F=O), y-intercept, slope, and type (the four basic types described by Ogle)[17] were tabulated following completion of the data collection.

It is important to note that, based on random selection, one half of the subjects performed the phoria testing first, while the other halves' fixation disparity curve assessment was generated first. This controlled any effect one test might have on the other.

RESULTS

Hypothesis 1 was studied using a descriptive analysis. Table I depicts those subjects who demonstrated an esophoric shift and those who did not. As for Hypothesis 2, individual regressions, analysis of variance, and multiple regression correlations were utilized to investigate the relationship between the esophoric shift and the four fixation disparity curve parameters (type, slope, y-intercept, x-intercept).

Of the 50 subjects, 12 showed a progressive shift of at least 5 prism diopters between the first and last near phoria measure (see Table I). The direction of shift was toward increased esophoria in subjects 1-11 (and toward exophoria in subject 12). This indicated that 22% (11/50) showed the esophoric shift. The resulting 95% confidence interval for the population proportion of subjects who showed the esophoric shift is between 11% and 33% (i.e., the margin of error is 0.11).

Each of the four fixation disparity curve parameters (x- intercept, y-intercept, slope, and type) were correlated with the esophoric shift by individual regression. Curve type proved to be the best predictor (r=.413, p=.003) although the correlation coefficient is considered to be moderate. The remainder of the parameters were not statistically significant as indicated in Table II. The only other parameter which provided a correlation approaching statistical significance was the y-intercept, r=.271, p=.06.

Table I.
Progressive Near Phoria Measures for the 50 Subjects

No.	Values						
1	6x	4x	2x	1x	0	0	
2	16e	18e	19e	21e	22e	22e	
3	16x	12x	10x	8x	10x		
4	9e	12e	13e	14e	15e		
5	4e	6e	8e	12e	12e		
6	4x	3x	1x	1e	3e	2e	
7	3x	1x	4e	2e	3e		
8	12e	14e	15e	18e	20e	20e	
9	18x	16	13	12x	12x		
10	6e	8e	9e	12e	12e	11e	
11	5e	14e	12e	13e			
12	5e	2e	0	1x	1x		
13	4e	3e	2e	3e			
14	0	2e	0	2x	0		
15	4x	4x	2x	4x			
16	3x	3x	3x	3x			
17	6x	6x	5x	6x			
18	8e	8e	6e	8e			
19	12e	8e	10e	10e			
20	4x	4x	6x	5x			
21	1e	3e	2e	3e	2e		
22	4x	2x	8e	8e	8x	10x	8x
23	6e	4e	4e	3e			
24	8e	10e	10e	8e			
25	8x	7x	8x	9x			
26	8x	6x	7x				
27	3x	4x	4x	5x			
28	6e	4e	5e	3e	5e		
29	12x	14x	14x	13x			
30	5x	5x	5x				
31	2e	1e	1e				
32	2e	1e	0	1e			
33	1x	1x	1x				
34	1e	3e	2e	3e			
35	3e	3e	3e				
36	11x	12x	12x	12x			
37	1e	0	0	0			
38	2e	2e	2e				
39	3e	3e	2e	3e			
40	3e	1e	0	1e			
41	4x	4x	4x				
42	8x	8x	8x				
43	3x	3x	4x	3x			
44	10x	7x	7x	8x	8x		
45	18x	19x	16x	18x	18x		
46	6x	6x	6x				
47	9x	10x	9x				
48	12e	10e	8e	9e			
49	7x	9x	8x				
50	7x	6x	5x	5x	5x		

Sequential near phoria values (e = esophoria, x = exophoria) obtained, for the 11 subjects demonstrating the esophoric shift (numbers 1-11), the one subject demonstrating an exophoric shift (number 12), and the remainder of subjects (numbers 13-50) who did not demonstrate any shift.

Table II.
Correlation between fixation disparity curve parameters and esophoric shift.

	r	p
eso-shift vs. x-intercept	.266	.111
y-intercept	.271	.060
slope	-.098	.500
type	.413	.003

Table III.
Mean esophoric shift and standard deviations by fixation disparity curve type.

	Mean eso-shift	Standard deviation	n
Type I	0.500	1.878	20
II	2.750	3.256	16
III	2.000	0.000	1
IV	2.846	3.078	13

Since the curve type demonstrated the highest correlation with the esophoric shift, a closer look at the specific types of curves was indicated. An analysis of variance was utilized to compare the mean esophoric shift for each type of curve (I - IV). This analysis revealed that the esophoric shift was more likely to occur in Types II, III, and IV than in Type I, as indicated in Table III. This trend was found to be statistically significant, $F=5.81$ (3,46) and $p=.0019$.

The most significant statistical relationship was obtained when all four fixation disparity curve parameters were used as predictors of the esophoric shift with a multiple regression. The multiple correlation coefficient was $r=.659$, $p=.0012$, suggesting that curve type and x-intercept have value as predictors of the esophoric shift. However, these results should be viewed with some caution since no x-intercept was obtainable due to the nature of the curves of 14 subjects (Type II curves). As a result, this multiple regression was based on only 36 subjects, rather than the entire sample size of 50 subjects.

DISCUSSION

Birnbaum's contention that esophoria increases during repeated nearpoint von Graefe phoria testing, in a significant number of patients, was substantiated. There has been much written about the possible effects of nearpoint visual stress on the accommodative-vergence system.[10-14] It has been suggested that the sympathetic nervous system is activated during nearpoint visual functioning, resulting in some inhibition of the accommodative system.[10] This could result in a tendency toward overconvergence of the eyes to sustain accommodation via the CAC ratio. This overconvergence has been labeled the esophoric shift.[14]

Birnbaum's study[14] and our findings indicate that a significant number of patients do demonstrate overconvergence during nearpoint tasks. This is consistent with Skeffington's[1] model of nearpoint stress in which convergence is driven to be located closer to the individual than accommodation.

An understanding of the esophoric shift can be increased by determining its relationship with other binocular assessment probes, such as fixation disparity. Our study did demonstrate that the type of fixation disparity curve was most closely correlated with the esophoric shift. Fixation disparity curves Types II, III and IV were more likely to manifest the esophoric shift. Type I curves did not show this tendency. These results are interesting in attempting to determine the basis for the phenomenon of the esophoric shift. It has been suggested that curve Types II, III and IV exhibit inadequate vergence adaptation and more visual symptoms than Type I.[18,20] Future studies with larger populations of abnormal curve types should further investigate this relationship. It would be significant to determine how the Type II, III and IV curves correlate with the esophoric shift when analyzed individually. Due to insufficient numbers of subjects, especially for Type III curves (only one subject), our results were not definitive in this area.

In multiple regression analysis, curve type and x-intercept showed the greatest value in predicting the esophoric shift. These results should not be construed to indicate that the x-intercept alone is a better predictor than the y-intercept. While multiple regression indicated that the curve type and x-intercept together were the best predictors of the esophoric shift, individually the magnitude of the y-intercept actually had a higher correlation with the esophoric shift than the x-intercept. Both correlations, however, were low (see Table II). Furthermore, it must be noted that the Type II curve (most prevalent next

to Type I) does not characteristically show an x-intercept. In fact, the x-intercept was not obtainable for most of the Type II subjects. Therefore, it is noted that these patients were not included in the multiple regression.

In addition to future investigation of curve types and esophoric shift, the theory of the esophoric shift being caused by increased sympathetic output from prolonged nearpoint viewing should be directly studied. In other words, an attempt should be made to physiologically substantiate the sympathetic output changes purportedly caused by nearpoint demands. Additionally, it would be important to determine what stress reactivity factors cause certain individuals to manifest the esophoric shift. Furthermore, if the proposed sympathetic stimulation theory for the esophoric shift is substantiated, we recommend that the notion of the esophoric shift being related to development of myopia and/or vergence and accommodative dysfunctions should be experimentally explored. This could lead to improved methods of recognizing visual stress and stress-related visual dysfunctions so that preventive care via therapeutic stress-reduction vision therapy techniques[21] could be implemented.

SUMMARY

This paper has corroborated Birnbaum's finding of the esophoric shift phenomenon in some individuals. We have taken his results a step further in correlating fixation disparity parameters with this esophoric shift. Further areas of investigation are needed to clarify the relationship of nearpoint visual processing and the esophoric shift. This may lead to implications for practitioners to better understand, prevent and treat patients' visual dysfunctions.

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ACKNOWLEDGMENTS

We would like to thank Dr. Paul De Land for his significant efforts in providing the statistical analysis for this project. Similarly the word processing work of Pat Humpres and Judy Badstuebner are greatly appreciated.

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Date accepted for publication:
May 24, 1990