
This paper from an ophthalmology group in Columbus, Ohio, reported a retrospective chart review of patients who had undergone home-based computer orthoptics for convergence insufficiency. Included were patients from 5 to 16 years of age who had been diagnosed with convergence insufficiency based on the following criteria: NPC break of at least 6 cm, failure of Sheard’s criterion or BO break less than 15Δ, exophoria at near at least 4Δ greater than at distance, and documented nearpoint complaints. Excluded from the study were patients with previous treatment for convergence insufficiency, strabismus surgery, amblyopia, vertical strabismus, or more than 1.50 D of anisometropia based on spherical equivalents. Some of the patients had intermittent exotropia. The patients all underwent training with Computer Orthoptics HTS home vergence therapy program (http://www.computerorthoptics.com).

Forty-two patients were included in the analysis. Thirty-five were treated with both computer orthoptics and push-up exercises with an accommodative target. Seven did computer training only. Five patients with very remote near points of convergence wore base-in Fresnel prism and did push-up exercises for two weeks before beginning computer training.

Near point of convergence averaged 24.2 cm (SD=15.3) before treatment and 5.6 cm (SD=1.1) after treatment. The mean positive fusional vergence findings were 11.3Δ (SD=4.7) before treatment and 26Δ (SD=5.1) after treatment. NPC improved to 6 cm or less in 39 of the 42 patients. For the three patients whose NPCs were greater than 6 cm after treatment, the mean NPC was 41.6 cm before treatment and 8.6 cm after treatment. Thirty-nine of the 42 patients met Sheard’s criterion after treatment.

Testing on the patients included monocular push-up amplitude of accommodation. Thirteen of the 42 patients were diagnosed with accommodative insufficiency as well as convergence insufficiency. These patients wore reading glasses or bifocals along with the convergence training, with +1.25 D and +1.50 D being the most common add powers. In these patients, the mean NPC was 26.2 cm before treatment and 6.1 cm after treatment.

All 42 patients reported improvement of symptoms after treatment. Twenty-seven of the patients reported complete resolution of symptoms. The 15 patients who did not have complete resolution of symptoms exhibited compliance problems. The authors suggested that their study “demonstrates that a home-based computer orthoptic program can reduce the magnitude of symptomatic convergence insufficiency.” (p.143)

Mitchell Scheiman, the optometrist who led the Convergence Insufficiency Treatment Trial (CITT) studies, had an editorial in the same issue of the journal. He stated that it was “gratifying to know that there is continued interest in investigating the treatment of convergence insufficiency.” (p. 123) but he identified several methodological problems with the Serna et al. study. He noted that there was no control
group and no masking of subjects and examiners to minimize bias. Scheiman also observed that because many of the patients also had treatments in addition to computer training it cannot be stated that computer training alone yielded the results reported. Scheiman suggested that the study was also limited by the fact that it did not have a standardized instrument for assessment of symptoms before and after training.

The authors countered Scheiman's editorial with a letter to the editor. They suggested that symptoms should be a secondary outcome measure and not the only indicator of success of treatment because symptoms are typically nonspecific. They expressed their feeling that computer training does offer some advantages and that their study supported the need of additional research. In a reply to that letter, Scheiman reiterated many of the points he made in his editorial and he noted that the study at most could “be used to form a hypothesis that the treatment studied may have an effect.” (p. 513, his italics)


This paper from the University of California Berkeley reports on three experiments designed to explore the nature of the effect of differences between the distance of the accommodative stimulus and the convergence stimulus on the visual discomfort associated with stereo displays. They used the term vergence-accommodation conflicts to refer to situations where the plane of the accommodative stimulus and the plane of the convergence stimulus were not coincident. To make the relationship of these two planes more clear, they expressed vergence stimulus in meter angles (reciprocal meters) rather than prism diopters. Thus when the diopters of accommodative stimulus and the meter angles of convergence stimulus differed, there was a vergence-accommodation conflict.

Experiment 1: The first experiment was designed to examine the effect of viewing distance on the visual discomfort with a vergence-accommodation conflict. The 24 subjects in this experiment varied in age from 19 to 33 years and had normal steroacuity on the Titmus Stereo test.

With the experimental arrangement, the authors attempted to mimic the vergence-accommodation conflicts associated with viewing stereo displays. The experiment used two display screens, one viewed by each eye. They were viewed in a haploscope with mirrors and liquid crystal polarization modulators in front of the eyes. The fixation objects were random dot stereograms with sinusoidal variation in depth. The subjects viewed these objects while accommodative stimulus (AS) and the convergence stimulus (CS) changed between pairs of set levels. There were six sets of stimulus pairs: (1) AS=0.1 D & CS= 0.1 MA with AS=0.1 D & CS=1.3 MA (far distance, with vergence-accommodation conflict); (2) AS=0.1 D & CS=0.1 MA with AS=1.3 D & CS=1.3 MA (far distance, with no vergence-accommodation conflict); (3) AS=1.3 D & CS=1.3 MA with AS=1.3 & CS=2.5 MA (medium distance, with conflict); (4) AS=1.3 D & CS=1.3 MA with AS=2.5 D & CS=2.5 MA (medium distance, no conflict); (5) AS=2.5 D & CS=2.5 MA with AS=2.5 D & CS=3.7 MA (near distance, with conflict); and (6) AS=2.5 D & CS=2.5 MA with AS=3.7 D & CS=3.7 MA (near distance, no conflict). It may be noted the amount of conflict was the same at all three distances, 1.2 reciprocal meters.

After each of the six conditions, subjects completed a symptom questionnaire with five questions answered on a Likert scale with 1 indicating no symptoms and 5 indicating severe symptoms. The five questions asked how (1) tired are your eyes?, (2) clear is your vision?, (3) tired and sore are your neck and back?, (4) do your eyes feel?, (5) does your head feel? A second questionnaire asked the subjects to compare the conflict vs. no conflict conditions at each distance and indicate which (1) was most fatiguing?, (2) irritated your eyes the most?, (3) gave you more headache?, (4) did you prefer?

The symptom scores on the first questionnaire of five questions were greater in the vergence-accommodation conflict conditions than in the no conflict conditions for eye tiredness, vision clarity, and eyestrain, but there was no significant difference for neck and back discomfort or headache. Eye tiredness was significantly worse in the conflict situation at distance and nearly significantly worse with conflict at mid distance, but not significantly different at near. Blur was significantly worse in the vergence-accommodation conflict situation at all three distances.

The second questionnaire of four questions asked the subjects to compare vergence-accommodation conflict vs. no conflict for each of the three distances. General fatigue was significantly greater in the
conflict situation for far viewing but not at the other two distances. Eye irritation was significantly greater in the conflict condition than in the no conflict condition for all three distances. There were no significant differences in headache at any of the three distances. There was less preference for the vergence-accommodation conflict condition than for the no conflict condition at far and at near, with no significant difference at mid distance.

The authors concluded from the first experiment that “vergence-accommodation conflict caused somewhat more discomfort at far than at near distance.” (p. 12)

Experiment 2: The second experiment was designed to examine the effect of the direction of the vergence-accommodation conflict on level of discomfort at different viewing distances. Fourteen subjects, ranging in age from 20 to 34 years, served as subjects in this experiment. The haploscopic arrangement and the fixation object were the same as in the first experiment.

As in the first experiment, there were six sets of stimulus pairs. In this experiment, there was a change to a vergence-accommodation conflict situation in all six conditions. In conditions 1, 3, and 5, the plane of the convergence stimulus (CS) moved to a point farther from the subject than the plane of the accommodative stimulus (AS); the authors referred to that as negative conflict. In conditions 2, 4, and 6, the plane of CS moved to a point closer to the subject than the plane of the AS; the authors referred to that as positive conflict.

The six conditions were as follows: (1) AS=0.1 D & CS= 0.1 MA with AS=0.1 D & CS= -0.7 MA (far distance, negative vergence-accommodation conflict); (2) AS=0.1 D & CS=0.1 MA with AS=0.1 D & CS=0.9 MA (far distance, positive vergence-accommodation conflict); (3) AS=1.3 D & CS=1.3 MA with AS=1.3 D & CS=0.5 MA (medium distance, negative conflict); (4) AS=1.3 D & CS=1.3 MA with AS=1.3 D & CS=2.1 MA (medium distance, positive conflict); (5) AS=2.5 D & CS=2.5 MA with AS=2.5 D & CS=1.7 MA (near distance, negative conflict); and (6) AS=2.5 D & CS=2.5 MA with AS=2.5 D & CS=3.3 MA (near distance, positive conflict). The amount of conflict in this experiment was thus 0.8 reciprocal meters in each condition. This experiment used the same five question symptom questionnaire and the same four question comparison questionnaire as in the first experiment.

For the far distance, eye tiredness and eyestrain symptoms were significantly greater for negative conflict than for positive conflict. There appeared to be a trend toward more blur for negative conflict than for positive conflict for far distance, but the difference was not statistically significant.

At near, the trend was toward greater symptoms for positive conflict than for negative conflict, but the only symptom that showed a statistically significant difference was eyestrain. For mid distance, there was no overall trend, but the headache symptom score was significantly greater with positive than with negative conflict.

In the four question comparison questionnaire, negative conflict clearly caused more symptoms than positive conflict at the far distance. At far, the negative conflict caused significantly more general fatigue, more eye irritation, more headache, and was less preferred than positive conflict. At mid distance, negative conflict caused significantly more fatigue and eye irritation than positive conflict. At near distance, the comparison questionnaire did not show statistically significant differences between negative conflict and positive conflict for any of the four questions.

In this experiment, the authors also asked the subjects every two minutes to indicate how tired their eyes were on a one to five scale. In all six conditions, the average level of discomfort increased in a roughly linear fashion over 18 minutes. The authors noted that they reported the mean data because the individual data were difficult to interpret. They also noted that the mean data may not accurately represent the time course of increase of discomfort in all individuals.

From this experiment, the authors concluded that convergence stimuli behind the plane of accommodation are less comfortable than convergence stimuli in front of the plane of accommodation for far viewing, while convergence stimuli in front of the plane of accommodation tend to be less comfortable for near viewing.

Experiment 3: In this experiment, the authors investigated whether an individual’s dissociated phoria and zone of clear single binocular vision (ZCSBV) were predictive of levels of reported symptoms. Twenty-four persons, ages 19 to 34 years, were subjects in this experiment. Twenty of these 24 subjects had participated in Experiment 1, and 14 of the 24 had participated in Experiment 2.

To measure phorias, the investigators used the Risley prisms in a phoropter for the von Graefe prism.
dissociation test with flash presentation of a vertical line. Three phoria measurements were taken at each of four distances: 3 m, 77 cm, 40 cm, and 25 cm. Average phorias for the 24 subjects were slightly eso at 3 m and slightly exo at 40 cm.

Fusional vergence ranges were measured in a phoropter at the same four distances where the phorias were taken. The test target was a column of six small high contrast letters. Base-in measurements were done before base-out and each measurement was taken three times.

The investigators then calculated discomfort prediction scores for different distances based on Sheard's criterion, Percival's criterion, and the amount of the phoria. These prediction scores were then correlated with the discomfort questionnaire scores from Experiments 1 and 2. A total of 120 correlation coefficients were calculated: 5 questionnaire questions x 4 distance conditions (far, mid, near, and overall) x 2 experiments x 3 discomfort prediction methods.

Out of the 120 correlations, 42 were statistically significant (p<0.05) and 10 were marginally significant (0.05<p<0.10). Using a significance level of p<0.05, one would expect that 6 out of 120 would be significant by chance. Thus many more correlations were significant than would be expected from chance.

The eye tiredness and eyestrain questions had the greatest number of significant correlations of the five questions on the symptom questionnaire. For eye tiredness, 14 of 24 correlations were significant. For eyestrain, 11 of 24 correlations were significant.

It appeared that the abilities of Sheard's criterion, Percival's criterion, and the amount of the phoria to predict symptoms were about the same. For Sheard's criterion, 19 of 40 correlations were significant or marginally significant, compared to 18 of 40 for Percival's criterion, and 15 of 40 for the amount of the phoria. The authors concluded from Experiment 3 that phoria and the ZCSBV are related to visual discomfort associated with viewing 3D stereo displays.

In the Discussion section of the paper, the authors expounded on various implications of their results and on various aspects of the nature of stereo displays. One situation that they addressed was that in which display size and on-screen disparities are fixed, but viewer distance from the screen is varied. In this situation, their analysis suggested that “increasing viewing distance yields a progressively larger range of comfortable on-screen disparities.” (p. 23) Thus individuals who experience visual discomfort watching 3D movies could try sitting farther away from the screen (or, of course, they could seek optometric care).

The authors also talked about percentage rules that stereo cinematographers use to try to assure comfortable viewing. For content that requires vergence to posture closer than the screen, they try to have disparities no more than 2-3% of the screen width. For vergence behind the screen, cinematographers try to limit the on-screen disparity to no more than 1-2% of screen width. The authors concluded that “the percentage rule, coupled with reasonable assumptions about viewing distance, is a fairly reasonable guideline for creating comfortable viewing, but it may require some modification.” (p. 24)

The authors also devoted a portion of their discussion to the concept of zone of comfort. That concept was originated by Percival who suggested that the middle third of the lateral extent of the zone of clear single binocular vision represents a zone of comfort. The authors noted that zone of comfort descriptions such as Percival's are dichotomous in that there is a sharp delineation between comfortable and uncomfortable, while it seems more likely that zones of comfort should be more graded or continuous.

References