INTRODUCTION:
The 1980's were exciting and challenging times for Optometric Vision Therapy (OVT). Exciting, because of many corroborating advances in neuroscience and the advent of personal computers. Challenging, because of the need to standardize and develop controlled research and evidence based therapy procedures in response to The American Academy of Ophthalmology.

This study demonstrates, through controlled scientific research, that standard vision training regimens as well as computer assisted orthoptics significantly increase vergence ranges at nearpoint. The power and possibilities of computer assisted vision therapy is today self evident, but at that time, it was new and innovative. This poster and its accompanying historical technical timeline help to clarify and understand the profession's efforts in research and innovation to move OVT to what it is today.

Methods

Part I: Objective

The goal of this research was to conduct a comparative study, using standard research methods, which would investigate the effectiveness of computer-assisted vergence training versus standard vergence training. Thirty-nine subjects were assigned to three equal groups. One group received standard vergence training; another received vergence training using the microcomputer techniques; and the third, control, group received no vergence training. The control was necessary because, other than individual case reports, there appears to be an insufficiency of reported, documented, controlled studies to support the efficacy of standard vergence training. Therefore, the microcomputer technique was compared to both a standard sequence for base-in and base-out training, and to a control group which received pre- and post-testing only.

Procedure:
Forty-eight volunteers from 20 to 30 years of age were assessed for these characteristics:

1. 20/30 or better best corrected distance acuity.
2. Spectacle correction within +/-1.00 diopter sphere and cylinder of patient's ametropia.
3. No strabismus.
4. Stereopsis (60" arc).
5. No previous visual training.
6. No ocular pathology.

Next, two independent clinicians measured and recorded volunteers' nearpoint base-in and base-out blur, break, and recovery values three consecutive times.

They used standard phorometry techniques with Risley prisms in a standard phoropter with the volunteer fixating on 20/20 letters at 40 cm. Clinicians also took phoria
measurements using the modified Thorington technique. All volunteers received the same instructional set. For the volunteers selected to be subjects, this constituted the pretest.

Using the pretest results, volunteers were grouped according to the magnitude of the phoria. Then, volunteers with similar phorias were randomly distributed among the three test groups. This yielded three groups of 13 subjects, matched according to phoria size, but randomly assigned. Volunteers who didn't fall into any of these groups were eliminated from the study.

Group vergence data were then statistically compared. No significant difference was found among the groups.

All subjects in the standard and computer groups received an orientation session in which they learned the study procedures, instrument techniques, suppression checks, etc. Subjects trained 10 minutes per day, 5 days per week for 13 training days. Each week a new stimulus (instrument or target) was introduced in a 5-minute instruction period. All training was conducted in a specific training room. Subjects were instructed to divide their training time equally between base-in and base-out tasks. Subjects signed in on a training log with each visit to assure compliance.

The standard group followed standard procedures for near duction training. Subjects used the Wheatstone Mirror Stereoscope, Polachrome Orthopter, and the Aperture Rule Trainer (single and double aperture) in sequence. Each instrument was used for approximately 1/3 of the training time.

The computer group used the following equipment: a Commodore 64 computer, disk drive, color VDT and joystick, and 10 diopter base-up OD, base-down OS prism spectacles.

Original software was developed using the Copeland Fusion Technique. This technique was chosen because standard color VDTs do not have sufficient color purity to obtain adequate cancellation of the unwanted image in an anaglyphic situation.

The subject viewed two targets on the VDT, one above the other, through vertical dissociating prisms. The prisms cause the two targets to become four ocular images when the working distance is too large or too small. However, with the proper working distance, the vertical dissociation produces three ocular images. When the images are aligned vertically, no prismatic demand is produced. As the targets separate, a base-in or base-out demand is created dependent upon the target direction.

Once fusion is achieved, target speed and lateral movement can be controlled through two modes: automatically by the computer or manually by the subject using the joystick. In the automatic mode, the targets move at a constant speed between 1/3 and 1/2 prism diopter per second. They alternate base-in and base-out for each trial. In the manual mode, the patient controls speed and vergence direction of the targets (targets always
move in opposite directions). In this mode, the subject can slow or reverse the stimuli to help maintain fusion as limits of fusional ranges are approached. At a working distance of 40 cm, the Commodore monitor has a range of 40 prism diopters of base-in and 40 prism diopters base-out demand in 1/3 diopter increments.

Training time was divided among three different targets of increasing difficulty. The first target is a large cross with peripheral suppression checks designed to train gross fusion. The second target is a square with the word SEE inside, containing a stimulus for accommodation and central suppression checks. The third target is the arcade-style "Eye-Man," which incorporates the accommodation stimulus, central and peripheral suppression checks and fixation disparity checks.

This program uses a bi-modal feedback system. With each increment of target separation on the VDT, the VDT displays a score and sounds a beep. When the subject reaches his fusion limit, he presses the fire button on the joystick. The targets stop and the trial score is presented with the previous high score and average.

**Computer Training Sequence**

To train on the microcomputer, the subject proceeds as follows. After selecting one of the three targets, the subject loads the program into the computer from a floppy disk. The "doctor set-up" appears on the VDT and the subject types in his name. At this point, the subject may choose to review his or her previous scores. The computer then gives a personalized message of instruction. From this, the subject selects either the automatic or manual mode and the targets appear. Now, the subject puts on the prism spectacles, locates the correct working distance, achieves fusion and begins the training. The score, direction, and time appear continually on the screen. When fusion can no longer be maintained or if suppression is noted, the subject presses the joystick fire button to stop the trial. The current score, average, and high scores appear. Subjects trained 10 minutes per day: 8 minutes with joystick control and 2 minutes in the automatic mode.

The control group did no training, receiving only the pre-and post-tests.

Twenty to twenty-one days after the pretest, one day after concluding the training, all subjects received the post-test. The procedures followed exactly those of the pretest. Each clinician post-tested the same subjects that he pretested to decrease the possibility of measurement error. The clinicians did not know to which group each subject pertained, making this a single-blind procedure.

**Analysis**

Analysis of the results was done with the aid of biomedical statistical software (DMDP) developed by UCLA.

Individual pre- and post-test trial scores were compared statistically to determine if measurement error or learning between trials took place. Because no significant difference existed among the trials, the means of all the pre- and post-test measurements
were taken individually and collectively to compare group pre- and post-test results. Then, the pretest means were subtracted from the post-test means to show the magnitude and direction of change for blur, break, and recovery. This information appears in Tables I, II, III, and IV.

To determine if any significant difference in the amount of change existed among the three groups, a one-way analysis of variance (ANOVA) was run to test the equality of the three (standard, computer, control) means. In cases where a significant result was obtained, Levene's test for the equality of the three variances was conducted. In cases where this was significant, multiple two-sample separate variance t-tests were used on each pair of means. If the Levene test was not significant, multiple two-sample pooled variance t-tests were conducted on each pair. In each case the significance was adjusted lower to account for the multiple comparisons. In order for all pairs to be tested simultaneously at .05, each individual pair was tested at .016667. Table V summarizes the results and p values. An asterisk indicates a significant result. It is remarkable that the computer group showed significantly improved base-in ranges.

**Discussion**

From the data and statistical analysis, we can say that the standard training group showed increases in blur and break ranges over the control groups, but insignificant increases for recovery ranges. Recovery requires return to single binocular vision after diplopia.

Recovery is only partially enhanced by sliding vergence techniques. We did not train jump vergences, which more fully train recoveries. It should be noted that recovery did improve slightly for the standard group, but not significantly.

Although a significant increase in total vergence ranges was noted for the standard group, there was no significant improvement in the base-in direction. This is not to imply that base-in vergences cannot be trained by standard means. However, with the method and duration of our study, no improvement was shown.

Vergences in the base-out direction, for the standard and the microcomputer group, showed a very large and significant improvement in blur and break. Recovery values did improve, but not significantly.

In the comparison of the microcomputer technique group to the control group, we found the blur and break ranges increased significantly, but recovery ranges did not. Again, we propose that recovery could be better trained using jump vergences, but this was not attempted.

There was a significant increase in total vergence ranges for the microcomputer group, and a large and significant improvement in blur and break in the base-in direction (at the .001 level of significance). Remarkably, every subject in this group showed an increase in their base-in ranges. Recovery also improved, but not significantly.
Comparison of the training effects of the microcomputer and standard groups showed similar results in blur, break, and recovery. In all cases, the computer group results exceeded those of the standard group but not significantly.

In the base-in direction, the microcomputer test subjects significantly exceeded the standard subjects. This improvement occurred despite flicker and decreased accommodative accuracy of the VDT. Increased patient motivation and ease of mastering the divergent procedures in the microcomputer technique may have been positive factors. For whatever reasons, this study has shown that the microcomputer technique holds a distinct advantage in training base-in vergences at near.

In the base-out direction, the standard group results were slightly greater than those of the computer group, but there was no significant difference between the two groups. These results may be explained by recognizing that the majority of the microcomputer subjects had reached the maximum base-out limit of the computer VDT, and the training duration of the study was curtailed after 13 sessions. To rectify this and increase the base-out limit on the VDT, more powerful base-up and –down prism glasses may be used in the future. This would decrease the working distance and increase possible ranges.

The goal of nearpoint vergence training is to alleviate the symptoms of nearpoint vergence dysfunction by increasing the overall range and flexibility in both base-in and base-out directions, particularly in the direction opposing the phoria.

Symptoms of near vergences dysfunction include asthenopia, blurred vision, intermittent diplopia (causing words and columns of numbers to run together), a manifest head tilt or near work postural changes, and/or the closing or covering of one eye.

Nearpoint vergence difficulties are held to be indicated when the following ranges are associated with the above symptoms:

1. Base-out to blur less than 14 prism diopters; to break less than 18 prism diopters; to recovery less than 7 prism diopters.
2. Base-in to blur less than 14 prism diopters; to break less than 19 prism diopters; to recovery less than 10 prism diopters.

Comparing these figures to Table VII (Summary of Average Change), we see that the magnitude of change we achieved in this study is clinically significant in the reduction of symptoms of nearpoint vergence difficulties. This training would be particularly beneficial for those experiencing nearpoint symptoms while using a VDT.

The microcomputer program used in this study proved to be effective in nearpoint vergence training, but can be improved in several ways for future application. The targets can include more suppression checks, scoring can be made more rewarding, and the whole program can be made more “user-friendly.” We predict that the microcomputer technique for training nearpoint vergence ranges will soon be a valuable supplemental tool in visual training practices.
The software we developed was a prototype of things to come. Use of the computer in training oculomotor difficulties such as saccades and pursuit abilities, perceptual training, peripheral awareness, and tachistoscopic presentation will greatly enhance visual training practices of the future.

This study lays the foundation for further systematic study and research in microcomputer-assisted vision therapy.