$\boxed{symposium\ paper}$

Review of Computerized Orthoptics with Specific Regard to Convergence Insufficiency

JEFFREY COOPER*
State College of Optometry, State University of New York, New York, New York

ABSTRACT

Traditional vision training or orthoptics has used line or contour targets to eliminate suppression and improve vergence performance. Manipulation of these stimuli is slow and arduous. Line stimuli require an experienced doctor/technician to interpret responses. Recently, automated vision training using microprocessor anaglyph stimuli, i.e., random dot stereograms (RDS), has been used in an operant conditioning paradigm. This technique has improved motivation of the patient, improved reliability, and provided standardization of therapy. In addition, the utilization of RDS associated with operant conditioning has been shown to improve vergence performance and to reduce asthenopia in the convergence insufficiency patient.

Key Words: vision training, orthoptics, vergence, fusion, random dot stereograms, operant conditioning, asthenopia, convergence insufficiency, binocular vision

Orthoptic and vision training have utilized vectograms, stereoscopes, synoptoscopes, and other types of devices to present visual stimuli binocularly. Traditional methods of changing stimulus parameters (e.g., vergence demand)

have been slow and unreliable. Thus, reproducibility in testing and training may be questionable because doctors and technicians may alter targets at different speeds and instruct or motivate patients differently. Moreover, traditional vision training techniques require an experienced doctor/technician to interpret patients' responses and to use that information to alter stimulus conditions in order to improve binocular response. These problems are observed in the young or noncommunicative patient.

The difficulties noted above have led some practitioners to abandon orthoptics/vision training. They may also be responsible for variability in reported success rates of orthoptics. In a similar area, visual field testing, microprocessor-controlled response-stimuli presentation has improved reliability, improved detection rate, and in general brought scientific validity into the area of in-office perimetry. Recently, research-oriented automated microprocessor-controlled methods have been reported in the field of orthoptics/vision training.

Cooper and Feldman[1] demonstrated that RDS presented in an operant conditioning paradigm could be used to improve stereoscopic responses in young children. In their study, young children were tested with a Titmus stereo test, a Random dot E test, and with a RDS test in an operant conditioning paradigm. The RDS test used by Cooper and Feldman required the patient to wear Polaroid glasses while looking at a screen, and to push a button which contained a visual two-dimensional pattern that matched the one projected on the screen. The RDS was projected with a stereoscopic square one-half of the time or with a RDS that lacked disparity (flat fusion stimulus) the other one-half of the time. Correct responses were reinforced, whereas incorrect responses were not. If the child could not perceive the stereo RDS, monocular (brightness con-

trast) cues were superimposed; they were gradually eliminated after correct responding. Eventually all monocular cues were removed, requiring the patient to respond only to stereoscopic cues. It was found that the percentage of correct responses to stereo targets was improved dramatically with reinforcement. Most children aged 3 years or older were able to respond successfully to a RDS presented in this manner. Nonreinforced responses to stereograms were poorer and more variable. Cooper and Feldman[2] concluded that RDS presented in an operant conditioning paradigm were particularly effective in evaluating binocular responses and detecting a constant strabismus because RDS do not contain any monocular cues and require bifoveal alignment for perception (Table 1).

In a later study, Feldman and Cooper modified their automated operant RDS technique by utilizing errorless discrimination along with cue fading techniques.[3] This time both the RDS containing disparity (S+) and a RDS lacking disparity (S−) were presented simultaneously (Figs. 1 and 2). The left to right location of the S+ was altered randomly. Patient responses were made by breaking an infrared photocell beam when the child tried to touch the stimulus. Both the contrast of the monocular cue in the stereoscopic RDS and the contrast of the incorrect stimulus (no stereo, S−) were reduced; that is, the monocular cue faded out while the contrast of the S− was faded in. The technique enabled valid and reliable responses in children as young as 2½ years of age. Traditional testing techniques that required an experienced doctor or technician resulted in no responses or unreliable responses in many children under 4 or 5 years of age.

TABLE 1. Number of patients passing or failing the operant RDS discrimination test according to visual diagnostic classification.

Visual Diagnosis	RDS Test Performance	
	Pass	Fail
Normal[a]	14	0
Constant strabismus	0	13
Amblyopic-strabismus	0	11
Microtropia	0	6
Anisometropic amblyopia	5	5
Congenital pathology	1	5
Noncongenital pathology	5	3
Intermittent exotropia	10	3
Intermittent esotropia	4	3

[a] Normal refers to patients whose visual diagnosis did not include a strabismus (constant or intermittent), amblyopia, or ocular pathology.

Similar computerized techniques have also been used by others. Fox et al.[4] used computer-generated dynamic RDS with a preferential viewing procedure in order to investigate binocular responses in infants. Their subjects viewed the dynamic RDS while wearing red-green anglyph glasses. A stereoscopic vertical bar was moved from the center position to the left or right. A trained observer viewed the position of the infant's eyes. Appropriate fixation, i.e., movement of the eyes corresponding to the position of the vertical bar, signified stereoscopic appreciation. Stereopsis was demonstrated in infants as young as 6-months-old.

The experiments by Cooper and Feldman[1-3] and Fox et al.[4] demonstrated that appropriate stimulus presentation associated with effective reinforcement could be used to investigate binocular vision in patients who lacked sophisticated communication skills. Both research groups used computerization to present and manipulate stimuli, and to present reinforcement when necessary. Computerization was required to make rapid, almost instantaneous changes in stimulus parameters and to provide immediate feedback of reinforcement. Manual techniques would have been too slow and arduous.

In another experiment, Cooper and Feldman[5] used their operant conditioning techniques with automated presentation of RDS to determine if vergence training resulted in an increase in vergence ranges. They used an A-B reversal design to control for placebo effects. The experimental group (A) received vergence training; the control group did not (B). During vergence training, correct responses resulted in positive reinforcement and a concurrent increase in vergence demand, whereas incorrect responses resulted in a reduction of vergence demands. The control group received the identical stimuli and reinforcement; however, neither correct nor incorrect responses resulted in any alteration of vergence demand. Their results demonstrated that automated convergence training yields a rapid increase in maximum convergence range, whereas placebo training does not. Furthermore, patients who improved their vergence ranges using this system transferred their ability to other vergence tasks involving vectograms and prisms. Cooper and Feldman also demonstrated that patients who did not respond to traditional orthoptic therapy were treated successfully with automated vergence training (Fig. 3).

Recent research by Daum et al.[6] supported Cooper and Feldman's previous work that computerized convergence training improves positive fusional vergences. Daum et al. demonstrated transfer of improved vergence abilities on prism bar and amblyoscope testing devices.

In a later clinical study Cooper et al.[7] designed

FIG. 1. Young patient makes a reaching response which breaks an infrared beam. Correct response results in presentation of a cartoon reinforcement. (Reprinted from J Am Optom Assoc 1980;51:768.)
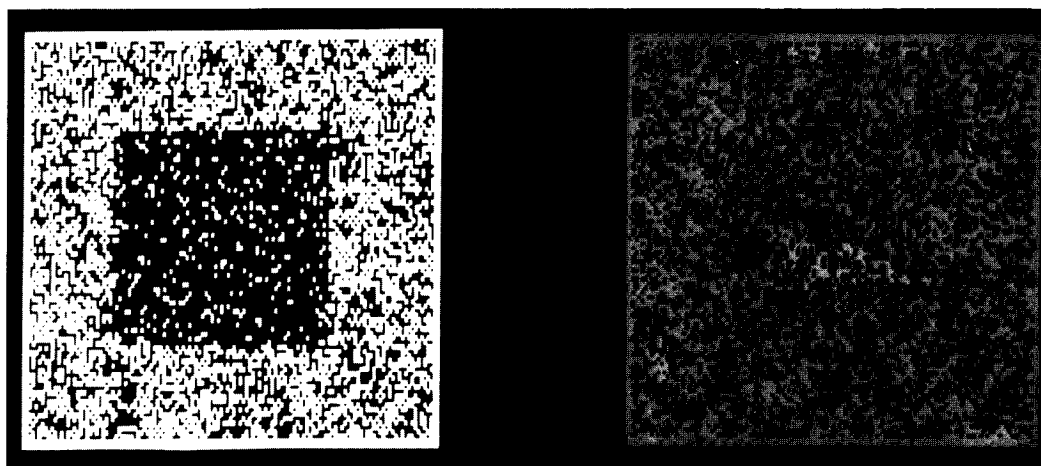
FIG. 2. RDS presentation with fading in of both the S+ (monocular cue) and the S− (flat fusion dot pattern). Patient responds to S+ by a reaching response portrayed in Fig. 1. (Reprinted from J Am Optom Assoc 1980;51:769.)

an experiment to determine if orthoptics/vision training was successful in treating convergence insufficiencies and reducing asthenopia. They again used an A-B-A crossover design to control for experimental bias, placebo effects, and order effects. It was found that convergence training resulted in an improvement in convergence ranges, which only minimally transferred to other testing conditions, e.g., positive relative convergence as measured with prisms or vecto-grams. On the other hand, transfer of vergence abilities from one task to another had been

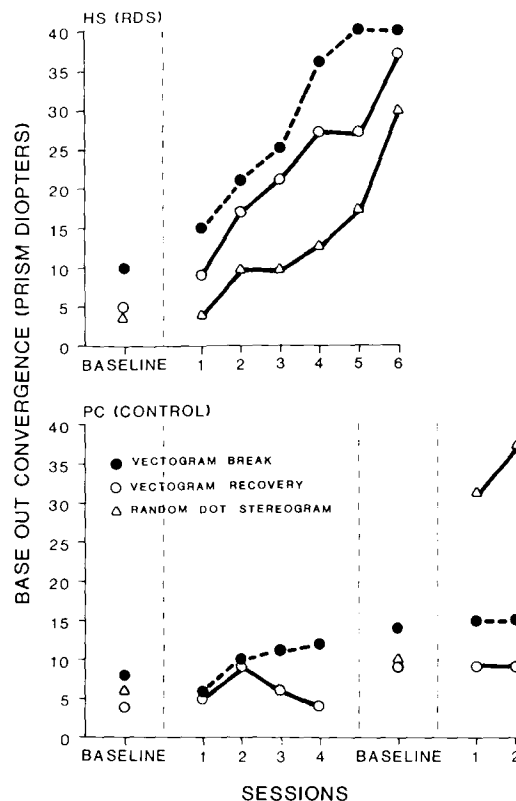FIG. 3. Representative convergence performance for each session of patient given automated convergence training using RDS (top panel) and a matched control patient exposed to identical target without increasing convergence demand (bottom panel). It is readily apparent that vergence training increases fusional ranges for both RDS and vectograms, whereas control therapy does not result in an increase in fusional ranges. Vectogram and RDS performance are presented in prism diopters. After control therapy the patient received convergence therapy. (Reprinted from Am J Optom Physiol Opt 1980;57:211.)

found previously in normal patients.[5] Therefore, Cooper et al.[7] concluded that the convergence insufficiency patient must be treated with a variety of vergence stimuli to obtain transfer. They also found a decrease in asthenopia on a scaled questionnaire as well as a flattening of the patient's fixation disparity curve after vergence training. During placebo therapy no such improvement occurred. They concluded that orthoptics was effective in remedying convergence insufficiency with its accompanying symptoms (Figs. 4 and 5).
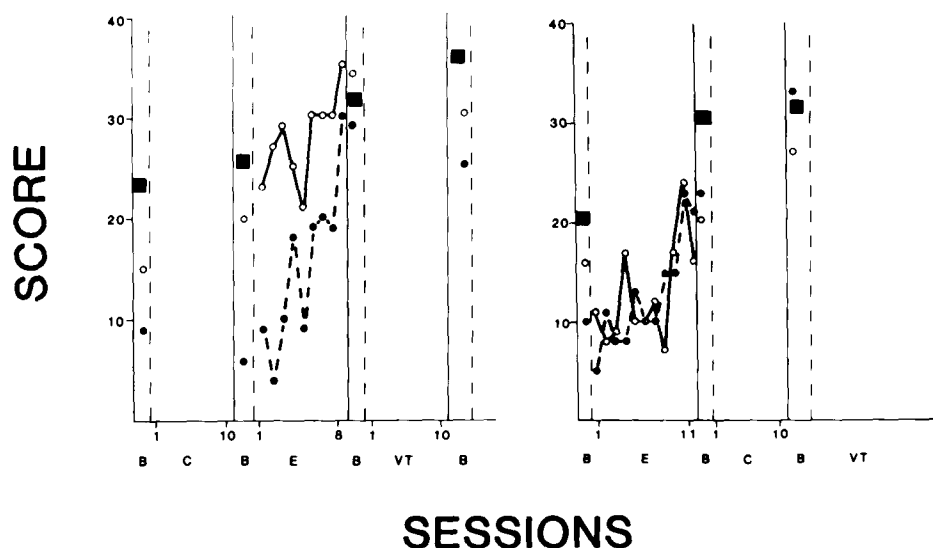
Cooper et al.[8] have recently used a similar automated A-B crossover design to determine if monocular accommodative therapy results in improved accommodative abilities. Their patients demonstrated a statistically significant

improvement in accommodative facility, an increase in accommodative amplitude, and a reduction in asthenopic symptoms. Within a short period of time a 55% improvement in amplitude and a reduction in symptoms occurred. Again, the experimental design controlled for effects that were coincidental or due to experimental bias or placebo (Fig. 6). Improvement in accommodative facility is important in the convergence insufficiency population because the majority of patients with convergence insufficiency have a secondary accommodative anomaly.[7]

Kertesz[9] showed that automated training with microprocessor produced anaglyphic, large target, vergence stimuli that resulted in an improvement in vergence ranges and a reduction in asthenopia in patients who had a convergence insufficiency. All their convergence patients had previously failed to benefit from traditional orthoptics. Of the 29 convergence insufficiency patients treated, 23 increased their fusional ranges with a concurrent alleviation of symptoms. Treatment included slowly separating 57° dichoptic targets and RDS which were presented in both convergent and divergent directions. Therapy required 5 to 15 sessions. Kertesz and Kertesz concluded that computer-generated, large stimuli are more effective in remedying convergence insufficiency than traditional orthoptic techniques. However, Kertesz and Kertesz did not control for stimulus parameters (large vs. small, stereo vs. flat), motivation, skill of the therapist, and/or speed of vergence. Thus, their success may have been due to extraneous factors. Somers et al.[10] used microprocessor-generated stimuli to treat patients with binocular anomalies. They reported that patients treated with computer-produced vergence stimuli showed more rapid and complete improvement than traditional techniques. Griffin[11] reported that microprocessor-produced anaglyphs resulted in an improvement in convergence ranges similar to traditional methods and a greater improvement in divergence ranges than traditional methods.

The above studies have shown the clinical effectiveness of automated microprocessor-generated anaglyphs in increasing fusional ranges. Methods which incorporated operant conditioning seemed to be the most effective. However, many of these research studies utilized sophisticated computer equipment and techniques not yet available to the clinician. Cooper and Citron[12] demonstrated that a personal computer (PC) could produce sophisticated anaglyphs, which could be moved to create a variety of vergence stimuli.

With the advent of small, powerful PC's that can produce sophisticated anaglyphic targets, commercially available computerized vision

SESSIONS

FIG. 4. Prism diopters of fusional vergence and total asthenopia scores (ordinate) of patient are plotted against the number of sessions (abscissa). The weekly sessions are divided into baseline (B), control (C), experimental (E), and orthoptics (VT) phases. Patient in the left panel had control RDS training followed by the experimental phase, whereas the patient in the right hand panel had the experimental phase followed by the control portion. Baseline findings were measured on all patients before testing and after control, experimental, and orthoptics (vision training) phases. Asthenopia scores (■), RDS fusional convergence break points in prism diopters (○), and vectrographic fusional convergence break point in prism diopters (●) were measured during baseline testing. RDS fusional convergence break points and vectographic fusional convergence break points were measured during each session of the experimental phase. Fusion range measurements were not taken during the control phase. (Reprinted from Am J Optom Physiol Opt 60:985,1985.)

training instruments have become available. The first was the CAT distributed by Bernell Corp. Recently, Computer Orthoptics, distributed by Teletherapy (Indianapolis, IN), has developed a computerized system for diagnosis and treatment of binocular anomalies.[a] These systems present anaglyphic binocular stimuli, which may be changed or altered instantaneously to produce any vergence demand up to 50 Δ. Diagnostic programs include standardized fusional range testing with four different targets, RDS presented in an operant conditioning paradigm to measure fusional ranges automatically, different first degree targets to measure phorias, subjective angle and objective angle, motor fields to determine muscle paresis, and accommodative facility testing. Testing procedures are standardized in computerized systems, removing examiner and interexaminer variability.

Behavior modification techniques are used with Computer Orthoptics to foster patient cooperation, which in turn may improve patient response. Correct responses are reinforced positively by auditory feedback and by increasing vergence demand. Incorrect responses are denoted by a "boop" sound and associated with a

reduction in vergence demand. Thus, the patient's own responses modify the training regimen; i.e., patients "go at their own speed." Other training programs are designed to improve vergence ability with flat fusion targets. In addition, vergence programs automatically separate targets within established ranges at controlled speeds. The speed of vergence can be changed easily. Various jump duction techniques have been designed which produce unpredictable vergence demands. Furthermore, RDS have been incorporated within a jump vergence program to improve step or voluntary vergence ranges automatically. The following cases are illustrative and generally representative of how automated vergence therapy is performed.

PATIENT 1

A 6-year-old noncommunicative female received a routine eye examination. Her mother stated the girl complained of frequent, dull aching headaches occurring in the afternoon, and double vision; other ocular and health histories were normal.

Best corrected vision with plano OU was 6/6 (20/20) either eye. Extraocular movements were full and concomitant. Slitlamp examination and

---
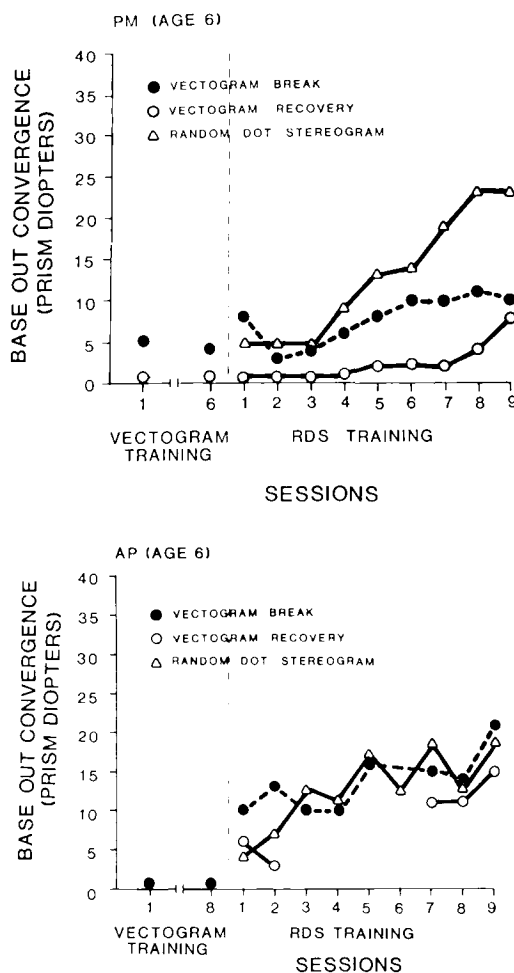[a] Principal author has proprietary interest

FIG. 5. Convergence performance of two representative patients who had failed traditional convergence training. AP had a divergence excess type of intermittent exotropia, whereas PM had a convergence insufficiency. Both patients experienced an immediate improvement in convergence ranges with exposure to automated convergence training and a concurrent elimination of their deviation. (Reprinted from Am J Optom Physiol Opt 1980;57:209.)

funduscopy were unremarkable. Distance cover testing indicated orthophoria, whereas near cover testing revealed a 10^{Δ} intermittent exotropia (exotropia occurring about 80% of the time). Nearpoint of convergence (NPC) was 25/46 cm (10/18 in), with diplopia occurring during deviation. Stereopsis was 20 sec arc on the Randot test (old version). Phorometric findings were not possible due to communication problems.

Topper vectogram using localization as a response cue for binocularity revealed base-out (BO) $X/3/1^{\Delta}$ and base-in (BI) $X/7/3^{\Delta}$. Computer Orthoptics testing of subjective angle measured

10^{Δ} of exophoria; a unilateral cover test done during subjective alignment indicated alignment, i.e., normal retinal correspondence. Vergence measurement with RDS revealed BO ranges of $X/4/1^{\Delta}$ and BI ranges of $X/12/6^{\Delta}$. Worth 4 dot testing indicated crossed diplopia with no evidence of suppression. Monocular accommodative facility testing with the Computer Orthopter using $+2.00/-2.00$ flippers was 11 cpm.

Therapy began with vectograms, pencil push ups, Keystone stereograms, and RDS vergence programs of the Computer Orthopter. She could not maintain attention nor respond accurately to Vectograms, Keystone stereograms, or synoptophore targets. Therefore, RDS were used exclusively to increase both BO and BI vergence ranges. The RDS were presented with a small stereoscopic square in one of four positions, i.e., top, bottom, left, or right. Correct responses, using a joystick to indicate location of the stereoscopic square, resulted in a beep for positive reinforcement. This was associated with a concurrent increase in vergence demand. As long as correct responses were made, indicating binocular fusion, vergence ranges increased by 1^{Δ} per response. However, loss of fusion produced inability to perceive the RDS as indicated by an inappropriate joystick response. Incorrect responses were recorded by an inappropriate joystick response or lack of response within a 6-s time period (time error). Whenever an error occurred auditory feedback was delivered (boop sound) and the vergence demand decreased by 2^{Δ}. This self-motivating system was effective in maintaining attention, and in improving convergence and divergence ability. Fusional range improved to $BO = 55^{\Delta}$ and $BI = 20^{\Delta}$ in 5 30-min sessions. An additional three sessions were given to ensure retention of this new skill.

After this a RDS jump duction program was used. The initial setting was $BO = 5^{\Delta}$ and $BI = 0^{\Delta}$. The patient first made a response to the BO vergence demand for 5^{Δ}, then the BI target was presented at 0^{Δ}. The next stimulus presentation was at 6^{Δ} BO followed by 1^{Δ} BI. As long as the response was correct the jump duction task was automatically incremented by 1^{Δ}; i.e., 7 BO, 2 BI, 8 BO, 3 BI, 9 BO, 4 BI, etc. If an error was made, the vergence demand was decreased by 2^{Δ}, thus ensuring correct binocular responding. A decreasing vergence demand only occurred on the side on which error was made. This method resulted in an incremental jump duction. The patient was able to obtain large jump ductions on the order of $BO = 45^{\Delta}$ and $BI = 15^{\Delta}$.

These two RDS procedures produced large sustained (ramp) and large step vergence ability. The last phase of training utilized rapid vergence changes. In one such task, a flat fusion
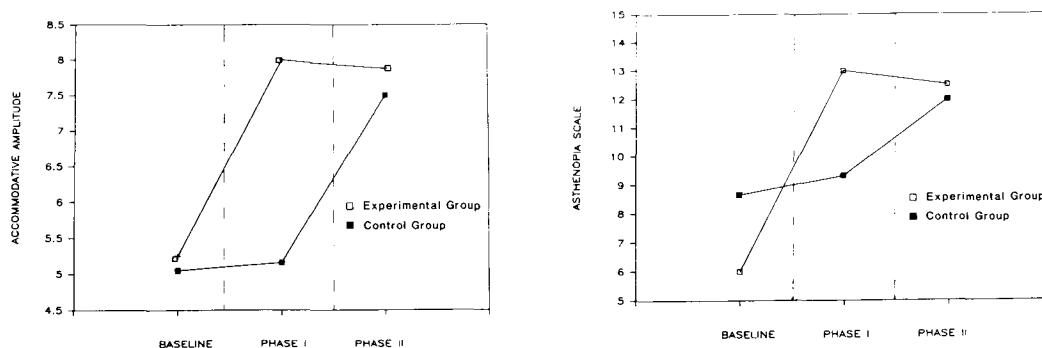
Fɪɢ. 6. Asthenopia and accommodative amplitude for three conditions is presented: baseline, phase 1, and phase 2. Between phase 1 and phase 2 the experimental group, which had monocular accommodative therapy, became the control group (placebo therapy) and vice versa. It is clear that accommodative therapy decreased asthenopia and improved accommodative amplitude. (Reprinted from Am J Optom Physiol Opt 1987;64:433.)

target changed smoothly and rapidly from a preset BO to a preset BI value. The speed of the target was systematically changed from 2.50^Δ/s to 10^Δ/s and the target separation speed varied between 45^Δ BO and 10^Δ BI.

After 12 sessions she showed orthophoria at distance and a small exophoria at near (40 cm) with the cover test. NPC was to the nose; prism vergence ranges using a muscle light with the Krimsky technique revealed BO $>45^\Delta$; occlusion to break fusion resulted in an immediate recovery. BI ranges were $20/15^\Delta$. Topper vectogram fusion ranges were BO $>33^\Delta$ and BI $14/4^\Delta$. RDS BO ranges were full (greater than 55^Δ) and BI were $22/15^\Delta$. In summary, there was no evidence of the convergence insufficiency and no further report of diplopia or headaches. The patient has been followed for 2 years without a recurrence of symptoms.

PATIENT 2

This girl was an extremely bright and academically successful 10-year-old. She had a long history of constant diplopia with reading, which she relieved by occluding her eye with her hand. Her family history indicated that her mother also had a convergence insufficiency.

Unaided visual acuity was 6/6 (20/20) each eye. No refractive error was found. Cover testing at distance showed orthophoria, and at near 15^Δ constant exotropia. NPC was 51/63 cm with diplopia occurring during deviation. Extraocular movements were full and concomitant. Testing revealed the following: distance phoria 1^Δ exo; distance BO X/1/0; distance BI X/1/0^Δ; near phoria 15 $^\Delta$ exo; near BO X/-16/-15^Δ; BI X/ $17/16^\Delta$ (measured from the phoria). She responded to the 20 sec arc target on the original Randot test at 50 cm. Stereopsis was observed on Topper vectogram at 50 cm. As soon as the vectogram was separated in either a BO or BI

direction diplopia was noted. Fusional ranges were nonexistent. Testing using either a large target or RDS on the Computer Orthopter resulted in the same phenomenon. Accommodative testing demonstrated reduced positive relative accommodation (-1.00 D) and negative relative accommodation ($+1.00$ D), respectively; monocular accommodative amplitudes were normal (10 D).

Office therapy began with Vectograms and the Computer Orthopter large fusion targets and RDS vergence program. The patient was told to separate the targets slowly in a massaging motion (BO and BI) while trying to maintain fusion. She was given Brock string, Vectograms, and pushups for home therapy. After four sessions, no further progress was made. The patient was frustrated in not knowing what to do with her eyes. On the fifth session limited fusion ranges were obtained on the RDS vergence program, i.e., 5^Δ. Two sessions later BO ranges were 10^Δ BO and 3^Δ BI. Vectogram ranges were BO $3/1^\Delta$ and BI $3/1^\Delta$. By the eighth session the patient had learned to make real vergence movements. RDS ranges improved rapidly to BO 25^Δ and to BI 10^Δ; vectogram ranges improved to BO $25/10^\Delta$ and BI $11/1^\Delta$.

She now reported less diplopia and a decrease in asthenopia. Within 9 to 10 sessions, vergence improved rapidly to BO $= 45^\Delta$ and BI $= 12^\Delta$. However, vergence movements could only be maintained if separation was slow. Pushups and Brock string performance improved dramatically (convergence to 2.5 cm). At this point the goal was to increase the speed of separation. Using a manual vergence program, vergence demand was increased slowly from 2.5^Δ/s to 10^Δ/s (#9 to #1 setting). Target size was decreased. Next the auto program was used to build sustaining ability. Disparation occurred automatically between BO $= 30^\Delta$ and BI $= 10^\Delta$. The speed was set at 7^Δ/s. This was done for 5 min before

increasing the speed, the final goal being rapid smooth vergence movements at 10^Δ/s.

At this point asthenopia and diplopia were eliminated. Voluntary or step vergence training began with the step jump duction RDS program as previously described. She rapidly developed jump or step abilities between 45^Δ BO and 15^Δ BI. Home exercises using loose prisms and Brock string imagining a bug walking up and down the string supplemented office therapy. Binocular accommodative rock techniques using various vergence targets were performed (goal ± 2.00 D OU: BO = 30^Δ and BI = 15^Δ).

Random jump duction training was done using unpredictable small stimuli to ensure rapid fusional responses. At the end of 16 sessions reevaluation showed unaided visual acuity of 6/6 (20/20) OU and orthophoria at distance and 4^Δ exophoria at near by cover test. NPC was to the nose. Phorometric findings were ortho at distance and 4^Δ exo at near. BO at near was >40/25^Δ and BI X/26/20^Δ. PRA was −3.00 D and NRA was +2.50 D. No symptoms were reported. A 1-year follow-up found no degradation of skills or recurrence of symptoms.

PATIENT 3

This boy was a 7-year-old juvenile diabetic who was not performing at expected levels academically. His father had a long history of fatigue while reading and a diagnosis of convergence insufficiency. The boy stated that he was tired after reading and that his eyes hurt. He thus avoided reading. He denied a history of headaches.

Unaided visual acuity was 6/6 (20/20) each eye. No refractive error was present. Cover testing elicited 8^Δ of exophoria at 40 cm. NPC was 8/17 cm. Extraocular muscle movements were full and concomitant. Stereo acuity was 20 sec arc on the (original) Randot test. Slitlamp and fundus examinations were unremarkable. Testing revealed the following: distance phoria 3^Δ exophoria BI 4/10/−3^Δ, near phoria 9^Δ exophoria; near BO X/12/−3^Δ; near BI X/8/3^Δ; PRA = −1.50 D, NRA +1.50 D, and accommodative amplitude was 12 D each eye. Vectogram findings were BO X/8/4 and BI 2/1$^\Delta$. Accommodative flexibility was normal with ±1.50 D.

A program of vision training began with traditional accommodative rock, stereograms, and vectograms. He became "bored" with these activities within two sessions. He worked with the RDS vergence program and within 5 sessions improved his BO ranges to 30^Δ and BI ranges to 10^Δ. Repeated vectographic training demonstrated transfer (BO = X/14/10, BI = 7/9/3). Accommodative rock with the Computer Orthopter monocular accommodative rock pro-

gram used positive reinforcement feedback contingent upon correct responding to improve accommodative facility to +2.00 D to −6.00 D.

After adequate smooth (ramp) vergence ranges had developed, we began step jump duction vergence activities. Office training was supplemented with home techniques. Traditional techniques using stereograms, vectograms, and loose prism were met with resistance. However, using RDS in a jump duction technique, as described previously in patient 1, resulted in cooperation. After a few sessions the boy refused to do the RDS program because "it was boring." Additional motivation was provided by using the highest vergence level presented on the screen as encouragement "to beat his record." Finally, goals were established to allow him to receive a toy as reinforcement. Final BO ranges were 16/48/10^Δ and final BI ranges were X/12/8^Δ. He could jump from 47^Δ BO to 10^Δ BI for 15 min without any signs of fatigue. NPC was to the nose.

His mother reported that his reading scores had improved, that he was reading for longer periods of time, and that his attention had improved. He stated he was comfortable while reading. Though there was no control for placebo and/or Hawthorne effect we feel that the improvement was a result of the improvement in accommodative and vergence skills because no other therapy was being applied concurrently. A 6 month re-evaluation demonstrated no loss in subjective or objective changes acquired during vision training.

Success in improving vergence abilities with this boy was related directly to the motivational aspects of behavior modification. Initially, "beeps" and "boops" provided strong positive and negative reinforcement; however, over time this reinforcement became less effective. The clinician switched reinforcement to "praise" based upon "beat your previous score" and performance improved dramatically.

The ability to control behavior and to improve fusional vergence was directly dependent upon the use of the following: binocular stimuli which lacked monocular cues, i.e., RDS, rapid change of stimuli occurring after a response; and immediate reinforcement. These conditions could not be met with manual manipulation of vergence stimuli in a synoptophore, stereoscope, or with vectograms.

DISCUSSION

Research studies have shown that computerization can improve binocular responses and ability in young and noncommunicative patients where traditional training has failed.[1,3,4] Additionally, accommodative[8] and vergence

training[5,6] with computerization results in an increase in both accommodation and vergence abilities which are not due to placebo effects. Asthenopia is reduced or eliminated when accommodative and vergence skills are improved.[7-11] Computerized orthoptics have been shown to be effective in remedying convergence insufficiency where traditional orthoptics have failed.[5,9]

Computer-generated analyphic stimuli coupled with behavior modification techniques have been used to improve orthoptic therapy. These systems have enabled the clinician to motivate his/her patients more effectively and to treat patients in a more controlled manner. The three patients discussed demonstrated that an automated system can improve vergence abilities in a young noncommunicative patient, in a very difficult child, and in a hyperactive demanding child. These three patients are representative of over 100 patients whom we have treated. Computerized orthoptics have been used to treat various accommodative and binocular anomalies.

Computerized orthoptics allow for standardization of orthoptic testing and therapy. It improves intra- and interexaminer/therapist reliability. Computerized orthoptics permit development of specific vergence abilities, i.e., sustained ramp vergence, slow ramp vergence, fast ramp vergence, increasing step vergence, and unpredictable step vergence. Computerized orthoptics should lead to more effective diagnosis and therapy of the young noncommunicative patient.

REFERENCES

1. Cooper J, Feldman J. Operant conditioning and assessment of stereopsis in young children. Am J Optom Physiol Opt 1978;55:532-42.
2. Cooper J, Feldman J. Random-dot-stereogram performance by strabismic, amblyopic, and ocular pathology patients in an operant-discrimination task. Am J Optom Physiol Opt 1978;55:599-609.
3. Feldman J, Cooper J. Rapid assessment of stereopsis in preverbal children using operant techniques: a preliminary study. J Am Optom Assoc 1980;51:767-71.
4. Fox R, Aslin RN, Shea SL, Dumais ST. Stereopsis in human infants. Science 1980;207:323-4.
5. Cooper J, Feldman J. Operant conditioning of fusional covergence ranges using random dot stereograms. Am J Optom Physiol Opt 1980;57:205-13.
6. Daum KM, Rutstein RP, Eskridge JB. Efficacy of computerized vergence therapy. Am J Optom Physiol Opt 1987;64:83-9.
7. Cooper J, Selenow A, Ciuffreda KJ, Feldman J, Faverty J, Hokada S, Silver J. Reduction of asthenopia in patients with convergence insufficiency after fusional vergence training. Am J Optom Physiol Opt 1983;60:982-9.
8. Cooper J, Feldman J, Selenow A, Fair R, Buccerio F, MacDonald D, Levy M. Reduction of asthenopia after accommodative facility training. Am J Optom Physiol Opt 1987;64:430-6.
9. Kertesz AE, Kertesz J. Wide-field fusional stimulation in strabismus. Am J Optom Physiol Opt 1986;63:217-22.
10. Somers WW, Happel AW, Phillips JD. Use of a personal microcomputer for orthoptic therapy. J Am Optom Assoc 1984;55:262-7.
11. Griffin JR. Efficacy of vision therapy of nonstrabismic vergence anomalies. Am J Optom Physiol Opt 1987;64:411-4.
12. Cooper J, Citron M. Microcomputer produced anaglyphs for evaluation and therapy of binocular anomalies. J Am Optom Assoc 1983;54:785-8.

AUTHOR'S ADDRESS:
Jeffrey Cooper
State College of Optometry
State University of New York
100 East 24th Street
New York, New York 10010-3677