COMPUTERIZED VISION THERAPY FOR HOME AND OFFICE TREATMENT OF ACCOMMODATIVE & VERGENCE DISORDERS, & AMBLYOPIA

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Abstract

Vision therapy or orthoptics is the standard treatment for symptomatic accommodative-vergence anomalies and amblyopia. Computerization of vision therapy has improved treatment results by: standardizing protocols; providing positive or negative reinforcement based upon responses; eliminating experimental (therapist) bias in research and/or therapy; and standardizing stimuli and methodology for diagnosis/treatment. This paper reviews the literature regarding the efficacy of the automated treatment of accommodative vergence anomalies, and amblyopia. The use of the Computer Orthopter™, its home based program, HTS™ and amblyopia programs are discussed in detail.

Key Words

accommodation, amblyopia, Computer Orthopter™, HTS™ systems, convergence insufficiency, convergence, vision therapy, operant conditioning, orthoptics, random dot stereogram

INTRODUCTION

Millions of people spend a significant amount of time reading or viewing computer monitors. Unlike distance visual activities, these tasks have common features that seem to exacerbate near vision symptoms, i.e., stagnation of both accommodation, vergence and elimination of retinal disparity cues. Thus, disorders of accommodative vergence are more meaningful in today's society. Not surprisingly, the most common complaints associated with computer use are visual symptoms[1-3] and are the leading reason why patients make appointments for eye examinations.[4,5] It has been estimated that computer related visual complaints cost a least 1.2 billion dollars annually in eye care, not to speak of lost work efficiency and quality of life issues.[6] Though the exact relationship between binocular anomalies and reading is controversial, it has long been implicated as a factor.[7-11]

Based upon current models of accommodative vergence interactions, an appropriate protocol might be initial prescription of lenses, which includes prism and/or additional plus, to decrease severe asthenopic symptoms and/or diplopia. I proposed that when these lenses are prescribed this must be *immediately* followed by vision therapy (VT) to improve fast and slow vergence. Prescription of lenses without subsequent VT will usually result in accommodative and/or vergence adaptation. Long term wearing of prism may also result in subsequent alteration in muscle length by sarcomere additions and subtraction.[12,13]

Improvement in fast, reflexive accommodation and/or vergence as the result of successful VT should result in the reduction of prism or lens power to enhance vergence adaptation (slow vergence). Patients with milder symptoms rarely require lenses prior to the initiation of therapy. Generally speaking, VT permanently alters reflexive accommodative and vergence behavior and provides for long term stabilization.[14,15] Recent clinical trials have demonstrated the efficacy of VT as compared to prisms in reducing asthenopia.[16, 17]

In patients diagnosed with amblyopia, improvement in visual acuity and visual functioning has been demonstrated with the combination of VT and some form of occlusion or restrictive vision devices. Elimination of vision in the "good eye" may include patching, atropine and/or Bangerters filters.[18-23] Recently, pilot clinical trials have demonstrated the importance of using appropriate hand eye coordination tasks with patching or atropine.[18, 24, 25]

COMPUTER BASED VT

Background

Traditional VT requires the use of a therapist who has sufficient knowledge and experience to administer various devices such as stereoscopes, vectograms and anaglyphs. It also requires the patient to be sophisticated enough to provide reliable and accurate responses. Even with the best therapist, the changing of targets or stimuli during traditional VT is often slow, arduous and unreliable. Further, there has been little standardization of instructional sets, rate and amount of stimulus changes, and means to apply positive and negative reinforcements. These factors may result in variability of treatment and its results. An analogous situation occurred in visual field testing. Before computerized perimetry was available, testing was tedious, time consuming and unreliable. Manual perimetry also required the use of a tester with more than a scant knowledge of the anatomy and physiology of the primary

visual pathway. However, with the advent of the microprocessor-controlled response presentation system, the testing of visual fields has virtually negated the use of a sophisticated tester. It has also improved reliability and detection rate, decreased testing time, allowed for randomization of stimuli presentation, and allowed for statistical evaluation of responses. Overall, automated threshold visual field testing has become the state-of-the-art. The use of microprocessor control of stimuli has allowed for similar changes in VT.

Evidence Based Studies Using Computerized VT

Cooper and Feldman were the first to demonstrate the effectiveness of computerization in VT by using random dot stereograms (RDSs) in an operant conditioning paradigm.[26, 27] RDSs are devoid of monocular cues and stereopsis can only be appreciated during binocular fusion. This effectively eliminates any monocular cues that might be present in line stereograms. Consequently, stereopsis on a RDS cannot be reported by patients with constant strabismus, including microtropia, since bifoveal fixation is required. Further, this is true regardless of the size of the disparity of the targets.[27] When the RDSs are presented in an operant conditioning paradigm, the patient makes a response to the stereoscopic stimulus; correct responses are positively reinforced, while incorrect responses are negatively reinforced.[26, 28, 29]

In another study, the same researchers[28] used an operant conditioning paradigm to determine if computer based RDS vergence therapy improved vergence amplitudes. The experimental group received vergence therapy while the control group did not. Later, the control group became the experimental group and the experimental group became the control group. During vergence therapy, in the experimental group, correct responses resulted in the computer automatically and immediately giving the subject a positive reinforcement (beep) and increasing the vergence demand. Incorrect responses resulted in the deliverance of a "boop" and a concurrent decrease in the vergence demand. Thus, the subject's behavior controlled the vergence demand. Success was met with harder demand; failure, with an easier task. The control group received identical stimuli and reinforcement; however, neither correct nor incorrect responses resulted in a change in the vergence demand. This study clearly demonstrated that automated computerized VT resulted in a rapid increase of fusional amplitudes with concurrent transference of this ability to other vergence tasks such as vectograms.

Cooper[30] also reported that patients with clinical vergence anomalies, who failed to respond to traditional methods using an experienced therapist, were successfully treated with automated vergence therapy. Daum et al[31] also demonstrated that automated therapy produced more effective results than those obtained with traditional use of prisms, stereoscopes and vectograms. Additionally, they also showed that shorter, more frequent sessions were preferable to longer, spaced-out therapeutic sessions. From Daum's results, one may infer that once or twice a week in-office therapy should be augmented with effective home therapy to improve results.

Cooper et al[32] performed the first prospective controlled study that evaluated the ability of VT to eliminate the signs and symptoms associated with convergence insufficiency (CI). Again, one group received vergence therapy (experimental) while the other group did not (control). Both groups received identical RDS stimuli with appropriate reinforcement. They used a scaled questionnaire before and after treatment. Patients were treated in an A-B-A cross-over design to control for experimental bias, placebo and order effects. It was found that therapy improved convergence amplitudes; reduced asthenopia as measured on their scaled questionnaire; and flattened fixation disparity curves. Similar results were found in a study with automated accommodative therapy.[33]

Kertesz and Kertesz[34,35] treated a group of CI patients who had failed traditional orthoptic treatment regimens. They used automated large stimuli vergence targets. The researchers reported that 23 of 29 patients studied (80%) significantly increased their fusional ranges with a concurrent reduction of symptoms. Feldman et al,[36] in a subsequent study, found that the size of fusional amplitudes was directly related to the size of the stimuli, i.e., the larger the target the larger the amplitude. Neither detail nor disparity influenced fusional amplitudes. From this research, they suggest that therapy should begin with large stimuli, progressing to smaller stimuli.

Sommers et al[37] used computerized VT techniques and compared them to traditional techniques. Patients treated with computerized techniques showed more rapid and complete improvement of their binocular anomalies. Similar findings have been reported by Griffin[38] It is also clear from the aforementioned studies that computerized VT, using RDSs in an operant conditioning paradigm, is more effective than traditional therapy. In addition it decreases the need for an experienced therapist, shortens therapy by improving motivation, and by improving reliability.

Schieman et al[16,17] utilized RDS in an operant conditioning paradigm in both segments of the "in office therapy" arm of their studies that evaluated the most common treatment regimens for CI. They compared VT to placebo therapy, and pencil pushups. The Computer Orthoptics™ and HTS™ programs were used in conjunction with vectograms, Brock string, lifesaver cards, etc. (Both programs are fully discussed in the following section entitled *The Computer Orthoptics*.) In office therapy used the Computer Orthoptics™ which was controlled by the therapist, and the automated home based therapy (HTS™) were used in both studies. The results demonstrated that VT was more effective than base in prism, placebo therapy, or pushups in reducing asthenopia in symptomatic convergence insufficiency patients.

Recently, Goss and his associates[39] performed a study to determine the effect of normalization of accommodation, vergence and eye movements according to specific criteria on reading scores. The subjects were third graders who were randomized into one of two groups. One group received placebo therapy and the other group active therapy, i.e. "real HTS" Because the school year ended before the study could be completed, the results were inconclusive.

Goss et al repeated the experiment with a control group who did not receive placebo therapy in a sample of third graders in order to determine the effect of the therapy on reading scores. The group that completed the HTS™ program improved their reading scores by 1.8 years as compared to the control group's improvement of 0.9 years. Those who used HTS™ but did not complete therapy improved their reading scores by 1.4 years. This study provides further support for the inclusion of VT in a program to improve reading scores, and that for optimal results, the subjects should attain the stated clinical criteria.

COMPUTER ORTHOPTICS

Computer Orthoptics™, a group of in office therapy programs, was first introduced approximately 25 years ago**.** The original system used anaglyphs to diagnose and treat oculo-motor, accommodative, and vergence disorders. Approximately 12 years ago, a more advanced computerized therapy program was introduced that used liquid crystal glasses to present binocular stimuli. Liquid crystals allow for the presentation of full color, realistic stimuli.

The most recent version is The Computer Orthopter™ (VTS3), developed and produced by HST, Inc.[a] It simulates the performance of a vectogram, stereoscope, troposcope, and Brock Stereo Motivator (BSM) in a single unit**.** Changing stimuli is easily and rapidly performed. This comprehensive unit has a diagnostic program that includes testing of: phorias, fusional amplitudes, fixation disparity, suppression, motor fields, pursuits, and saccadics. See Figures 1-4 The therapeutic programs include techniques for ocular motility, accommodation, and vergence. Stimuli consist of a variety of first degree (simultaneous perception); second degree (flat fusion); and third degree targets (stereopsis). These targets vary in size and suppression control features. They can be presented at the objective angle to treat strabismus or, in an operant conditioning paradigm, to improve both fast and slow disparity vergence. Targets may be presented at near or projected at distance. Stimuli can either be monocularly flashed or alternatively flashed at various frequencies to break suppression. Vergence targets can be presented manually (examiner controls the targets) or automatically (program controls changes in vergence and/or movement of targets). One of the most important features is that stimuli can be presented at both distance and near. Distance projection is stereoscopically compelling.

The real power of the Computer Orthopter™ (VTS3) is to combine a host of first, second, and third degree targets in an operant conditioning paradigm. The use of RDS, which requires bi-foveal fixation, eliminates the possibility of responding to monocular cues.[27] Therapy is automatically altered based upon previous responses. Thus, successful viewing of a RDS results in positive reinforcement and a concurrent increase in vergence, while an incorrect response results in delivery of negative reinforcement with concurrent decrease in vergence. Accommodative stimuli are employed in the same operant conditioning paradigm. This regimen has been scientifically tested to show its validity.[33] Cooper[40] has previously proposed that therapy should begin with large vergence targets that are slowly disparated. Subsequently, the size of the target should sequentially be decreased and speed of disparation should be increased. As therapy progress the tasks should be made more complex by adding patient movement, stimuli movement, distracters**,** such as requiring the patient to engage in a conversation**.** After normalization of fusional amplitudes, jump ductions should be added.

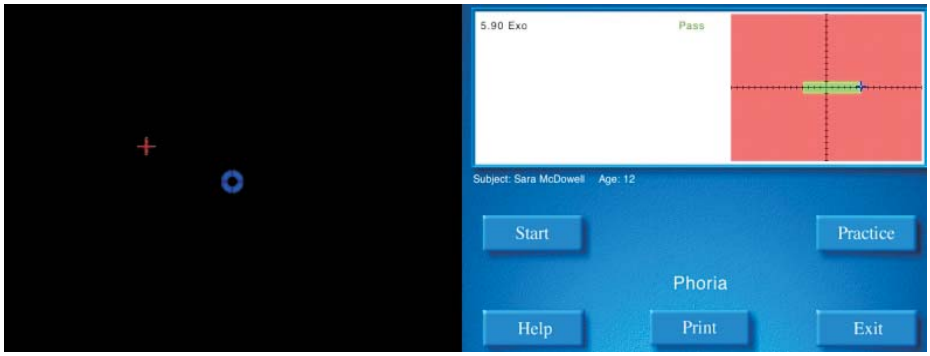

Figure 1. Classic first degree stimuli in anaglyph form that can be used to measure the subjective angle.

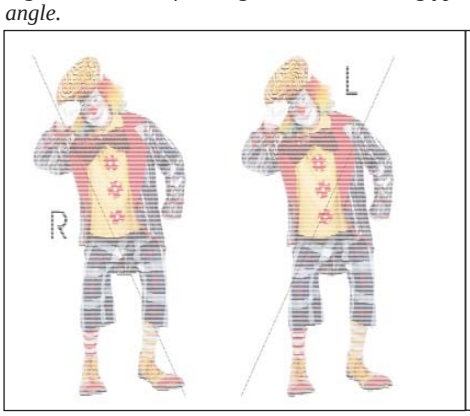

Figure 2. Flat fusion target with suppression controls.

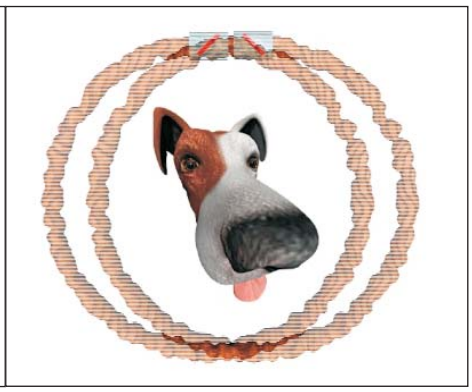

Figure 3. Stereo target in which the peripheral rings can have their disparity manipulated to vary stereoscopic retinal disparity.

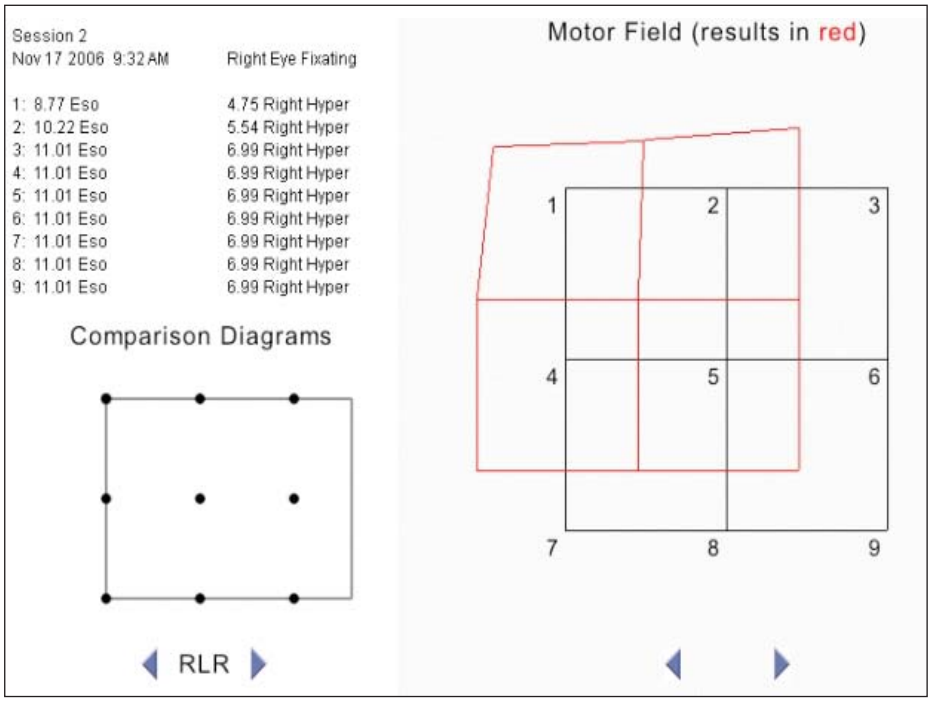

Figure 4. Motor Fields Window.

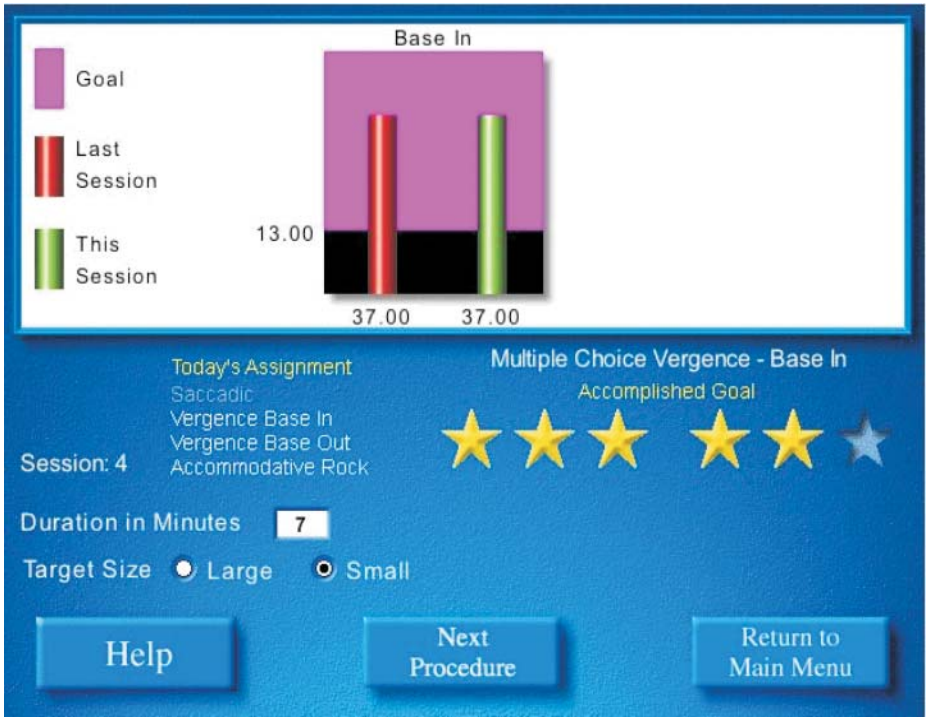

Figure 5. Daily summary for the HTS™. Note bar graphs depict daily performance plotted against the goals. Stars are given for cumulative performance. Daily tasks are assigned.

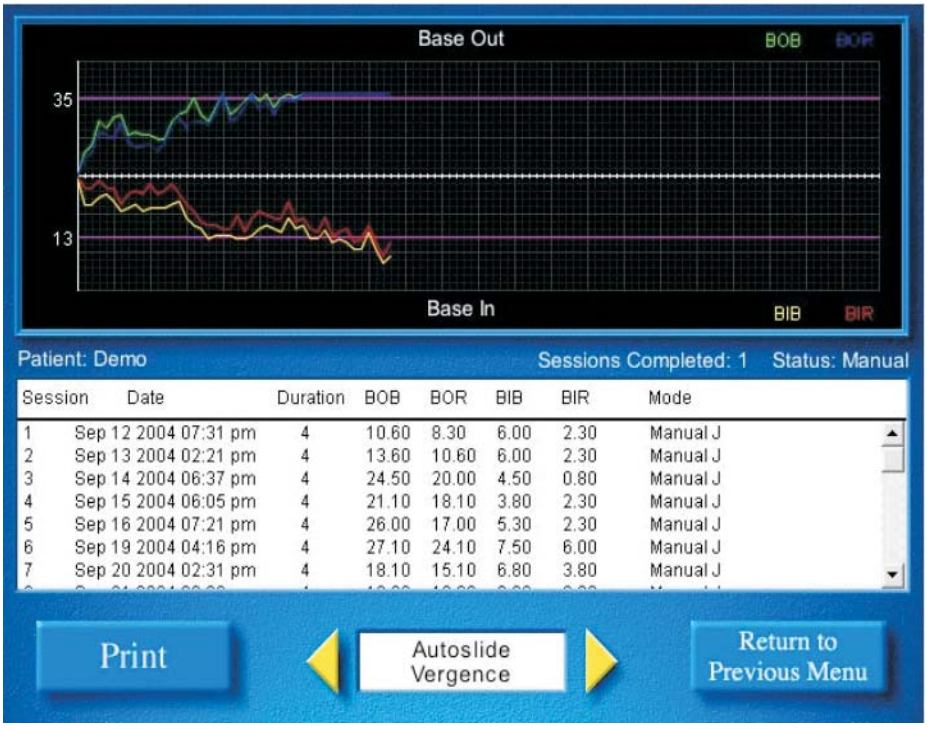

Figure 6. Cumulative graph for the HTS™ shows progress over time. There is one graph per task.

COMPUTER BASED HOME VISION THERAPY (HTS™)

Some patients are not able to participate in office therapy. They may not have the time, they may live too far from an office that provides in office vision therapy, and/or they may not be able to afford in office therapy. Though office based therapy is considered the standard, stand alone home therapy has its place in our treatment regimen. In addition, office therapy augmented by home therapy, in our experience, dramatically enhances the effectiveness of in office therapy by reinforcing office based learned skills. This is supported by research that shows therapy repeated for numerous short intervals is more effective than therapy performed for the same amount of time once.[41]

There are relatively few studies supporting the use of stand alone traditional home-based VT programs.[42,43] Nevertheless, my experience has been there are a number of problems with this type of therapy. For example, it is difficult to monitor compliance. It is difficult to make sure that therapy was done properly. It is difficult to increase or decrease the task demands based upon past performance. Home therapy often fails for one or more of the following reasons: the patient did not understand the instructions; the patient needed more than one technique to alter vergence behavior; the parent could not work with the child so that the therapy was not performed, or was carried out incorrectly.

Recently, HTS, Inc.[a] revamped its previous home-based computerized program to address the previously described problems. The new version improves compliance by providing detailed instructions for performing the various techniques and provides internet access to allow the doctor/technician to remotely monitor, control, and reinforce therapy. See Figures 5 and 6. The utilization of a disc allows the patient to perform therapy with or without internet capabilities.

Therapy can be prescribed in either an "auto mode" or "manual mode." In the auto mode, therapy is predetermined with alterations based upon previous progress. The doctor/therapist can modify the "Auto Program," e.g. eliminate accommodative rock in presbyopic patients. It begins therapy with help screens using a "video man" to describe each therapeutic regimen in detail. See Figure 7. After the patient understands the directions, the program automatically begins therapy. Ocular motilities, accommodation, and vergence therapy in an operant conditioning paradigm are incorporated. Correct responses are positively reinforced with a concurrent increase in the difficulty of the task, while incorrect responses are negatively reinforced with concurrent reduction in the difficulty of the task. The RDS sequence is as follows: therapy to increase divergence amplitudes with a large RDS, followed by therapy to increase convergence amplitudes with a large RDS. After the criteria are reached, the RDS are made smaller. Next RDSs are presented in a jump duction or step activity and lastly, they are presented in a constantly changing vergence activity. The sequence of

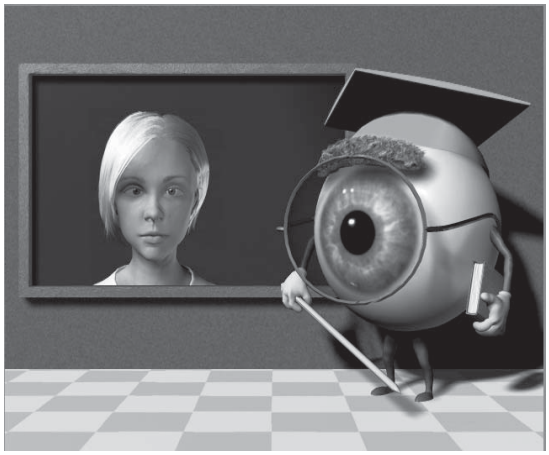

Figure 7. Video man gives detailed instruction prior to therapy. Task and goals are presented.

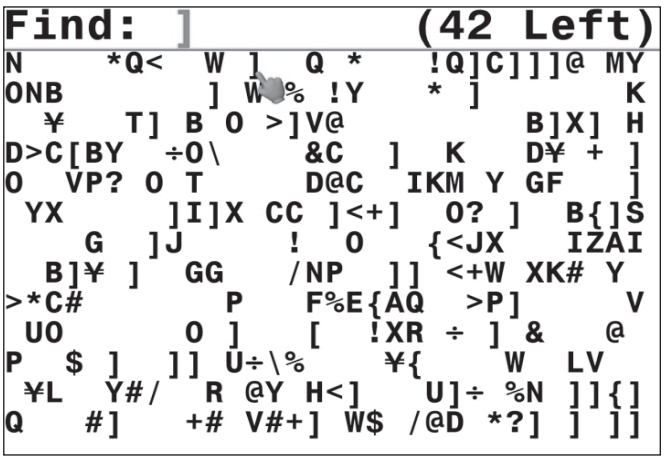

Figure 8. Typical amblyopia therapy task. All tasks begin at a level slightly greater than the recorded vision. As therapy progresses the targets become smaller and closer together (contour interaction). In some tasks, in which the targets are moving, the speed is increased.

events is identical to the series of experiments which demonstrated the effectivity of RDS in an operant conditioning paradigm.[31-39] A similar paradigm is used to improve accommodation and ocular motility.

The purpose of therapy is to systematically develop the appropriate reflex. The computer automatically assigns the patient three tasks a day; the computer determines time and order. The patient follows the simple instructions. At the end of each session, there is an automatic recording of each task. A performance screen allows the doctor, parent, and patient to view previous performance two ways. The first provides tabular data of each session that includes the date, time, task performed, level achieved, and the level of performance. The second is a graph of all the sessions, so that one can quickly determine the cumulative effects of therapy. Therapy is manipulated based upon previous performance, i.e.. success leads to harder tasks.

Patients who participate in home therapy only are scheduled in our office for an intermediate exam at one week, one month, and several months after the assignment of the home therapy. The HTS™ also serves as a powerful adjunct to those who are receiving in-office therapy. We prescribe the HTS™ to all of our patients who are undergoing active VT due to an accommodative/vergence anomaly.

HTS™ has released a new home therapy amblyopia program designed to systematically improve hand eye coordination, visual acuity, crowding effect and visual memory. Stimuli are presented in an operant conditioning paradigm so that correct responses are positively reinforced with a concurrent decrease in the size of the stimuli and/or speed of the target. Incorrect responses are negatively reinforced. See Figure 8.

The doctor inputs the visual acuity and the side of the amblyopic eye. Then the patient is instructed to use the program five days a week. Six of the twelve programs in the amblyopia program are randomly assigned each day; thus, at the end of two days, each task has been preformed one time. Success results in decreasing the size of the target so that it is harder to resolve. Additionally, in tasks where the targets are moving, the speed is systematically made faster with success. The doctor has the option of eliminating the patch and performing the tasks monocularly in a binocular field. This feature is double password protected to make sure the doctor wants to prescribe therapy in this manner to decrease the possibility of inducing irretractable diplopia.

There are limited unpublished studies demonstrating the benefit of this program, and a more rigorous clinical trial is currently about to begin.

CONCLUSION

RDSs presented in an operant conditioning paradigm have resulted in improved therapy for patients with accommodative and vergence dysfunctions. Numerous studies have demonstrated that computerization of VT techniques are superior to traditional methods of therapy. Computerization improves patient motivation, eliminates experimental bias, simplifies therapy goals, provides immediate reinforcement to encourage correct responding, and provides meaningful data to evaluate progress. The significant and increasing number of home computers and the policies of managed care have fostered the use of computer based VT to supplement office therapy or be a stand alone modality for home based therapy.

Dr. Cooper is a developer of the Computer Orthoptor™ and HTS™ and has a financial interest in these systems.

Source

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EDITORIAL continued

know,' and if knowing, we have concluded that we are being asked to take senseless and frightening risks, then we should no longer accept the counsel of those that tell us that we must fill our world with poisonous chemicals; we should look about and see what other course is open to us."

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