

Article

The Effect of HTS Vision Therapy Conducted in a School Setting on Reading Skills in Third and Fourth Grade Students

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ABSTRACT

Background: Home Therapy System (HTS) is a computer program designed to improve accommodation, vergence, and eye movements. The purpose of the research described in this paper was to investigate whether normalization of accommodation, vergence, and eye movements in third and fourth grade students using HTS vision therapy in a school setting improved reading performance.

Methods: Subjects were divided into two groups: those receiving real therapy (n=39) and those receiving placebo therapy (n=32). The school year ended before any of the 39 treatment subjects had reached HTS criteria for therapy completion. Therefore, we performed a second study which was composed of a control group which did not receive therapy and a second group which received active HTS therapy. Fourteen of the 34 treatment subjects had sufficient training to meet or exceed all seven of the HTS training goals. School achievement scores were measured with the STAR test.

Results: In the first study, the mean increases in reading grade equivalent were 0.7 (SD=1.0) for the treatment group, and 0.9 (SD=1.1) for the placebo group; and the mean increases in math grade equivalent were 1.5 (SD=1.5) for the treatment group, and 1.3 (SD=1.5) for the placebo group, neither difference being statistically significant. In the second study, the mean increases in reading grade equivalent were 1.4 (SD=0.7) in the treatment group, and 1.0 (SD=0.8) in the control group. These results showed a statistically significant difference ($p<0.01$). The mean increase in grade equivalent for 14 treatment subjects who reached all of the HTS recommended post-therapy training goals was 1.8 (SD=0.7), which was significantly greater than the increase in the treatment subjects who did not reach those goals ($p<0.005$).

Conclusions: The results of the first study demonstrate that when HTS training is not completed according to the recommended criteria, reading scores will not improve more than with placebo therapy. The greater increase in grade equivalent reading scores in the treatment group than in the control group in the second study suggests a positive effect of training when the HTS program is carried out to completion. Our results suggest the importance of completing the recommended training protocols in order to achieve significant improvements in reading with the HTS system.

KEY WORDS

fusional vergence, math skills, ocular accommodation, ocular convergence, orthoptics, reading skills, vision therapy.

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INTRODUCTION

An initial part of the reading process involves ocular focus of and alignment with print letters, thus requiring accommodation, vergence, and eye movements. Reviews of the literature have documented a relationship of anomalies of refraction, binocular vision, and eye movements with reading difficulties.¹⁻¹⁰ Vision therapy is a standard treatment for binocular vision disorders, and there is a sound scientific basis for improvement in accommodation and vergence function with vision therapy.¹¹ Furthermore, vision therapy has been shown in clinical studies to improve accommodation and vergence skills and to decrease or eliminate the symptoms of non-strabismic binocular vision disorders.¹²⁻³⁰

These relationships imply that reading and learning skills could be improved with vision therapy. A recent review of the literature examined studies of the effect of vision therapy on learning.³¹ The majority of the eleven studies reviewed suggested that there is “a weak but positive relationship between oculomotor vision therapy and improved reading skills, such as reading rate and comprehension.” The authors of the review noted that the overall trends of these studies suggest that the improvement from vision therapy “is equivalent to that of conventional reading therapy but that the most improvement exists when both vision therapy and reading training are used...”³¹

Vision therapy can be conducted with a variety of training procedures. Vision therapy utilizing operant conditioning paradigms is available for use with personal computers.^{32,33} This allows vision therapy to be performed anywhere there is a computer, such as the home and/or the school. The Home Therapy System (HTS) is a commercially available computer-based vision therapy system designed to improve vergence, accommodation, pursuits, and saccades.³⁴

This paper describes two studies which were conducted to determine whether the normalization of visual skills using the HTS vision therapy program would improve reading skills in a normal population of elementary school children.

General Organization of the Studies

Two separate studies were conducted at North Vernon Elementary School in North Vernon, Indiana, a small town of approximately 7,400 people. They will subsequently be referred to as study 1 and study 2. The population of North Vernon consists of 95.5% Caucasian, 2.6% African American, 0.6% Hispanic, and 0.9% other.³⁵

In study 1, fourth grade subjects were randomized into treatment and placebo groups. The treatment group subjects received training using the HTS system. The placebo group did training procedures which were almost identical to the HTS training procedures, except that there were no stimuli for changing accommodation, vergence, or making eye movements.

In study 2, there were treatment and control groups. The treatment group consisted of students in two third grade classrooms, who did HTS training. The control group consisted of students in three other third grade classrooms, in which therapy was withheld.

Scheduling constraints during study 1 resulted in the treatment group subjects receiving substantially fewer therapy sessions than would be necessary to reach recommended levels of improvement before the end of the school year. Thus study 1 was not completed when it was stopped at the end of the school year. Study 2 was then undertaken in the following year so that most, if not all, of the treatment group subjects could complete therapy. Again in the second study a less than optimal number of therapy sessions were completed, but more than in the first study, with many of the subjects completing therapy goals.

SUBJECTS

In study 1, 77 fourth grade students ranging from nine to 11 years old participated in the study. Subjects were randomly assigned to either the treatment group (n=39) or the placebo group (n=32). A screening with autorefraction before the beginning of the study found that none of the subjects had significant uncorrected refractive errors. Subjects used the HTS system for 20 minutes up to three times per week for twelve non-consecutive weeks which were interrupted by various school breaks, illnesses, or various activities. The therapy was scheduled to occur during the children's computer class. The actual number of therapy sessions completed by subjects in the treatment group ranged from six to 35. The placebo group performed a placebo HTS program which was designed so that it would not stimulate the changes in accommodation, vergence, or eye movements that the standard HTS program does.

In study 2, there were 34 subjects from two third grade classrooms in the treatment group. All subjects assigned to the treatment group demonstrated appreciation of a random dot stereogram. Therapy was performed in twenty minute sessions three times per week at school from November to May, with the exception of the students' Christmas and Spring breaks. Reading test scores from 63 students from three other third grade classrooms were used as control data.

School Achievement Testing Methods

STAR Reading achievement tests were administered by the school before and after therapy in both studies. STAR Math achievement scores before and after therapy in study 1 were also available and were included in the analysis. The STAR tests are produced by Renaissance Learning and have been validated based on a national sample of 60,000 students.³⁶ Test results were expressed as grade equivalents for both studies.

THERAPY METHODS

HTS Therapy in the Treatment Group in Both Studies

The Home Therapy System (HTS) consists of a series of computerized vision therapy procedures for accommodation, vergence, pursuits, and saccades done by an individual on the computer. The random dot stereogram computer programs, the vergence part of HTS, have been shown to improve fusional vergence ranges and reduce eyestrain symptoms.³⁷⁻³⁹ The treatment groups performed the following HTS procedures: Pursuits, Saccades, Base In, Base Out, Auto Slide Vergence, Jump Ductions, and Accommodative Rock.

Pursuits: The monitor screen displayed the letter E, which moved across the screen in a random pattern. Every 1.5 seconds the direction the letter E was pointing changed randomly. The subjects' task was to use the arrow keys on the keyboard to indicate the direction the letter E was pointing while visually tracking its movement. Auditory signals were presented which indicated whether responses were correct or incorrect.

Saccades: The monitor displayed an arrow that was pointing up, down, left, or right. The subject used the arrow keys on the keyboard to indicate the direction the arrow was pointing. After every response the arrow randomly moved to a different location and changed its orientation. Auditory signals were presented which indicated whether responses were correct or incorrect.

Vergence Base-In and Vergence Base-Out: The subject was presented with a random dot stereogram, a large square made up of red and blue dots within which was a small stereo square appearing to pop out of the screen. The small square could only be seen when wearing red/blue glasses and when the eyes bifoveally fixated. The stereo square was located to the top, bottom, left, or right of the larger square on the monitor screen. The subject used the arrow keys on the keyboard to respond to the position of the stereo target. Correct responses caused the left and right eye views to separate by a distance producing a 0.5Δ increase in vergence demand. Incorrect responses decreased the vergence demand 1.0Δ . Correct and incorrect responses were reinforced by different auditory tones. Subjects progressed to Auto Slide Vergence if they were able to reach 13Δ on Vergence Base-In and 35Δ on Vergence Base-Out.

Auto Slide Vergence: The auto slide also used random dot stereograms. With the arrow keys on the keyboard, each subject responded to the location of the small stereo square popping out of the screen as a three-dimensional figure. Correct responses occurred only if subjects made appropriate vergence responses for the changes in vergence stimulus. After two incorrect responses for a particular vergence stimulus, the opposite vergence stimulus direction was presented to the subject.

When subjects achieved 13Δ base-in and 35Δ base-out they proceeded to Jump Ductions.

Jump Ductions: The jump ductions procedure, also using red/blue glasses to view random dot stereograms, is more challenging than either of the other vergence procedures. In order to make correct responses, this procedure required rapid vergence adjustments to different levels of vergence stimulus.

Accommodative Rock: The subject wore red/blue glasses and used monocular accommodative rock flippers. They were presented with four blue squares that each had a dot set at 20/30 visual acuity threshold. The dot was located to the top, bottom, left, or right of the blue square. The blue squares were seen by the left eye through a minus lens. After a response to the four blue squares, the subject was presented with four red squares. The red squares were seen by the right eye through a plus lens. When 13 cycles per minute and 80 percent correct response for each eye were achieved for a given flipper level, the program gave a prompt to use the next highest flipper level. Lens flipper powers were: level one, $+0.75/-1.50$ D, level two, $+1.25/-2.50$ D, level three, $+1.75/-3.50$ D, level four, $+2.00/-4.00$ D, level five, $+2.25/-4.50$ D, and level six, $+2.50/-5.00$ D.

Therapy Procedures in the Placebo Group in Study 1

Pursuits: The subject responded the same as the experimental group using the arrow keys to indicate the direction the letter E was pointing. The letter E changed orientation, but it did not move across the screen; thus it did not provide a stimulus for pursuit movements.

Saccades: The subject responded the same as the experimental group, using the arrow keys to indicate the direction the arrow was pointing. The arrow changed its orientation but remained centered on the monitor screen. Therefore, no saccadic eye movements were stimulated.

Vergence procedures: The subject responded the same as the experimental group, using the arrow keys to indicate the position of the stereo square within the larger square. Correct responses did not separate the left and right eye views; therefore there was no change in vergence stimulus from what was present from the viewing distance alone.

Accommodative Rock: The subjects responded the same as the experimental group. All flippers contained plano lenses, so there was no change in accommodative stimulus.

HTS Post-therapy Goals

HTS has recommended particular levels of achievement on their programs as the post-therapy goals.⁴⁰ Table 1 summarizes these post-therapy goals. Reaching all of those goals represents completion of the HTS therapy program. The number of sessions different patients take to reach all seven goals varies considerably, with a majority of patients requiring at least 50 to 60 sessions to meet all seven goals.⁴¹

Table 1.
HTS Post-therapy goals from the Home Therapy System Doctor's Manual.⁴⁰

Training procedure	Post-therapy goal
Pursuits	At speed level 4: percentage correct > 80%; average response time: <0.95 if using arrow keys or <0.80 if using joystick
Saccades	Percentage correct > 80%; average response time: <0.95 if using arrow keys or <0.80 if using joystick
Base-in break	>13
Base-in recovery	>8
Base-out break	>35
Base-out recovery	>25
Accommodative rock	Average cycles per minute > 13; percent correct left and right eye > 80% (using +2.50/-5.00 D flipper lenses)

Table 2. Mean increases in grade equivalent and the statistical significance of the differences by t-test.		
	Increase in reading grade equivalent	Increase in math grade equivalent
Study 1- treatment group	0.7 (SD=1.0)	1.5 (SD=1.5)
Study 1- placebo group	0.9 (SD=1.1)	1.3 (SD=1.5)
Statistical significance	not sig.	not sig.
Study 2 – treatment group	1.4 (SD=0.7)	--
Study 2 – control group	1.0 (SD=0.8)	--
Statistical significance	p<0.01	--

Due to various time constraints, none of the treatment group subjects in Study 1 had sufficient therapy sessions to reach all seven therapy goals. The number of sessions ranged from 6 to 35, with 13 of the treatment group subjects having less than 20 sessions.

The treatment subjects in study 2 underwent more therapy sessions than the subjects in study 1. Twenty-six of the 34 treatment group subjects in study 2 had more than 35 therapy sessions. In the second study, 14 of the 34 treatment group subjects reached all seven therapy goals. The 14 subjects who reached all seven criteria averaged 44.8 therapy sessions (SD=4.9; range=37 to 53). The 20 treatment group subjects in study 2 who did not reach all therapy goals averaged 39.7 sessions (SD=10.5; range=19 to 51).

DATA ANALYSIS

The changes in grade equivalent level from the beginning of the study to the end of the study were determined for the treatment groups in each study and for the placebo and control groups. Differences in means were tested by the Student t-test. Statistical significance was established at the 0.05 level. For study 2, we also did a subgroup analysis separating the treatment group by whether or not all of the seven HTS norm criteria (for base-in break, base-in recovery, base-out break, base-out recovery, saccades, pursuits, and lens flippers) had been met by the end of the study by the treatment group subjects.

RESULTS – STUDY 1

The increase in reading grade equivalent in the treatment group averaged 0.7 (SD=1.0), as shown in Table 2. In the placebo group, the increase in reading grade averaged 0.9 (SD=1.1). The difference between these means was not statistically significant.

The average increase in math grade equivalent in the treatment group was 1.5 (SD=1.5). The mean math grade equivalent increase in the placebo group was 1.3 (SD=1.5). The difference in the means was not statistically significant. The increases in grade equivalent in both treatment and placebo groups in both reading and math were close to that which might be expected with maturation and regular education.

RESULTS – STUDY 2

The mean increase in reading grade equivalent in the treatment group was 1.4 (SD=0.7). The mean increase in the control group was 1.0 (SD=0.8). The difference was statistically significant (p<0.01).

Of particular interest was a subgroup analysis in which the treatment group was divided into those who met all seven HTS post-therapy goals and those who did not. Fourteen of the treatment group subjects reached the levels of all seven goals by the end of the study. The mean increase in reading grade equivalent for these fourteen subjects was 1.8 (SD=0.7). The remaining treatment subjects had an average increase in reading grade equivalent of 1.1 (SD=0.5). The difference in these means was statistically significant (p<0.005). A plot of the improvement in grade equivalent as a function of the number of the goals met is shown in Figure 1. The difference between the mean for the 14 subjects who completed therapy and the mean for 63 control subjects was also statistically significant (p<0.0005).

DISCUSSION

Importance of Reaching Training Goals

In the first study, the real therapy group and the placebo group demonstrated statistically similar improvements. The mean improvements in grade equivalent were not significantly different in the treatment and placebo groups. A likely explanation for this lack of difference in reading and math score improvements was that the treatment group never achieved the criteria for normalization of all visual skills. Scheduling problems

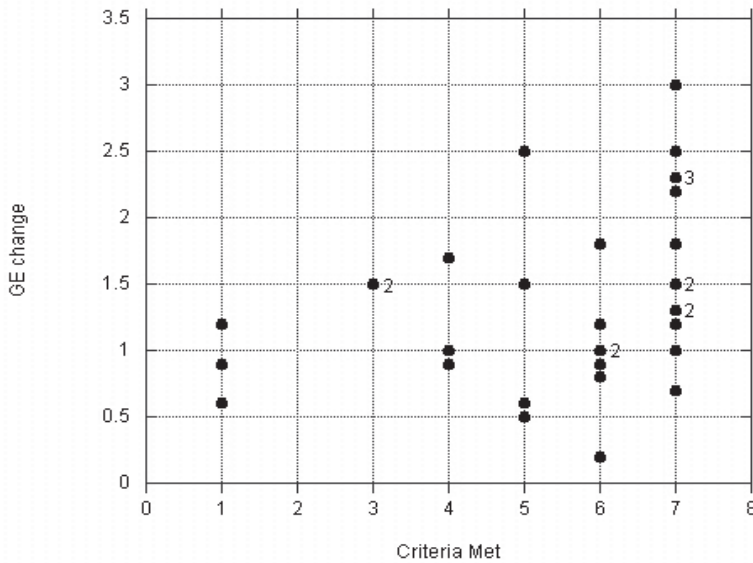


Figure 1. Scatterplot of the improvement in reading grade equivalent (GE) as a function of the number of the seven post-therapy criteria which were met by the training group subjects in study 2.

in school resulted in too few therapy sessions being completed by the end of the school year for the subjects to reach normalization of visual skills.

The fact that there was a positive effect of training in study 2 but not in study 1 and the fact that in study 2 the treatment subjects who met all HTS post-therapy goals had greater improvement in reading scores than the subjects who didn't meet the post-therapy goals suggest that there is a threshold level that the therapy needs to meet before improvement in reading occurs. A comparable finding is that from Atzmon et al.⁴² who reported a positive effect of convergence training on reading, but suggested that convergence ranges must be improved to much higher than normal levels for the beneficial effect on reading.

It is interesting to note that the improvement in reading grade equivalent was about the same in the control group in study 2 as it was in the placebo group in study 1. The subjects who finished therapy in the second study had a much greater improvement in reading score (1.8) than did the placebo and control groups (0.9 and 1.0).

As with any form of therapy, motivation and compliance are important in determining whether individuals will reach acceptable levels of visual ability. Fourteen of the treatment group subjects met or exceeded all of the post-therapy performance goals established by HTS. Those fourteen subjects had a much greater increase in grade equivalent than the control group, suggesting a high level of improvement in visual skills is necessary for academic improvement.

Other Comments

Computer programs which are designed largely to improve visual processing and visual attention have been successful in improving reading skills.⁴³⁻⁴⁶ Just as with

vision therapy procedures performed without computers, procedures done with computers are directed toward the improvements of particular visual functions. HTS is used for the improvement of visual skills such as eye movements, accommodation, and vergence. The HTS system is not designed specifically to train other functions such as visual processing or visual attention, but it is possible that it may have positive effects in areas of visual function other than accommodation, vergence, and eye movements.

Subjects were included in this study regardless of their level of school achievement and whether or not they had any accommodation, vergence, or eye movement disorder. All subjects performed the same type of therapy. Vision therapy is usually prescribed to treat a specific binocular anomaly. Perhaps gains in the treatment groups would have been greater if the research had been limited to students with reading difficulties and/or anomalies of ocular motor skills. It is further possible that gains would have been greater if training had been done five times per week during consecutive weeks as recommended by HTS, rather than the three times per week or less as in these studies.

Vision therapy often incorporates some combination of in-office and at home therapy procedures, which varies among practitioners. Most practitioners recommend some combination of in-office and at home procedures for best treatment effects.^{47,48} This research used only treatment which was done in the school setting using computer vision therapy. It has been suggested that advantages of computer programs as an at home part of vision therapy as compared to many traditional at home procedures may include reduced need for the practitioner to interpret patient responses, less likelihood of a patient being able to fake expected responses, and more effective feedback to the patient.⁴⁸

CONCLUSIONS

Placebo and control groups demonstrated improvement in reading scores consistent with maturation. Use of the HTS system, an automated computer program which uses operant conditioning to improve accommodation, vergence and eye movements, resulted in the greatest improvement of reading scores if the HTS therapy was completed. The reading grade equivalent score improvement in the treatment subjects who completed HTS therapy was 1.8 compared to 0.9 for placebo subjects and 1.0 for control subjects. Treatment subjects who did not use HTS enough to meet the manufacturer's criteria did not achieve results which were significantly different from placebo therapy.

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