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Evaluation of a custom biofeedback computer program for stabismus using the Apple IIGS and Visigraph Eye Monitoring System

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Evaluation of a custom biofeedback computer program for strabismus using the Apple IIGS and Visigraph Eye Monitoring System

Abstract
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Degree Type
Thesis

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Evaluation of A Custom Biofeedback Computer Program for Strabismus Using the Apple IIGS and Visigraph Eye Monitoring System

by

Sylvia Ryan
Alan LeRoy

A thesis submitted to the faculty of the College of Optometry Pacific University Forest Grove, Oregon for the degree of Doctor of Optometry May, 1992

Advisors:
Robert L. Yolton, Ph.D., O.D.
Hannu Laukkanen, O.D.
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Recieved her Bachelor's Degree in Computer Science/Business from Aurora University in Illinois. After moving to Arizona and working within the insurance industry for two years, she decided to pursue her interest in Optometry and is currently a candidate for the Degree of Doctor of Optometry in May of 92 from Pacific University College of Optometry.

Alan LeRoy
Recieved his Bachelor of Science degree from the University of Waterloo, Waterloo, Ontario, Canada and is currently a candidate for the Degree of Doctor of Optometry in May of 92 from Pacific University College of Optometry. Post educational plans include settling into private practice in Castlegar, British Columbia, Canada.
ABSTRACT:

A custom biofeedback computer program for strabismus using the Apple IIGS and Visigraph Eye Monitoring System was evaluated. Two strabismic subjects underwent training sessions using the program and the Visigraph Eye Monitoring System. Numerous difficulties were found including: premature program termination, computer "freeze", lag in tone produced compared to eye movements, and patient motivational factors. The lack of future availability of the Visigraph Eye Monitoring System also hinders the value of the program. The program demonstrated great customizability along with the ability to produce hardcopy information about training session data. The program was also found to be extremely easy to use. The relative usefulness of the program increases the benefit of further modifying and/or rewriting the program for a more powerful computer.
Introduction:

Biofeedback is a two step process involving the monitoring of a bodily function which is not typically under conscious control and returning information to the subject regarding status of that function. Biofeedback has been used with varying degrees of success for the treatment of conditions including limitation of gaze, myopia, amblyopia, nystagmus, and strabismus. Strabismus, by definition, is a neuromuscular control problem when no sensory anomalies are present. It has been shown in the literature that it is possible to correct strabismus through biofeedback training. (1),(2),(3),(4)

One of the difficulties encountered by strabismic patients is the inability to know where the eyes are pointing. Typically, when an eye is deviated, suppression occurs in order to avoid diplopia. This suppression, in turn, removes the sensory cues that are used to help align their eyes. A traditional approach to treating strabismus consists of first breaking down the suppression and then using the sensory system to help align the eyes. (2)

Another approach involves the use of biofeedback to train the motor system first. Auditory biofeedback provides signals that correspond to ocular deviation and these signals can be used by the patient to reduce the ocular deviation. (5)

It is not the purpose of this paper to contribute evidence for the success of biofeedback training for strabismus, but rather to evaluate a computer biofeedback program for use in conjunction with ICT's Visigraph monitoring system. The evaluation consists of rating areas such as: reliability, ease of use, output, customizability, and relative usefulness of the program.

The custom developed software for this project was written using the Pascal language. The software's function is to interpret the information from the Visigraph Eye Monitoring device and produce an auditory feedback stimulus for use in the treatment of strabismus. The Visigraph Eye monitor is a commercial unit which has been marketed as a device to record eye movements during reading tasks. It utilizes the Apple II line of computers connected to the device through an analog-to-digital converter inside the computer. The software supplied with the Visigraph Eye Monitoring system has the capability to compute reading speed and make various eye movement measurements, such as the number of saccades and regressions per line read.

The biofeedback program in this study was developed for use with the Apple IIGS. This is the newest and most powerful computer in the Apple II line. While allowing for increased processing power as compared to its predecessors, the Apple IIGS maintains the ability to run software written for older models. By developing software that is compatible with the Apple II line, the usefulness of the Visigraph Eye Monitoring device could be enhanced by allowing individuals who already own the device to obtain the biofeedback software as an add-on feature. This would greatly expand the functional uses of the device.

In biofeedback training, an objective method of monitoring eye position is required. In this study, infrared emitters and detectors incorporated into the Visigraph monitoring device were used to monitor the subject's eye position. The infrared reflections as measured by the Visigraph were interpreted by the computer to determine eye position. An auditory tone based on the amount of ocular deviation from orthotropic position was emitted by the computer to notify the patient of the degree of misalignment. Greater deviation was represented by a higher pitched tone while a lower pitched tone represented a small deviation. Alignment was indicated by no tone being produced.

One important feature of biofeedback equipment developed in this study, as compared to previous devices, is the ability to monitor the progress of a patient over a
period of time. The software includes the ability to sum the results of each trial during a training session and then print these results in a hard copy form. The printout displays the recorded eye position in bar graph format (see Figure 1).

The program incorporates the ability to vary the desired number of trials per training session, the length of each trial, the duration of each rest period between trials, and the size of a deadzone value. The deadzone value reflects the preciseness of ocular alignment necessary to eliminate the tone. The larger the deadzone, the larger the range of misalignment within which no tone will be produced. A large deadzone is useful in the early stages of training to promote motivation and a sense of accomplishment and success for the subject. By gradually decreasing the deadzone, more precise alignment of the eyes is trained until cosmetic alignment is achieved.

Baseline tropia measurements were taken during a comprehensive vision examination using the Hirschberg method. This consisted of neutralizing the apparent deviation with a prism bar. Subjects chosen did not demonstrate any signs of eccentric fixation or ARC responses and were ages 24 and 40. One subject was a 16 prism diopter right esotrope with 20/20 unaided acuity OS and light perception OD. The other subject was a 10 prism diopter left exotrope correctable to 20/20 OD and OS. Subjects were advised of possible benefits of the biofeedback training (partial or complete cosmetic alignment) as well as possible associated risks (no improvement in alignment, ocular deviations may worsen, development of diplopia) before training sessions began. Sessions were scheduled three times per week for approximately 30 minutes per session over a period of ten weeks ending in May 1991.

The subject was aligned in the Visigraph device using the chin rest and the lighted controls designed for this task. With one eye occluded, the subject adjusted the position of the aiming light until it was seen as fully circular and at its brightest.

Methods:

Two subjects who demonstrated a constant tropia were chosen for this study.
The investigators also judged the alignment based on the corneal reflections of the aiming lights. The procedure was then repeated for the other eye. The habitual lens prescription was used for alignment, calibration and training. In the case of the subject with light perception OD, alignment for that eye was judged solely by the investigators based on maximum intensity and fullness of the corneal reflection of the aiming light.

Once aligned, the subject then underwent a calibration procedure used to tell the computer about the positions of the eyes. With one eye occluded, the subject viewed a character generated by the computer software and displayed on the far left of a computer screen set 85 cm from the Visigraph device. The character was displayed again at the center of the screen and then to the far right. At each position, the subject pressed a button at the bottom of the Visigraph device to indicate to the computer that the eye was positioned at the specified location. The process was then repeated for the other eye. In the case of the subject with light perception OD, calibration was obtained by placing a penlight in front of the displayed character directed toward the eye and instructing the patient to move the eye until the corneal reflex was centered in the pupil. After all six calibrations were made, position data were displayed on the screen. The investigators evaluated the calibration data and if they were within acceptable limits, proceeded with the trial. Ideally, the right and left calibration numbers were equidistant from the central value and the measurements were balanced between the two eyes. The result of the calibration was that the computer now had three postural measurements for each eye, which, when overlapped, produced a range through which the eyes could be monitored for an esotropic or exotropic posture. If both eyes pointed at the center display character, alignment was achieved and no tone would be emitted by the computer.

During training, the subject was instructed to look at a character displayed at the center of the screen and was instructed to reduce the tone generated by the computer by changing their eye position. They were also asked to keep the character clear. Maintaining clarity was done to prevent the subject from utilizing accommodation to affect the vergence system.

The subject was asked to concentrate on the feeling of the eye position and its relation to the pitch of the tone. During the trial, the subject's eyes were observed by the investigators to evaluate the association of the tone and observed eye movements.

The ultimate goal for the subject was to turn the tone off completely and to keep it off as long as possible. The investigators recorded the frequency with which the subject was able to turn off the tone for less than three seconds and for greater than three seconds. After each individual trial, the subject was asked if they had any feelings regarding what the eyes were doing during the trial or any factor they wanted to bring to the investigators' attention.

Before each new trial the subject was realigned and recalibrated. After all trials in the training session, the computer calculated and graphed the subject's performance.

Before each training session, subject data and session parameters were keyed into the computer. The parameters used were two minute trials, five trials per training session, one minute rest periods between trials, and a deadzone value of 60. The deadzone value was set arbitrarily at the beginning of the study as being large enough to allow subjects to experience early success. This value was decreased as the subject progressed thereby requiring more precise alignment of the eyes to turn off the computer tone. The decision to reduce the deadzone was based on the subject's ability to turn off the tone for more than three seconds 1/2 to 2/3 of the time during a trial session. The deadzone
value was then decreased at the next training session.

Results:

<table>
<thead>
<tr>
<th>Session#</th>
<th>Trial 1 Off</th>
<th>&gt;3</th>
<th>Trial 2 Off</th>
<th>&gt;3</th>
<th>Trial 3 Off</th>
<th>&gt;3</th>
<th>Trial 4 Off</th>
<th>&gt;3</th>
<th>Trial 5 Off</th>
<th>&gt;3</th>
<th>DZ</th>
</tr>
</thead>
<tbody>
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<td>0</td>
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<td>6</td>
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<td>4</td>
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<td>0</td>
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<tr>
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<td>0</td>
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<td>4</td>
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<td>8 [2]</td>
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<td>9 [3]</td>
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<td>4</td>
<td>4</td>
<td>11</td>
<td>5</td>
<td>12</td>
<td>37</td>
</tr>
</tbody>
</table>

Note:  
Off refers to the tone being off for less than 3 seconds  
>3 refers to the tone being off for 3 or more seconds

[1] Patient reported eyes do not sting or feel as tired or hurt, and that less effort was needed during this session compared to the previous.

[2] Patient reported that the screen character was jumping around or moving during this session.

[3] Patient reported that opening of the eyes seemed to make the task easier. Patient felt that less effort was needed during this session than the previous. Patient felt less stressed and stronger during this session.

- Indicates that the program terminated prematurely and training data for these trials were not obtained.
Table 2: Training Data for Patient R

<table>
<thead>
<tr>
<th>Session#</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
<th>DZ</th>
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</thead>
<tbody>
<tr>
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<td>Off &gt;3</td>
<td>Off &gt;3</td>
<td>Off &gt;3</td>
<td>Off &gt;3</td>
<td>60</td>
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<tr>
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<td>5</td>
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<td>12</td>
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<tr>
<td>5 [2]</td>
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<td>18</td>
<td>15</td>
<td>12</td>
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<td>11</td>
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<tr>
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<td>7</td>
<td>11</td>
<td>4</td>
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<td>12</td>
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<td>7 [4]</td>
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<td>12</td>
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<td>11</td>
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</tr>
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<td>6</td>
</tr>
</tbody>
</table>

Note:  
Off refers to the tone being off for less than 3 seconds  
>3 refers to the tone being off for 3 or more seconds

[1] Patient reported had to relax eye more than previous trials
[2] Patient reported a feeling of more control during this session
[3] Patient reported an overall tiredness during this session
[4] Patient reported felt like holding eye more in control to keep tone off. Examiners noted first and last trial seemed difficult as patient seemed tense at this session
[5] Patient reported session seemed challenging and the whole process was becoming more precise. Patient was not trying to relax his accommodation.
[6] Patient reported the need to relax eyes and blur image and then focus rather than relax and keep target focused the whole time
[7] Patient reported ability to know when accommodating and when relaxing eyes
[8] Examiners noted patient was stressed prior to the session and was falling asleep

- Indicates that the program terminated prematurely and training data for these trials were not obtained.
Graphical Depiction of Training Data for Patient L:
Graphical Depiction of Training Data for Patient R:
Trial Numbers

Session #12

Trial Numbers

Session #10

Trial Numbers

Session #14

Trial Numbers
Session #15

Session #16

Session #17
Discussion:

Difficulties were encountered throughout the project relating to software reliability and subject participation. Sessions were often terminated prematurely due to the program running fewer trials than set by the investigators. This in turn would affect the graphical results printed, as the subject's performance could improve or worsen in the final trials of a training session but would not be included in that session's data. At other times, the computer mouse pointer would disappear from the screen or the program would freeze preventing the investigators from running the session. Subjects did not come to every training session and one subject began the project late with the result being that the anticipated number of training sessions was not met.

Despite these difficulties, the subject with light perception OD did appear to make substantial progress toward cosmetic alignment after 20 sessions. The subject had advanced to a moderately narrow deadzone value and numerous outside sources unrelated to this study had indicated they perceived a greater alignment of the subject's eyes towards the final stages of training.

The other subject showed little improvement in alignment after 9 sessions, but the number of sessions may be too low to justify commentary on the effectiveness of the software. In addition, this subject's deviation was present for a much longer time period than the other subject's which may also have an effect on the length of training necessary to demonstrate improvement.

In terms of ease of use, the graphical environment of the Apple IIGS allowed for easy operation of the biofeedback software. The use of menus to select options and the use of dialog box entry for program parameters allows even the minimally skilled computer user to operate the software. For those familiar with the Macintosh operating environment, movement to the Apple IIGS environment will seem relatively easy and second nature. Unfortunately, evaluating and determining acceptable calibration figures is more difficult and somewhat ambiguous as calibration standards have not been previously established. With training, however, the user would be able to perform this task effectively.

The graphical output, on screen and hard copy, makes for easy and informative result comparisons of a subject's progress throughout the training sequence. Not only does the graphical output allow the operator to quickly analyze the session's data, but it also provides the means for the biofeedback
program director and subject to evaluate progress.

The ability of the software to allow for various parameter changes such as number of trials to run per session, length of each trial, duration of each rest period, volume of tone produced and deadzone value allows for extreme flexibility in customizing a training program for each subject. One particularly noteworthy comment made by one of the subjects in this study is that it was felt to be more beneficial to have a smaller deadzone as this resulted in the tone being on a greater percentage of the time thereby providing more feedback with changes in tone as opposed to having the tone off completely. The goal in this case being a reduction in the pitch rather than elimination of the tone.

During the creation of the biofeedback software, there was a concern that the processing power of the Apple II GS would not be sufficient to perform the intense data gathering, data processing, and tone production necessary to give an accurate representation of the eye's measured position. Although response time for changes in tone would be enhanced with an advanced system and the computing power of the Apple II GS is greatly behind that of more technologically advanced modern systems currently available, it appears that the computing power of the II GS is sufficient to provide adequate feedback as to the position of the eyes. That is, there did not appear to be a significantly large lag between when the eye movement was made and when the change in tone was produced based on subjective evaluation by the subjects.

Insufficient data was collected during this study to evaluate the success of this software as a biofeedback tool due to the low number of sessions completed and the limited subject base, but there appeared to be a positive trend in results for the patient with light perception both subjectively and objectively. This and the limited availability of devices of this nature currently on the market make this software valuable. The difficulties encountered with its operation suggest the need for future modification to establish a more reliable product as reliability is the single largest factor hindering its performance. However, problems dealing with production of software for the Apple II GS and accessibility of the Visigraph Eye Monitoring device may cause further development to be abandoned. As of this writing, future availability of the Visigraph is in question. ICT, the company producing the Visigraph, is currently undergoing economic restructuring, and it has been reported that the Visigraph is currently not in production and will no longer be available. Attempts to deal directly with the company to obtain information or assistance with the Visigraph hardware have been unsuccessful. The Apple II GS is still available through mail order, but the computer market is shifting toward the more powerful Macintosh and IBM lines. The future of the Apple II GS is therefore as unpredictable as that of the Visigraph. If the Visigraph continues to be made available, a more feasible plan would be to have the program written for either the Macintosh or IBM/IBM clone lines of computers which would eliminate any question regarding adequate power for processing of this software and use in a biofeedback application.
References


