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The biofeedback correction of unsteady and eccentric fixation in amblyopia associated with strabismus and anisometropia

William Richard Hallmark
Pacific University

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The biofeedback correction of unsteady and eccentric fixation in amblyopia associated with strabismus and anisometropia

Abstract
The biofeedback correction of unsteady and eccentric fixation in amblyopia associated with strabismus and anisometropia

Degree Type
Thesis

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The Biofeedback Correction of Unsteady and Eccentric Fixation in Amblyopia Associated with Strabismus and Anisometropia

A Thesis
In Partial Fulfillment of Requirements for the Degree Doctor of Optometry

Presented to
The Faculty of the College of Optometry
of
Pacific University

March 1977

by
William Richard Hallmark

Advisor: Clifton M. Schor, O.D., Ph.D.
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Acknowledgements

I wish to thank Dr. Clifton Schor for his guidance in this investigation.

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Thanks, B.S.K.
The Biofeedback Correction of Unsteady and Eccentric Fixation in Amblyopia Associated with Strabismus and Anisometropia

Introduction

People with amblyopia are often afflicted with abnormal fixation control of their amblyopic eyes; people with normal binocular vision receive visual feedback to confirm or correct eye position to the eye's aim intent. If a visual system develops abnormally, a lack of sensory feedback may occur, thereby contributing to oculomotor anomalies. Of specific interest to us are the anomalies of unsteady fixation and eccentric fixation in amblyopia associated with strabismus and anisometropia. Since a lack of visual feedback appears to be the cause of monocular fixation errors and of fixation unsteadiness, it occurred to us that an alternative form of biofeedback might be of use in their connection.

The classical usage of auditory feedback is associated with Bangerter who has used it in several forms to signal errors in visually guided tracing. More recently, verbal auditory feedback has been used in normal subject to control the direction, magnitude, and occurrence of fixation saccades.

Characteristics of Eccentric Fixation

The normal eye, upon attempted steady fixation, is known to have three distinct kinds of movement. First, microsaccadic movements are constantly
taking place at the rate of about 85 per second. These movements have an extent of about 10" of arc. The second kind of movement is the slow drift, which occurs in random directions. Small, periodic, rapid saccades are the third type of eye movement found in the normal eye. These saccades occur about every second and have an extend of about 5' of arc.\(^1\)

The amblyopic eye, upon attempted steady fixation, has the three kinds of movements described above, but these movements are greatly exaggerated.\(^1,3,4\) It has been found that fixation steadiness is greater if the fovea is used for fixation. If a nonfoveal site is used to fixate, then the smaller the area of this site, the steadier the fixation. Unsteadiness increases when the fixation site is variable. Since anisometropic amblyopes usually have central fixation, they tend to have more stable fixation than squinting amblyopes.\(^1,5\)

Dark adapted amblyopes behave essentially as normals in terms of their eye movements upon attempted steady fixation.\(^1,4\)

Using the fovial center as a point of reference for measuring the angle of eccentric fixation, steadiness of fixation has been found to increase as the angle gets smaller. As this happens, visual acuity is also found to improve.\(^6\) Homer devised a formula to determine visual acuity at an eccentric retinal site, and the formula is used to approximate acuities in amblyopic eccentric fixations. The formula is: 
\[
MAR = EF + 1 \quad (1)
\]

\(MAR = \) minimum angle of resolution in minutes of arc

\(EF = \) eccentric fixation in prism diopters
Current Methods of Treatment

Accepted treatment regimens include either direct or inverse occlusion concurrently with training. Bangster's pleoptics methods depress eccentric retinal loci so that fixation will be more favorable with the fovea. Lights within the visual field are then flashed on and off to increase foveal transmission. When the peripheral retina is desensitized, the center of the afterimage scotoma is 'aimed' in monocular fixation drills. (1)

Bangster's Localizer, a box having illuminated holes, uses tactile feedback to establish centric fixation and to correct spatial localization. The patient points at and touches the illuminated holes. Bangster's Corrector consists of mazes of various complexity over which the patient traces out the "path" with a metal hand held stylus. If the patient moves off the "path," an electrical circuit is completed to then provide auditory feedback.

Another training device, The Drill, is designed to train hand-eye coordination and spatial localization. The patient's task is to place a metal rod into the center of a tube. If a poor placement is made, and the rod touches the side of the tube, a buzzer sounds to signal the error. (1)

Another Bangster device is called the Vibrating Localizer; it uses auditory, tactile, as well as visual clues for localization. The device is held behind a translucent screen; the sound and vibration of the device are required for localization. After correct localization from the tactile and auditory clues, illumination replaces the sound and vibration as feedback.
The Acoustic localizer also provides tactile, visual and auditory feedback for correct spatial localization and hand-eye coordination. With this device, the patient places a stylus into an illuminated hole. Tactile feedback is provided by a magnetic field that attracts the stylus. Auditory feedback occurs as the hole is approached and contacted by the stylus. (1)

Cippers' method provides visual feedback to correct position errors. The fovea of the amblyopic eye is tagged either with an afterimage or with Haidinger's brushes, and the patient's task is to then aim the tagged fovea at a target. (1)

The possible improvements to anomalous fixation by these and other means of biofeedback are the correction of position error and the correction of high amplitude micro saccades.

Methods

Our experimental objective is to measure and record micro saccadic eye movements of normal and amblyopic eyes under monocular viewing conditions. The subject's fixation instructions are modified periodically throughout the experiment: measurements of saccadic amplitude and frequency, and measurements of drift direction and duration are made both with and without biofeedback. Changes in these features are evaluated in terms of the instructions (i.e. visual task-demand), and in terms of the biofeedback provided or withheld. The types of biofeedback used are both auditory and visual. The visual biofeedback is provided by a Haidinger's brushes device, which gives a signal for aim position error. The auditory device obtains its
signal from an eye movement monitor; it is possible to obtain either a
position error signal from the auditory signal generator, or a burst of
sound each time a saccade is made. Both visual and auditory biofeedback
may be given to a subject simultaneously. In this study, the innate fixation
patterns after correction for the micro saccades are found for both normal
and amblyopic subjects.

Experimental Design and the Apparatus
Drift and saccadic fixation qualities will be examined under the
instructional preset for fixation. The fixational qualities are also
examined in the presence of biofeedback with the biofeedback being the
only variable. Any differences in the fixational features then only reflect
the influence of the biofeedback.

Parts of the apparatus are as follows:

1. The Eye Movement Monitor

The eye movement monitor is a Biometrics SSVH-2 Infrared Eye
Movement Monitor. It records the eye position of the fixing eye while the
subject performs various fixation tasks.

2. The Recorder

The resultant eye positions are recorded on a strip chart recorder
(Honeywell Visicorder), and the results are analyzed in terms of amplitude,
and frequency of saccades, and in terms of drift velocity and direction.
3. The Differentiator and Auditory Signal Generator

During the task of biofeedback, the voltage analogue of the derivative of the eye movements drives twin speakers so that bursts of sound are emitted by the left speaker during leftward saccades and by the right speaker during rightward saccades. The pitch of the burst is related to the magnitude of the saccades. The subjects sat between the two speakers with the left speaker on the left and the right speaker on the right such that the direction of the sound corresponded to the direction of the eye movements.

4. The Visual Stimulus

A. The subjects fixated a target consisting of a "plus" constructed of 1/8 inch wide black "Chart Pack" tape. The dimensions of the "plus" are three inches by five inches, and the tape is mounted on a three inch by five inch white index card. A small fluorescent dot covers the intersection of the two lengths of black tape. The target was placed 34 inches from the subjects' eyes.

B. The subjects were instructed to fixate a small spot on the screen of the Haidinger's brushes device so as to place the center of the moving propeller on the spot.

5. The Dental Acrylic Bite Board

A dental acrylic bite board was used to provide stability for the subjects' head positions, thereby greatly eliminating the introduction of noise into the measurements.
The following information is offered concerning the experimental subjects:

1. The Source

Our subject source is the Pacific University College of Optometry student and clinical populations.

2. Subject Characteristics.

Five of the subjects are either anisometropic or strabismic amblyopes having fixation tremor and possibly eccentric fixation. One subject has normal acuity, and no strabismus or anisometropia.

3. Subject Release Forms

The proper release forms have been obtained for each subject.

4. Instructions to the Subjects

During the experiment, recordings of eye movements are made under each of the following instructional presets:

A. The subject is instructed: "Look at the target."

B. While providing saccadic feedback, the subject was instructed to suppress the production of the feedback's rapid fire, high pitched squeal. He was instructed that each of these fleeting sounds reflect a micro saccade, and that he has voluntary control over them. The subject was told not to be concerned if he found his eye drifting off target. The subject was told:

"Just let it go ahead and drift. Don't make an attempt to look back at the intersection of the two black lines. Be rather oblivious to the presence of the target."
C. In the cases in which auditory position biofeedback was provided, the subject was instructed to move his eye from side to side until he found a position where sounds from both speakers were at an equally low tone.

D. When auditory saccadic biofeedback and visual position biofeedback were given, the subject was asked first to stop making saccades; he was then asked to try and control his drift to the extent that he align the fixation point with the center of the propeller on the Haidinger's brushes devise.

Discussion

A problem which exists when using an audio signal for position error correction is that the signal and therefore the null (i.e. on target) position may be changed simply by changing the palpebral fissure size. This is especially true of subjects with narrow fissures. Consequently this method of position error correction was abandoned in favor of Haidinger's brushes. An additional advantage of using Haidinger's brushes is that correction for both fixation position errors and fixation tremor may be given simultaneously. It is important to note that the problem of changing fissure size does not exist when the eye movement signal is passed through the differentiator.
Results

On the following pages are examples of the subjects' eye position records. In all cases the tracings were calibrated by having the subject look alternately from one point to another on the target. The gain on the eye movement monitor was adjusted to a convenient level. For subjects B.K., N.O., G.W., and K.S. the scale is approximately equal. For subject B.G. the scale is decreased by a factor of approximately 2.5; for normal subject S.H. the scale is increased by a factor of approximately 2.0. Additionally, the time scale for subject S.H. is compressed for some segments shown. All segments for all subjects cover a time span of 10 seconds.

In general, the eye movements shown were the ones used to calculate the results found in the accompanying tables. These segments were chosen as the best 10 second element illustrating minimum saccadic frequency and amplitude, and minimum drift rate. In the case of one subject, G.W., two fixation segments are shown, the one being more illustrative of drifts to the extent that measurements could be made; the other tracing gave smaller readings for saccades. Numerical evaluations are given for each saccadic test done. This was not possible for the drifts in many cases because the duration and directions were so variable. A qualitative evaluation of the drift characteristics is given for the cases in which a numerical evaluation was not possible.
<table>
<thead>
<tr>
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<th>AMBLYOPIA STEADY FIXATION</th>
<th>AUDITORY SACCADIC BIOFEEDBACK</th>
<th>AUDITORY POSITION BIOFEEDBACK</th>
<th>VISUAL POSITION BIOFEEDBACK</th>
<th>AUDITORY SACCADIC AND VISUAL POSITION BIOFEEDBACK</th>
<th>PERSISTENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AMP</td>
<td>RATE</td>
<td>AMP</td>
<td>RATE</td>
<td>AMP</td>
<td>RATE</td>
</tr>
<tr>
<td>G.W.</td>
<td>0.74</td>
<td>2.0</td>
<td>0</td>
<td>0</td>
<td>0.65</td>
<td>0.5</td>
</tr>
<tr>
<td>R.K.</td>
<td>0.68</td>
<td>1.3</td>
<td>1.18</td>
<td>1.1</td>
<td>0.77</td>
<td>1.4</td>
</tr>
<tr>
<td>M.O.</td>
<td>0.72</td>
<td>2.3</td>
<td>0.66</td>
<td>0.3</td>
<td>0.29</td>
<td>0.4</td>
</tr>
<tr>
<td>K.S.</td>
<td>0.63</td>
<td>0.6</td>
<td>0.39</td>
<td>0.3</td>
<td>0.30</td>
<td>0.2</td>
</tr>
<tr>
<td>B.G.</td>
<td>0.32</td>
<td>1.7</td>
<td>0</td>
<td>0</td>
<td>0.97</td>
<td>0.6</td>
</tr>
<tr>
<td>S.H.</td>
<td>0.13</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>0.24</td>
<td>0.2</td>
</tr>
</tbody>
</table>

(NORMAL)

**Note:**
The amplitude of the saccades (AMP) is given in degrees per saccade. The frequency of saccades (RATE) is given in saccades per second.

For subjects G.W. and K.S., persistence reading were taken directly after saccadic biofeedback as well as after the entire session (above right). Persistence directly after saccadic biofeedback for these two subjects is as follows:

G.W. AMP = 0.60 RATE = 1.0

K.S. AMP = 0 RATE = 0
<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>AMBLYOPIC</th>
<th>AUDITORY POSITION FEEDBACK</th>
<th>AUDITORY POSITION FEEDBACK</th>
<th>VISUAL &amp; VISUAL POSITION FEEDBACK</th>
<th>AUDITORY &amp; VISUAL SACC. PERSISTENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.W.</td>
<td>DX=NASAL RATE=0.50</td>
<td>NO DRIFT</td>
<td>NO DRIFT</td>
<td>DX=NASAL</td>
<td>NO DRIFT</td>
</tr>
<tr>
<td></td>
<td>DX=TEMP RATE=0.12 (both v)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.K.</td>
<td>DX=TEMP RATE=0.22</td>
<td>DX=V</td>
<td>DX=V</td>
<td>DX=NASAL</td>
<td>HIGHLY V. IN RATE &amp; DX</td>
</tr>
<tr>
<td></td>
<td>RATE=LOW</td>
<td>RATE=LOW</td>
<td>RATE=LOW</td>
<td>RATE=LOW</td>
<td>DURATION SHORT, BETWEEN ½ TO 1SEC.;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RATE UP TO 0.69 S</td>
</tr>
<tr>
<td>M.O.</td>
<td>DX=NASAL RATE=0.30</td>
<td>NO DRIFT</td>
<td>NOT DONE</td>
<td>NO DRIFT</td>
<td>DX=V; DURATION USUALLY</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NO DRIFT</td>
<td>ABOUT 0.5 SECONDS.</td>
</tr>
<tr>
<td>K.S.</td>
<td>DX=NASAL RATE=0 TO 0.27 (v)</td>
<td>DX=NASAL</td>
<td>DX=NASAL</td>
<td>DX=NASAL RATE=0.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DX=NASAL RATE=0 TO 0.49 (v)</td>
<td></td>
<td>DX=NASAL</td>
<td>RATE=0.30</td>
<td>DURATION=1SEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DX=NASAL</td>
<td>RATE=0.22</td>
<td></td>
</tr>
<tr>
<td>B.G.</td>
<td>NO DRIFT</td>
<td>NO DRIFT</td>
<td>NOT DONE</td>
<td>DX=NASAL RATE=0 TO 0.12</td>
<td>NO DRIFT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.H.</td>
<td>NO DRIFT (NORMAL)</td>
<td>DX=NASAL</td>
<td>NOT DONE</td>
<td>NO DRIFT</td>
<td>NO DRIFT</td>
</tr>
<tr>
<td></td>
<td>DX=NASAL RATE=0 TO 0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DUR=2SEC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
The following abbreviations are used in the above table: DX = DIRECTION OF DRIFT; TEMP = TEMPORAL; DUR = DURATION OF DRIFTS IN SECONDS; V = VARIABLE; The rate of drifts is given in degrees per second.
<table>
<thead>
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<th>Subject</th>
<th>Best Aided Acuity</th>
<th>RX</th>
<th>Fixation of Amblyopic Eye</th>
<th>Phoria or Tropia</th>
<th>Correspondence</th>
</tr>
</thead>
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<tr>
<td>G.W.</td>
<td>OD 20/15</td>
<td>+4.25 sphere</td>
<td>nasal/ sup. e. f. 6-8°</td>
<td>10° left</td>
<td>UARC</td>
</tr>
<tr>
<td></td>
<td>OS 20/40</td>
<td>+3.75 sphere</td>
<td>unsteady</td>
<td>SOJ</td>
<td></td>
</tr>
<tr>
<td>B.K.</td>
<td>OD 20/20</td>
<td>-7.00-2.50x180</td>
<td>central</td>
<td>12° SOJ @ J</td>
<td>HARC (troposcope)</td>
</tr>
<tr>
<td></td>
<td>OS 20/15</td>
<td>-6.00-2.50x180</td>
<td>unsteady</td>
<td>25° SOJ @ N</td>
<td>NRC (Bielschowsky)</td>
</tr>
<tr>
<td>M.O.</td>
<td>OD 20/15</td>
<td>+0.50-0.75x20</td>
<td>nasal e. f.</td>
<td>4° SOP @ N</td>
<td>NRC</td>
</tr>
<tr>
<td></td>
<td>OS 20/40</td>
<td>+0.50-0.75x55</td>
<td>unsteady</td>
<td>ortho @ J</td>
<td></td>
</tr>
<tr>
<td>K.S.</td>
<td>OD 20/20</td>
<td>+1.50-0.25x180</td>
<td>nasal e. f.</td>
<td>10° left</td>
<td>ARC</td>
</tr>
<tr>
<td></td>
<td>OS 20/60</td>
<td>+1.50-0.50x78</td>
<td>unsteady</td>
<td>SOJ</td>
<td></td>
</tr>
<tr>
<td>B.S.</td>
<td>OD 20/30</td>
<td>-1.25-1.25x75</td>
<td>central</td>
<td>4° XOP @ N</td>
<td>NRC</td>
</tr>
<tr>
<td></td>
<td>OS 20/15</td>
<td>-0.50-1.25x50</td>
<td>unsteady</td>
<td>5° XOP @ J</td>
<td></td>
</tr>
<tr>
<td>S.H.</td>
<td>OD 20/15</td>
<td>-1.75-0.25x88</td>
<td>central</td>
<td>2° XOP @ J</td>
<td>NRC</td>
</tr>
<tr>
<td>(normal)</td>
<td>OS 20/15</td>
<td>-2.00-0.12x176</td>
<td>steady</td>
<td>4° XOP @ N</td>
<td></td>
</tr>
</tbody>
</table>

Note:
Abbreviations used in the above table are as follows: sup.=superior; e. f.= eccentric fixation; SOJ=esotrope; XOP=exophore; SOP=esophore; N=near; J=far; UARC=Unharmonious ARC; HARC=Harmonious ARC; ARC=Abnormal Retinal Correspondence.
AMBLYOPIA STEADY FIXATION (DRIFT SEGMENT)

AMBLYOPIA STEADY FIXATION (SACCADIC SEGMENT)

AUDITORY SACCADIC BIOFEEDBACK

AUDITORY POSITION BIOFEEDBACK

VISUAL POSITION BIOFEEDBACK

AUDITORY SACCADIC AND VISUAL POSITION BIOFEEDBACK

PERSISTENCE DIRECTLY AFTER AUDITORY SACCADIC BIOFEEDBACK

PERSISTENCE
SUBJECT: B.K.

AMBYTOPIC STEADY FIXATION

AUDITORY SACCADIC BIOFEEDBACK

VISUAL POSITION BIOFEEDBACK

AUDITORY POSITION BIOFEEDBACK

PERSISTENCE
AMBLYOPIC STEADY FIXATION

AUDITORY SACCADIC BIOFEEDBACK

VISUAL POSITION BIOFEEDBACK

AUDITORY SACCADIC AND VISUAL POSITION BIOFEEDBACK

PERSISTENCE
SUBJECT: K.S.

AMLYOPTIC STEADY FIXATION

AUDITORY SACCADIC BIOFEEDBACK

AUDITORY POSITION BIOFEEDBACK

VISUAL POSITION BIOFEEDBACK

AUDITORY SACCADIC AND VISUAL POSITION BIOFEEDBACK

PERSISTENCE DIRECTLY AFTER AUDITORY SACCADIC BIOFEEDBACK

PERSISTENCE
AMBYLGYRIC STEADY FIXATION

AUDITORY SACCADIC BIOFEEDBACK

VISUAL POSITION BIOFEEDBACK

AUDITORY SACCADIC AND VISUAL POSITION BIOFEEDBACK

PERSISTENCE
NORMAL STEADY FIXATION

NOTE AND TAKE INTO ACCOUNT THE TIME SCALE DIFFERENCES (VERTICAL LINE SPACINGS) FOR THIS SUBJECT.

VISUAL POSITION BIOFEEDBACK

PERSISTENCE

AUDITORY SACCADIC AND VISUAL POSITION BIOFEEDBACK

SUBJECT: S.H.
Conclusions

We made the following observations during the sessions with the subjects, and we made the following deductions from the data collected:

1. Fixation stability varied within subjects on a given task as a function of time.

2. Fixation characteristics could be modified by various forms of biofeedback.

3. The effectiveness of the biofeedback varied between subjects (e.g., some subjects liked auditory; some subjects liked visual; some subjects liked both; some subjects did not respond well to either.)

4. Not all forms of biofeedback were equally effective for each subject, but there were some consistencies: saccadic auditory biofeedback and position visual biofeedback were generally very effective.

5. The rate of learning or delay of first modification of behavior differed for various forms of biofeedback. Visual is fastest. (Perhaps visual is fastest because the subject is accustomed to responding to a visual stimulus rather than an auditory one.)

6. A number of the subjects showed fixation improvement following biofeedback, however a control should be run to determine the influence of placebo on biofeedback.

7. Subjective reports by the subjects tell us that eccentric fixation is still present after saccades have been suppressed. It is necessary to correct the position error of eccentric fixation, preferably
with visual biofeedback, and enhance visual acuity.

8. All subjects report fading of the fixation target (Iroxler's phenomenon) with the elimination of saccades in steady fixation.