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Abstract
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Tilt Aftereffect As A Measure of Vision Therapy Success

By

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Steven J. Cool, Ph.D.
ABSTRACT:

In this study a method of testing binocularity called the Tilt Aftereffect (TAE) was used before and during a subject's vision therapy program. There were 8 subjects, each being treated for general binocular dysfunction by private practicing optometrists. The inter-ocular transfer (IOT) of the TAE was measured pre and post-therapy to determine the improvement in binocularity. It was found that there was no significant improvement in the subjects' ability to perceive the IOT of the TAE. There was a wide range of variability in the pre to post measurements. It is thought that this may be indicating that the binocular pathway responsible for the interocular transfer is in a state of change and instability due to the effects of vision therapy.
INTRODUCTION:

One of the goals of an optometric practitioner is to improve a patient's binocular abilities. When a patient presents with general binocular dysfunction vision therapy (V.T.) is often successfully used to improve binocularity. However, it is often difficult for a practitioner to determine to what degree binocularity has improved.

There is some controversy in the medical professions surrounding the issue of using vision therapy as a method of treating general binocular dysfunction successfully. There are many subjective tests used that prove that binocularity can be improved with V.T., but to date, there are not any objective tests commonly used to measure improved binocularity as the result of V.T.

In this research a method of testing binocularity called the Tilt Aftereffect (TAE) was used. The tilt aftereffect was first described by Gibson in 1933. It involves visual adaptation to an off-vertical grating, followed by a change in perceived vertical by the observer. Vertical lines will appear tilted in the opposite direction of the tilted adaptation grating. Gibson also found that an inter-ocular transfer (IOT) of the tilt aftereffect occurs when the off-vertical adapted eye is occluded and the non-adapted eye is allowed to view a vertical grating, again the vertical will be perceived tilted opposite the grating. Thus there is a transfer of information from one eye to the other. This transfer of information is thought to be via a neural pathway of binocular visual cortex cells in Brodman's area #17. This established the TAE as a possible objective measure of binocularity (Gibson, 1933).
Early studies of interocular transfer in human observers with reduced stereovision, as measured by standard subjective binocular tests supported the idea that both stereopsis and IOT may be indicators of cortical binocularity (Movshon et al, 1972; Mitchell and Ware 1974; Mann, 1978). These studies also showed a high correlation between binocularity as measured with the subjective Randot stereoacuity to the objective TAE findings. Mann (1978) has found that the amount of IOT is greater in subjects with higher degrees of binocularity.

In this study the TAE is used to measure binocularity before and during the patient's vision therapy program. The degree of binocular vision, as measured by TAE-IOT, was to be compared to Randot stereoacuity findings and to the optometrist's opinion of the patient's binocular abilities. The thought is that the TAE could be used as an independent, objective means of evaluating the success of V.T. procedures used in treating patients with general binocular dysfunction. If the results were positive, it was felt that this method of testing would provide the objective evidence that V.T. is a viable method of treating patients with binocular dysfunctions. This would make vision therapy a more acceptable mode of treatment for the public as well as the medical community.

METHODS:

Apparatus:

The TAE testing device is comprised of a 24" diameter polycarbonate globe with an affixed shroud, rubber face forming hood, and a chin rest. The distance from the patients eyes to the grid
targets is one meter. Just in front of the rubber hood is a centrally pivoting occluder, which can be adjusted so the target can be seen with only one eye at a time. Lighting is provided by three equally spaced 15 watt bulbs on the patient's side of the dome. These lights are not directly visible to the patient. The light intensity can be set with a rheostat separate from the on/off switch. Due to the nature of the construction, no vertical/horizontal or straight lines are visible to the patient (Figure 1).

Figure 1

Two targets are used, a grating tilted 10° off vertical and a vertical grating. The dome has a flat back insert with an oval hole cut in it. Behind this hole is a track for the plate with the 80° grating to ride on. Behind this is a solid back wall with the vertical grating and the adjustable pointer. When the 80° grating plate is slid into place, it completely fills the oval cutout blocking the vertical grating and pointer from view. The horizontal space between the two grids is five millimeters. The inside of the
instrument is painted flat black with the grating being black on white and the pointer white. The gratings are 36 arc seconds and the pointer the same. The gratings are circular and gratings and pointer are 6 centimeters in diameter. The center of the pointer is exactly horizontal and 5 centimeters to the left of the vertical grating (Figure 2).

![Figure 2](image)

The pointer is on a solid shaft that projects out the back of the device. Here, another pointer is attached. This pointer rides on a degree incremented protractor which is solidly mounted to the device. By this construction, there can be no variation between the inside and outside pointers and the protractors. A gear and chain drive on the end of the shaft connects to a gear and shaft which is within the patient's reach. The patient then sets the pointer by turning the knob on their end of the shaft. Even though a gear system is used here which inherently has play in it, the patient can set the pointer exactly to match their perception of vertical by slight movement of the knob.
Procedure:

The subjects were chosen for this study by several private practicing optometrists. They were to choose patients seen in their office that would be starting a vision therapy program for general binocular dysfunction. The subjects were tested on the day of their first vision therapy session. Using the apparatus previously described, a baseline for each subject was determined. This was obtained by asking the subject to set the measuring line parallel to the 90 degree grating lines, using only the right eye, with the left eye occluded. Each subject made five settings, separated by a 30-second rest period. The average of these settings was used as the vertical baseline for the subject.

The subject then viewed the 80 degree adapting grating for 2.5 minutes, using only the right eye. S/he then viewed the 90 degree test grating, using the right eye only, and was asked to set the measuring line, as quickly as possible, parallel to the lines of the test grating. This is a measure of tilt aftereffect. Again the subject viewed the 80 degree adapting grating, this time for 25 seconds, using the right eye only. S/he then viewed the 90 degree testing grating, using the left eye only with the right eye occluded and was asked to set the measuring line, as quickly as possible, parallel to the lines of the test grating. This gives a measure of the inter-ocular transfer of the tilt aftereffect. Finally, the subject viewed the 80 degree adapting grating for another 25 seconds, using the right eye only. S/he then viewed the 90 degree test grating, using the right eye only, and was asked to set the measuring line as
quickly as possible, parallel to the lines of the test grating. The procedure was repeated until five readings of the TAE and five readings of the IOT had been recorded. Following a 15 minute rest period the procedure was repeated using the left eye as the adapting eye.

RESULTS:

The results are presented in Table 1. There were eight subjects with general binocular dysfunction. The pre-therapy findings were taken at the start of the vision therapy program. The post-therapy readings were taken several months later. It was hoped that the post readings would take place at the subject's final vision therapy session, but because of time constraints, the post-therapy readings represent measurements taken several months into the V.T. program.

Table 1

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Adapting OD</th>
<th>Adapting OS</th>
<th>Ave. % IOT</th>
<th>%IOT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TAE</td>
<td>IOT</td>
<td>% IOT</td>
<td>TAE</td>
</tr>
<tr>
<td>C.K.</td>
<td>Pre</td>
<td>2.40 1.60</td>
<td>66.67</td>
<td>4.20</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>-0.80 1.80</td>
<td>300.00</td>
<td>0.80</td>
</tr>
<tr>
<td>K.H.</td>
<td>Pre</td>
<td>1.00 2.00</td>
<td>200.00</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>1.80 2.00</td>
<td>111.11</td>
<td>-0.40</td>
</tr>
<tr>
<td>K.D.</td>
<td>Pre</td>
<td>0.00 1.40</td>
<td>0.00</td>
<td>1.40</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.40 1.80</td>
<td>52.94</td>
<td>1.80</td>
</tr>
<tr>
<td>M.L.</td>
<td>Pre</td>
<td>1.00 2.40</td>
<td>240.00</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.80 3.80</td>
<td>100.00</td>
<td>2.80</td>
</tr>
<tr>
<td>R.F.</td>
<td>Pre</td>
<td>-0.80 -2.00</td>
<td>-250.00</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>1.40 1.40</td>
<td>100.00</td>
<td>-0.40</td>
</tr>
<tr>
<td>S.M</td>
<td>Pre</td>
<td>1.40 1.80</td>
<td>128.57</td>
<td>-1.00</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>1.00 2.60</td>
<td>260.00</td>
<td>2.60</td>
</tr>
<tr>
<td>D.H.</td>
<td>Pre</td>
<td>3.00 3.80</td>
<td>126.67</td>
<td>-1.20</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>1.40 1.80</td>
<td>128.57</td>
<td>1.40</td>
</tr>
<tr>
<td>L.W.</td>
<td>Pre</td>
<td>-1.20 0.00</td>
<td>0.00</td>
<td>-0.20</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>-0.20 0.40</td>
<td>200.00</td>
<td>1.40</td>
</tr>
</tbody>
</table>
The adaptation grating used in this study was set at 80 degrees. Therefore, the expected TAE when viewing the vertical test grating is greater than 90 degrees, since the TAE is in the direction opposite the adaptation grating. The TAE and IOT values in the table are in degrees from 90. When the subject set the pointer in a position less than 90 degrees the value is given a negative sign, and if positioned greater than 90 degrees it is given a positive sign.

The TAE values represent the tilt aftereffect as measured by the adapted eye. The IOT values represent the tilt aftereffect that has transferred to the opposite eye and is measured by the non-adapted eye. Each value represents an average of five readings. The percent IOT is found by dividing the TAE value by the IOT value. The %IOT value is positive when the IOT value is positive.

The average %IOT represents the average of two values, the inter-ocular transfer when the right eye was adapted and when the left eye was adapted. This gives an over-all average of the amount of transfer of the TAE between the two eyes. The delta %IOT is the difference between the post-therapy average %IOT and the pre-therapy average %IOT. These values show if there was an improvement or a regression in the ability to transfer the tilt aftereffect following vision therapy.

A difference t-test was used to compare the data. The difference between the pre and post values, delta %IOT, when analyzed showed there was no significant difference (t=0.97, df= 15). This means that there was no significant improvement in the subjects' ability to perceive the IOT of the tilt aftereffect, following several weeks in vision therapy. Some subjects did show improvement (C.K., K.D., S.M., D.H., L.W.), while others regressed (K.H.,
The interesting finding is that there is a wide range of change in the pre to post measurements of IOT.

DISCUSSION:

The results of this study have shown that there is a wide range of variability in the amount of inter-ocular transfer of the tilt aftereffect found during a subjects' vision therapy program. This may be indicating that the binocular pathway responsible for inter-ocular transfer is in a state of change and instability due to the effects of vision therapy. Perhaps when the subject reaches the end of their V.T. program this binocular pathway would be more stable and would provide less variability in the IOT findings. The visual system at the level of visual cortex is thought to be very "plastic" and susceptible to change through such influences as vision therapy. It is very possible that our findings are an indication of this change taking place in the subjects binocular system.

In review of the literature most studies have shown in normal subjects that approximately 70% of the tilt aftereffect is transferred inter-ocularly. In other studies the amount of inter-ocular transfer has been shown to be reduced in subjects with decreased stereopsis (Movshon et al., 1973; Ware and Mitchell, 1974; Mohn and Van Hof-Van Duin, 1982). It is interesting to note that Mohn and Van Hof-Van Duin (1982) found the presence of IOT in stereoblinds and although the IOT was reduced in these subjects, they felt that their findings cast doubt on the usefulness of IOT as a measure of cortical binocularity. In their review of previous literature they found that other studies found the presence of IOT in
35% of all stereoblind subjects tested.

In another study done by Buzzelli (1981) on the presence of IOT in periodic and constant strabismics compared to normals, he found no significant difference between the groups in their abilities to perceive or transfer the tilt aftereffect. Yet in this same study he suggests that vision therapy be utilized to equalize visual skills in both eyes and thus improve the transfer of the tilt aftereffect. He also gives mention to the study by Hohmann and Cruetzfeldt (1975) where vision therapy was given to subjects after strabismus surgery. It was felt that the vision therapy enhanced the tilt aftereffect and the inter-ocular transfer of it in these post-surgical strabismic subjects.

Although there seems to be some confusion in the literature about the effects of decreased binocularity on the inter-ocular transfer of the tilt aftereffect, most studies show that improved binocular abilities can enhance the effect. Vision therapy is a means to improve binocular abilities, and is thought to improve inter-ocular transfer. In this study, the findings seem to indicate that vision therapy is causing a change in the neural pathway responsible for IOT. Further research is indicated to help better understand the effects of vision therapy on the inter-ocular transfer of the tilt aftereffect. This may also help provide a more complete understanding of the neural pathway responsible for binocularity and stereopsis.
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