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A study of the magnitude of after effects of the wearing of a 3% meridional size lens axis 90 on judgements of the apparent frontoparallel plane

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Abstract
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"A STUDY OF THE MAGNITUDE OF AFTER EFFECTS OF
THE WEARING OF A 3% MERIDIONAL SIZE LENS AXIS
90 ON JUDGEMENTS OF THE APPARENT FRONTOPARALLEL
PLANE"

HARVEY ESTREN
DAVID GALLAGHER
MAY 10, 1974
PROBLEM: TO STUDY THE MAGNITUDE OF AFTER EFFECTS OF THE TURING OF A 3% MERIDIONAL SIZE LENS AXIS 90 ON JUDGEMENTS OF THE APPARENT FRONTOPARALLEL PLANE.

INTRODUCTION: For many years, researchers in the field of visual perception have reported that distortions of the visible world by the use of aniseikonic ophthalmic lenses and prisms produced tilt adaptation and figural after effects.

Researchers such as Gibson as early as 1933 reported that under conditions of continued viewing of a visibly distorted visual environment, the extent of the apparent distortion diminished as the subject continued to view through the distorting lens. This has often been noted as tilt adaptation.

The removal of the distorting lenses has been reported to produce apparent distortion in the opposite direction to the direction of the primary distortion. This phenomenon is known as a figural after effect and its mechanism is widely disputed and theorized by classical and modern visual researchers.

A common type of distortion is caused by magnification in only one meridian. This is easily replicated by placing a meridional lens before one eye so that the magnification is in the horizontal meridian only. Now as a subject fixates a line in the horizontal position in the frontoparallel plane, the lens increases magnification of the retinal image of the eye. This increases the size of the image on the retina and the image now extends to more peripheral areas. The disparities of the images of the two eyes is now changed by the lens and the corresponding stereoscopic response would be one in which the objects appear rotated away from the eye with the meridional magnification. Ogle diagrams this as follows:
Thus the points which were in the frontoparallel plane have been displaced in space as though rotated about point F. We also see an apparent spatial distortion in that the equal distances PF and FQ now appear to be unequal with FQ appearing longer. In summary, objects appearing on the right side of the field have been enlarged and pused away while those on the left side have been made smaller and brought nearer.

Epstein demonstrated an adaptive shift in stereoscopic depth following exposure to the exaggerated disparity produced by placing a meridional size lens (MSL) in front of one eye as evidence of a recalibration of disparity, attributable to the continuous pairing of disparity with discrepant monocular determinants of depth during the exposure period.

One of the principle unsettled issues in Epstein's study of adaptation concerns the locus of adaptation. Epstein advocates a visual shift hypothesis. Among the competing views, the hypothesis of proprioceptive shift has been prominent. According to this hypothesis, the shift underlying adaptation involves the felt position of parts of the body.
When changes in registered eye position are included in the domain of proprioceptive shift, the hypothesis insists that the relationship between disparity and perceived depth is unaffected.

In Epstein's 1972 study, the comparison of adaptation to meridional size lenses (MSL) and overall size lenses (OSL) was undertaken. From the results, Epstein concluded that the difference between the effects of exposure to the two types of lenses is more compatible with the visual recalibration hypothesis of MSL adaptation than with the proprioceptive shift hypothesis. The process of disparity does not change but the evaluation of it does.

Burian proposed a model in which stereoscopic vision does not change but he felt that stereopsis was ignored in favor of empirical cues. However, trials in a space eikonometer showed adaptations in the absence of empirical cues.

Gibson proposed a theory of "normalization" in which each individual acquires a subjective norm or reference axis for organizing reference space. In this model, a subject would classify a line with respect to individual subjectively established norms for different orientations. This theory is basically one of antiassociation in which the individual subject does not associate cues but detects "dimensions" of stimulation. These are developed by prolonged exposure to a visual stimulus and no reassociation occurs in other areas outside the stereoscopic condition. If the argument were to be extended to stereoscopic orientation, then there should be no recalibration, no reassociation, and no suppression of stereopsis.

The literature presently shows that although a marked after effect is observable in experimental conditions of meridional magnification, the precise mechanisms accounting for this are not agreed upon. We chose to study the magnitude of after effect produced by a meridional magnifier in making judgements of the apparent frontoparallel plane under
different experimental conditions to investigate the underlying theories of the after effect phenomenon.

**METHOD**: The apparatus consisted of a 3% meridional size lens mounted in an axis 90 orientation on a spectacle frame. A frontoparallel plane apparatus was utilized. This consisted of an array of irregularly spaced points of light of low illumination mounted on a moveable swivel base attached to a calibrated protractor to enable the experimenter to take readings of deviation of the plane from the straight ahead. A bite bar and shoulder press were utilized to insure correct orientation of the subject and to inhibit any cues from motion. The room was totally dark during the trials and prevented empirical cues from becoming a factor.

The subjects consisted of five students at Pacific University who were randomly chosen. Each subject exhibited stereopsis and wore the optimum refractive correction. Each subject underwent a practice session before the experiment commenced in which his errors in judgement of the frontoparallel plane were pointed out to him and visually compared with the objective frontoparallel plane. This was done to reduce variability, thereby increasing the probability of detecting a change in the apparent frontoparallel plane following adaptation conditions.

The four conditions consisted of:

1. Continuous viewing in the dark of the frontoparallel plane apparatus with no lens in place.

2. Continuous viewing in the dark of the frontoparallel plane apparatus while wearing the meridional lens over the right eye.

3. Perceptual hand eye body tasks while wearing no lens before judging the apparent frontoparallel plane.
4. Perceptual hand eye body tasks while wearing the meridional lens over the right eye before judging the apparent frontoparallel plane.

The time sequence consisted of ten minutes of dark adaptation followed by 12 pre-trial measurements. Epstein varied ten minute dark adaptation periods among subjects and found that those that had one or both eyes closed during this time showed greater adaptation effects to his lenses because no binocular disparity information could be processed. The suppression of binocularity will enhance adaptation.

We had the subjects dark adapt because the apparatus consisted of points of low illumination. We wanted only the dots to be visible to test stereodiscrimination in the absence of empirical cues.

Thirty minutes of each of the above conditions were then performed followed by removal of the lens (when applicable) and twelve post-trial measurements.

The perceptual hand eye body tasks performed consisted of:

1. walking rail 5 minutes
2. bean bag toss 5 minutes
3. Marsden bunt ball 5 minutes
4. walking steps 5 minutes
5. pegboard rotator 10 minutes

The twelve measurements of each trial were taken by coming from alternate directions on successive trials and the speed of presentation and the degree of initial deviation were altered to inhibit time cues to judgements.

Each condition was run at a different time rather than successively.

Condition one is the control condition for condition two, and condition three is the control for condition four. Condition two represents the Gibson condition and condition four represents the training condition supporting a recalibration theory.

Viewing through the lens might be said to always provide
the conditions for a "normalization" effect, and that it was our intent to determine whether the addition of specific perceptual motor tasks would produce more change than the continuous viewing alone.

RESULTS: For each subject, the mean of twelve post-exposure trials was subtracted from the mean of the twelve pre-exposure trials, and this difference was taken as the basic datum for a two way analysis of variance (conditions X subjects). The viewing conditions were the treatments and the intersubject differences were the blocks.

Conditions 1 & 3 which were the control conditions for 2 & 4 showed a mean of very close to the exact fronto:parallel as should be predicted from the practice sessions.

Our analysis of variance showed that F for treatments equaled 216.55 indicating a statistically significant difference among the viewing conditions. With degrees of freedom equal to 3 and 12, P was less than 0.01.

Our analysis of variance showed that F for blocks equaled 25.87 indicating that this difference between subjects was also significant. With degrees of freedom equal to 4 and 12, P was less than 0.01.

A student t test was then performed to evaluate the differences between conditions 2 and 4. Analysis showed that although in most subjects, the magnitude of change was greater in condition 4 than condition 2, there was no statistically significant difference between the two treatments. (t = 1.23; p > 0.05)

DISCUSSION: The results show that there is a significant adaptation to the wearing of the meridional size lens. This agrees with what Epstein and several other investigators have shown. The existing theories must now be evaluated in light of the fact there was no significant difference between treatments two and four.
A theory based on single cell responses could probably not account for these results. Since the environment is varied, there are no specific fixation cues, and the eye is free to scan the array, the disparity between the different points are so large and variable that the single cell disparity detecting units would not be saturated.

Gibson would regard the "norm" for "frontality" to be a particular gradient of disparities across a visible surface. With the 3% meridional size lens, the observed gradient would be shifted. Normalization would be a process in which this "norm" for frontality shifts in the direction of the "new" (inspection) gradient. Saturation of neural detector populations is not assumed to play a part in this, and probably would not play a part, for reasons cited in the previous paragraph.

Our discussion and conclusion is primarily based upon the concept of a modified depth judgement in which what you judge to be parallel is based on experience as well as disparity detectors. Judgements of the apparent frontoparallel plane are based on associations between disparity and other independent evidence of "frontality". These judgements are affected secondarily by learned cues and past experience.

The question arised as to whether we are modifying judgements via learned cues in both cases. If learning is involved, feedback is essential. Many opportunities for feedback are clearly present in kinesthetic hand eye tasks utilized in condition four. We now must evaluate if learning is taking place in condition two.

The experimental design allows for the eyes to move freely, to look in different areas and change the vergence posture to different disparities with the size lens on. This can be a source of feedback for spatial distortions.
The individual who must converge more to one side than to the other is receiving differential motor outflow cues to the relative nearness of the two sides of the array. Therefore the physical changes in eye position to respond to the apparent separation of the targets can possibly constitute a learning experience. Adler's *Physiology of the Eye* makes reference to the organ of Golgi in the tendons of the extra-ocular muscles which are sensory structures similar to muscle spindles. These tendon spindles have been reported in rich supply but there appears to be no conscious awareness of the information gathering.

The problem for a re-learning interpretation of condition two is as follows: Given that the subject has both disparity and oculomotor information that the inspection surface is rotated, how does he learn that it is objectively frontal? He must have some information on its true orientation with which to re-associate the available disparity and oculomotor cues. The argument for re-learning is weak because of failure to identify where the subject gets information to reassociate disparity with.

Elimination of the re-learning interpretation for condition two due to arguments presented in the previous paragraph and rejection of the neural theory of receptor cell habituation due to the experimental design of free scanning leave us with Gibson's hypothesis. Possibly, antiassociation takes place in which the individual subject does not associate cues but detects "dimensions" of stimulation upon prolonged exposure to a visual stimulus. In this experiment, a subject could classify a line with respect to individual subjectively established norms for different orientations.
APPARENT FRONTOPARALLEL PLANE APPARATUS

Diagram of an apparatus showing a rectangular plane with a scale on one side, and a subject at the bottom.
<table>
<thead>
<tr>
<th>Subjects</th>
<th>STARE (no lens)</th>
<th>STARE (lens)</th>
<th>TASK (no lens)</th>
<th>TASK (lens)</th>
<th>$T_i$</th>
<th>$T_i^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.L.</td>
<td>-0.42</td>
<td>-0.08</td>
<td>+1.41</td>
<td>+5.33</td>
<td>6.24</td>
<td>38.94</td>
</tr>
<tr>
<td>K.K.</td>
<td>-1.00</td>
<td>-2.25</td>
<td>-1.17</td>
<td>+1.17</td>
<td>1.05</td>
<td>1.56</td>
</tr>
<tr>
<td>L.C.</td>
<td>0.00</td>
<td>+4.42</td>
<td>+0.17</td>
<td>+3.67</td>
<td>8.26</td>
<td>68.23</td>
</tr>
<tr>
<td>D.G.</td>
<td>+0.33</td>
<td>+0.99</td>
<td>-0.83</td>
<td>+4.25</td>
<td>4.74</td>
<td>22.47</td>
</tr>
<tr>
<td>H.E.</td>
<td>-0.10</td>
<td>+2.49</td>
<td>+1.33</td>
<td>+3.25</td>
<td>6.97</td>
<td>48.58</td>
</tr>
</tbody>
</table>

$\bar{x} = -0.238$, $\bar{T_i} = -1.19$, $\bar{T_i^2} = 1.416$

$\frac{\sum T_i^2}{n} = 415.88$, $\frac{\sum x^2}{n} = 91.2598$

$T_u^2 = 37.70$
SS_{Tr} = \frac{415.88}{5} - 37.70 = 83.176 - 37.70 = 45.47 \\

SS_{Block} = \frac{179.78}{4} - 37.70 = 44.945 - 37.70 = 7.245 \\

SS_{Total} = 91.2598 - 37.70 = 53.5598 \\

SS_{Error} = 53.5598 - 45.476 - 7.245 = 0.8388 \\

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum Sq.</th>
<th>Mean Sq.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (Lens Conditions)</td>
<td>K-1 = 3</td>
<td>45.476</td>
<td>15.1586</td>
<td>\begin{align} F_{TR} &amp;= \frac{15.1586}{0.07} \ &amp;= 216.55 \end{align}</td>
</tr>
<tr>
<td>Blocks (Subjects)</td>
<td>n-1 = 4</td>
<td>7.245</td>
<td>1.8112</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>(K-1)(n-1) = 12</td>
<td>0.8388</td>
<td>0.07</td>
<td>\begin{align} F_{Error} &amp;= \frac{1.8112}{0.07} \ &amp;= 25.87 \end{align}</td>
</tr>
<tr>
<td>Total</td>
<td>N-1 = 19</td>
<td>53.5598</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
\[ t = \frac{\overline{X}_0}{s_{\overline{X}_0}} \]

\[ \frac{1.52}{1.24} = 1.2270 \]

\[ s_{\overline{X}_0} = \frac{s}{\sqrt{n}} \]

\[ s = \sqrt{\frac{\sum x^2 - (\sum x)^2}{n-1}} \]

\[ = \sqrt{42.90 - 52.76} \]

\[ = \sqrt{\frac{42.90 - 11.55}{4}} \]

\[ = \sqrt{30.65} \]

\[ = \sqrt{7.6625} = 2.768 \]

\[ \frac{S}{\sqrt{n}} = \frac{2.768}{\sqrt{4}} = 2.768 \]

\[ \overline{X}_0 = 1.2379 \]
BIBLIOGRAPHY


