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An Investigation of Prism Adaptation Latency

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ABSTRACT

Purpose. The latency of adaptation of the human vergence system to a change in convergence or divergence forced upon it by a prism was investigated in this pilot study. ***Methods.*** Adaptation was stimulated by a **5-s** period of binocular vision through a prism of 0 Δ, -8 Δ, or 8 Δ. Immediately thereafter and for a further period of 45 s, lateral heterophoria was monitored subjectively by an automated version of Duane's screen and parallax test. Adaptation was calculated from the phoria 40 s after the end of binocular vision. Tests were performed at 0.4 m. In the first test session, there was screening during the binocular period to test for flaws in the screening method. In the second session, there was no screening during the binocular period and phoria measurement was started without changing the power of the prism. In the third session, the prism was restored to 0 Δ after the period of binocular vision. Immediately after the last 5-s test, tests were repeated with 1 s of binocular vision. The subject had excellent visual acuity, stereoacuity, and stereolatency. ***Results.*** The test functioned correctly and showed good repeatability. The greatest adaptation to 8 Δ was **59%.** This was obtained with only 1 s of binocular vision. There was adaptation to -8 Δ with 5 s of binocular vision but it was obscured by adaptation to 0 Δ or 8 Δ which persisted from previous tests. ***Discussion.*** The reason why the subject's latency was not found more precisely is explained. Additional evidence is presented in support of the finding that prism adaptation can take place within 1 s (perhaps less) of binocular vision, and the persistence and dominance of adaptation to base-out prism at near is pointed out. Guidelines are proposed for the experimental measurement of prism adaptation latency.

Key Words: binocular vision, vergence adaptation latency, prism adaptation, lateral heterophoria

What has been described as prism,[1] oculomotor,[2] vergence,[3] or phoria[4] adaptation is revealed by changes in heterophoria[5] (or fixation disparity[6]) which follow the introduction of a prism before one eye. The initial effect on the phoria is to change it by the power of the prism. The direction of change is eso with base-in prism and exo with base-out if the phoria is measured with the prism still in place. Adaptation to the prism begins almost immediately. The time course of adaptation can be followed by measuring the phoria periodically. Such measurements show that the phoria changes exponentially and that it generally tends to revert to what it was before the introduction of the prism. Schubert[7] was the first to measure prism adaptation in this way and he found that adaptation to –6 Δ (base-in) was complete after **10** min of binocular vision through the prism.

How long it takes for adaptation to begin (its latency) has seldom been discussed. Schor[8] stated that "adaptation did not begin until 10 to 15 s after fusional vergence is stimulated." Evidence for an even shorter period of latency was in Schubert's[7] Fig. 1 where, at near, subject RA's adaptation was 63% complete after 15 s of binocular vision through –6 Δ. It was also evident in Henson and North's[9] Fig. 3, where there was 50% adaptation after 15 s of binocular vision through –6 Δ. If adaptation can be half completed after 15 s, it must begin soon after the introduction of the prism. In what follows, we will show that vergence adaptation can be in progress after only 1 s of binocular vision through base-out prism.

METHODS

The method used for measuring lateral heterophoria was first described by Duane.[10] It is a subjective cover test known as the screen and parallax test which, according to Scobee and Green,[11] is the best test for heterophoria. A screen big enough to block the view of one eye is moved repeatedly from in front of one eye to in front of the other and back again so as to produce alternating monocular occlusion. If this brings about a change in vergence (heterophoria), there is an illusion that everything in the field of view jumps from one position to another each time the screen is moved. This is what is meant by parallax. Parallax can be eliminated by a prism whose power matches the change in vergence. When parallax has been eliminated, the prism power is the same as the heterophoria.

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The Test

In the test apparatus used for this investigation, two liquid crystal shutters[a] (one in front of each eye) were used for screening. Electronically, these shutters could be made transparent (so as to permit normal vision) or translucent (so as to occlude the eye).[12] In the screening cycle, the left eye was occluded for 0.928 s, then both were occluded for 0.144 s, then the right eye was occluded for 0.160 s, then both were occluded for 0.144 s, and so on.

The right shutter was open 5.8 times longer than the left for the following reasons: (1) the left eye looked through the variable prism so it had to be screened while the prism power was being changed (the time required to change the prism power was proportional to the amount of change); (2) to ensure that the accommodation of the right eye was dominant; and (3) to ensure that the left eye did not have time to take up fixation.

A motorized prism[13] in front of the left eye was used to stimulate prism adaptation. When this was completed, the subject adjusted the prism by remote control (by turning the shaft of a rotary potentiometer) so as to eliminate parallax (and thereby measure heterophoria). Prism power could be set from 30 Δ base-in to 30 Δ base-out with an accuracy of about 0.1 Δ. A minus sign before the prism indicates base-in. The same kind of prism was before the right eye but its power was always 0 Δ.

The test distance was 0.4 m. The target was a near-vision test card with the letters KEEP SINGLE arranged vertically at its center. It was illuminated by a small lamp which was out of the field of view.

The Subject

Co-author JF is an experienced observer. His visual acuity is 20/13 (6/4) and his stereoacuity 2 sec arc. His stereolatency" of 16 ms proved that his stereopsis was in everyday use.

Test Procedure

The test was controlled by a digital computer. The following test parameters were entered into the program before the start of each test: (1) the prism power during the period of binocular vision; (2) the duration of binocular vision; and (3) whether the prism was to be returned to zero before the phoria test began or left as it had been during the binocular period. Choices of prism power were 0, 8, or −8 Δ and of time were 1 and 5 s. When the test was not being performed, both screens were open and the prism power was 0 Δ.

Before the test began, the subject was seated and looked at the fisation target through the test instrument (a modified phoropter). The potentiometer (for adjusting the prism power) was at his hand. When he was ready, the operator started the test.

[a] Artifex Corp., 4077 W. Segerstrom Ave., Santa Ana, CA 92704-6326.

Both shutters were translucent while the prism changed to the preselected prism power. When no change was required (because the power called for was 0 Δ), both were translucent for 0.5 s. As soon as the power was reached, both shutters were made transparent and remained in that state for the duration of the period of binocular vision. After this, both were made translucent for 0.5 s or for the time it took the prism to be returned to 0 Δ (if that had been called for). Then the phoria test began.

The screening cycle started with the right shutter transparent and the left translucent. Thereafter, the computer checked the potentiometer voltage each time the right shutter changed from transparent to translucent. Any change in voltage was translated into a proportional change in prism power. While this was taking place, both shutters were translucent.

The phoria was measured in this way for 45 s. Each time the potentiometer was checked, elapsed time and prism power were stored in the computer memory. When the test was completed, a graph of the results was prepared with an X-Y plotter. The subject watched the graph being plotted so he had about 1 min of normal binocular vision between tests.

RESULTS

Before examining the results, it is important to remember that adaptation was stimulated by the same variable prism that was used to measure the phoria. Because of this dual role, the stimulus for adaptation could not be left in place while the phoria was being measured. In the results which follow, the effect of complete adaptation would be to shift the phoria by an amount equal to the power of the prism which was adapted to. For example, it the phoria were -4 Δ before any stimulus to adaptation, it would be 4 Δ after complete adaptation to a prism of 8 Δ.

For the sake of simplification and to conform with Schor's[8] practice, the phoria will be given as the power in the prism 40 s after the end of the period of binocular vision. Adaptation will always be calculated with respect to the subject's usual phoria. This was found by testing with 0 Δ at the beginning of each session.

The order in which tests were performed is shown in the legend within each graph. A sample of each curve type is followed by a 3-digit decimal number. To the left of the decimal point is the testing session number. To the right is the number of minutes between the start of the session and the start of that test.

Testing the Test (Fig.1, Column 1)

In a previous version of the test, a defect in the screening method permitted 0.1 s of binocular vision every 1.26 s.[14, 15] To make sure that the revised

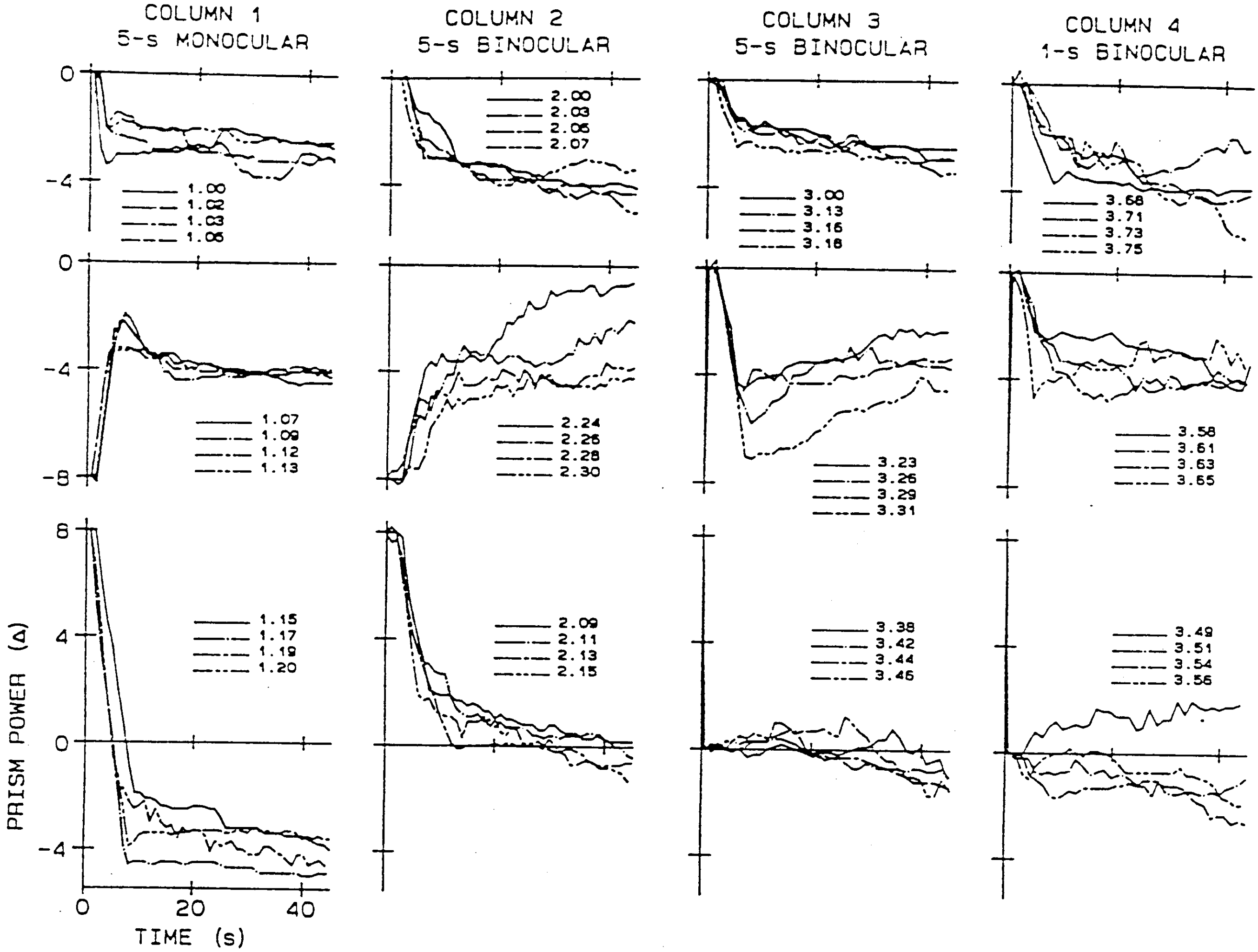

Figure 1. Graphs of the results of tests at near with prism of 0 (top row), −8 (middle row), and 8 Δ (bottom row). Test conditions were different in each of the four columns of graphs. In column 1, binocular vision was made impossible by screening during the 5-s period of "binocular" vision through the prism. In column 2, the conditions were the same as in column 1 except that the shutters were both open during the period of binocular vision. In column 3, conditions were the same as in column 2 except that the prism was returned to 0 Δ at the end of the binocular period. In column 4, the test was the same as in column 3 but with only 1 s of binocular vision through the prism. The order of testing is given in the legend in each graph. The number to the left of the decimal point is the session number. The number to the right is the time since the start of the first test.

version worked properly, tests were performed in which there was screening during the period when there would otherwise have been binocular vision through the prism. If the phoria test functioned as intended, there should be no sign of adaptation in these results.

The results of this special test with 0, −8, and 8 Δ during the binocular period are presented in the top, middle, and bottom graphs in column 1 of Fig. 1. There were four consecutive tests with each power. The average exophoria in the 0, −8, and 8 Δ graphs was −2.8, −4.2, and −4.1 Δ, respectively. Because the phoria with 8 Δ was the same as with −8 Δ, vision was never binocular while screening was in progress (otherwise there would have been some evidence of adaptation). The similarity of the curves in the middle graph show that the test has good repeatability.

Adaptation with 5 s of Binocular Vision (Fig. 1, Column 2)

The test session described above was repeated 2 days later but without screening during the initial phase of the tests. After 5 s of binocular viewing through 8 Δ (bottom graph), the average phoria was −0.2 Δ. With respect to the average phoria at the start of the session (−3.9 Δ in the top graph), adaptation was 46% complete.

With −8 Δ (middle graph), the phoria was −0.8 Δ in the first test, −2.4 Δ in the second, −3.7 Δ in the third, and −4.2 Δ in the fourth. We attribute this gradual reduction in eso bias to adaptation carried over from the preceding 8 Δ tests.

Starting the Phoria Measurement from 0 Δ (Fig. 1, Column 3)

The test session described above was repeated 36 days later but with the prism reset to 0 Δ at the end of each period of binocular vision. This was done to see whether power in the prism at the start of the phoria test had an effect on results.

In the 8 Δ tests, there was at first little or no parallax to be cancelled because the subject's adapted phoria was close to 0 Δ. After 20 s, an exo drift began (probably because adaptation was wearing off) so that by 40 s the average phoria was –0.8 Δ.

A comparison among these results and those in the graph immediately to the left shows that starting with 8 Δ in the prism gave the phoria an eso bias which diminished with time. At 12 s, the average eso bias (with respect to the results in column 3) was 0.9 Δ. After 40 s had elapsed, the bias was 0.6 Δ.

The –8 Δ results were different from those in the graph immediately to the left because of the order in which the 8 Δ and –8 Δ tests were performed. In column 3, –8 Δ was tested before 8 Δ so the eso bias seen in the middle graph is presumed to be a carry-over of adaptation to 0 Δ. More on this in the discussion.

Evidence of adaptation to –8 Δ can be seen in the bottom curve (3.31) at 8 s. At that moment, the phoria was -7 Δ (55% adaptation). From then on, the exophoria decreased progressively until, at 40 s, the phoria was -4 Δ (14% adaptation).

Adaptation with 1 s of Binocular Vision (Fig. 1, Column 4)

The tests described above were repeated but with 1 s of binocular vision. Testing began with 8 Δ. Adaptztion in the first 1-s test was 59%. This was not a carry-over from previous tests because adaptation to 8 Δ in the last 5-s test was 21%.

In the –8 Δ results, there was negligible adaptation at 40 s (10%). However, there was evidence of a short-term eso bias (during the first 10 s) which became less with each successive test. We attribute this to adaptation carried over from the preceding tests with 8 Δ.

Tests with 0 Δ ended the session (top graph). The average phoria was 0.9 Δ more exo than it had been at the beginning of the session. Perhaps this was a carry-over of adaptation from the preceding tests with –8 Δ.

DISCUSSION

When we undertook this investigation, it was to find out whether or not the revised version of the phoria test worked properly. It was only after all the data had been gathered and put into order that we realized that we had been investigating the latency of prism adaptation. This explains why we did not persist in reducing the duration of binocular vision until the subject's latency had been established with certainty.

The experiments reported here were preceded by others in which we tested for adaptation ai near (0.4 m) and at far (6.0 m) with 0 Δ, 4 Δ, –4 Δ, 8 Δ, and –8 Δ for binocular periods of 1, 2, 5, 15, and 30 s. These tests were performed in the same way as those in column 2 of Fig. 1 but without repeats. We intended to present graphs of these results in this report but were advised to delete them in order to simplify the presentation. This is mentioned to reassure readers that the results presented here have been replicated in other experiments.

An important finding of this investigation is that adaptation to base-out prism at near can be well on the way to completion after only 1 s of binocular vision through the prism (59% in curve 3.49). Adaptations in the earlier 1-s tests at near (mentioned in the second paragraph of this discussion) were 78% with 4 Δ and 56% with 8 Δ. This confirms that adaptation can be more than half completed with only 1 s of binocular vision. [At far, there was adaptation to base-out prism in the 2-s tests (10% with 4 Δ and 9% with 8 Δ) but none in the 1-s tests. In 1-s results with base-in, there was 28% adaptation with -4 Δ and 13% with –8 Δ. The later result confirms Sethi and North's finding that adaptation occurs even if fusion is not achieved.[16]]

Another finding has to do with the persistence of adaptation to base-out and its effect on the results of subsequent tests with base-in. This effect can be seen best in the middle graph of column 2 where adaptation to –8 Δ was dominated by previous adaptation to 8 Δ. That there really was adaptation to –8 Δ can be seen in the first 12 s of the middle graph where the phoria became more exo with each successive test (at 10 s it was –3.6 Δ in the first test and -5.2 Δ in the last). There is a similar pattern in the first 10 s of the middle graph in column 4 but this is much less obvious—presumably because the stimulus for adaptation was only 1 s. Whether or not base-in is adapted to in 1 s or less at near cannot be established from these results because of the dominance of adaptation to base-out.

As stated by Sethi,[17] "the phoria position is. . .an adapted position of the vergence system." Adaptation to the subject's habitual relation between vergence and accommodation may explain why the curves in the middle graph in column 3 have a transient eso bias. In another words, because 0 Δ is base-out with respect to –8 Δ, adaptation to it shows up in –8 Δ results. Adaptation to the habitual state of binocular vision may be the reason why the average phoria with 0 Δ (top graph of column 1) was about 1.4 Δ more eso than with –8 Δ or 8 Δ.

From esperience gained in this investigation we propose the following guidelines for the experimental measurement of prism adaptation latency: (1) always reset the prism to zero before starting the phoria test; (3) test with only one prism power per session and separate the sessions by 1 day to avoid contaminating the results with adaptation carried over from preceding experiments; (3) repeat the experiments without allowing binocular vision between tests until the subject's habitual state of adaptation no longer contaminates the results; and (4) always start testing with the shortest possible binocular exposure and increase it until adaptation is first detected in the results.

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ANNOUNCEMENT

James L. Kennerley Bankes, a prominent Harley Street ophthalmologist and optometrist, died on October 16th, 1993.

Dr. Kennerley Bankes was a lecturer at City University in London and served as a visiting professor at the School of Optometry at the University of Waterloo on two occasions. He taught in the continuing education program. Dr. Kennerley Bankes was an honorary consultant ophthalmic surgeon at the Royal Eye Hospital, the Chelsee and St. Luke's Hospitals, end subdean at St. Mary's Hospital Medical School, University of London.

He will be missed by all who knew him.