Oculomotor Imbalance in Binocular Vision and Fixation Disparity

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Preface

This monograph is the outcome of a number of years of research in the Section of Ophthalmology at the Mayo Clinic. What started as a simple experimental study of the correlation between the usual methods of measuring heterophorias and the fixation disparity technique of determining oculomotor imbalances turned out to have much greater implications. Although the promise of the study was not fully realized, sufficient valuable data were obtained to justify the writing of this monograph. It is hoped also that this monograph will dispel much of the misunderstanding of the phenomenon and the misuse of the words *fixation disparity* as found in the literature.

This study was aided greatly by the assistance of Miss Mary Cronin, orthoptist in the Section of Ophthalmology, and by Miss Lorette Hentges of the Section of Biophysics for her secretarial assistance and real assistance in the organization of the manuscript. Our appreciation also is due Mrs. Louise Reiher and Mrs. Janice Wakefield, both of the Section of Biophysics, for their assistance in organizing the data and preparing the figures. We are also indebted to Mrs. Jane Hazelrig for testing the mathematical model (Chapter 13) by utilizing a digital computer to conform theoretical curves to the data.

K. N. O., T. G. M., AND J. A. D.

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The Early Literature

HOFMANN AND BIELSCHOWSKY

The first mention of the phenomenon which we will call fixation disparity is found, as far as we have been able to ascertain, in the reports of experiments on binocular fusional movements by Hofmann and Bielschowsky[1] in 1900. They used the haploscope of Hering (Figure 1–1), which permitted the presentation of a different target to each of the two eyes for binocular vision, providing an accurate control of observation distance and a control of the convergence of the eyes. The background of the two targets consisted of identical pages of print. In the center of each of the targets a horizontal line was drawn, and on the target to be seen by the left eye a short narrow vertical line was drawn in the center above that line. On the right target a millimeter scale was placed horizontally below that line. With binocular observation of the targets, the images of the print were fused and the short vertical line was seen pointed to some scale division.

They found that, as the arms of the haploscope were moved to alter the convergence of the eyes (thus embarrassing the normal relationship between the stimulus to accommodation and the convergence of the eyes), the position of the indicator mark relative to the scale changed, in spite of the print appearing single. They correctly interpreted the phenomenon as one indicating the degree to which the images of all of the print details were actually perceived with disparate images. As the convergence of the eyes was *increased*, the indicator mark moved slightly in the direction of a *decreased* convergence—that is, the images of the print for the two eyes were seen in

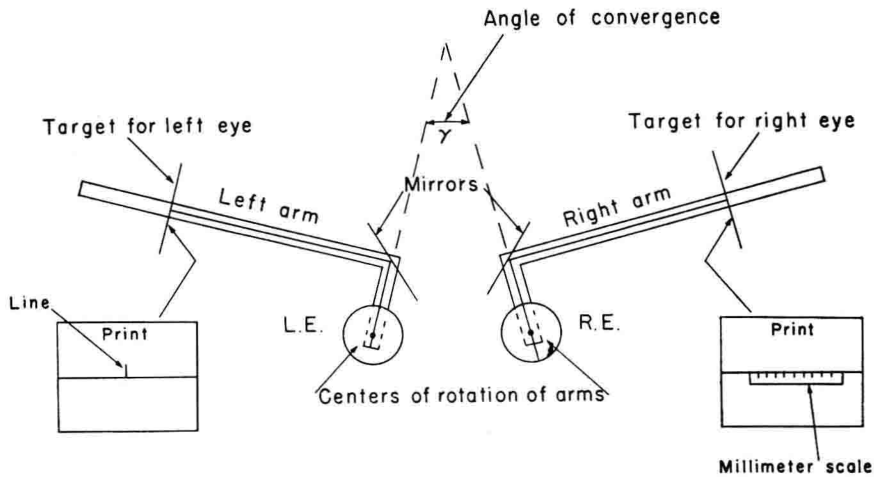

Fig. 1–1. Scheme of haploscope and targets used by Hofmann and Bielschowsky which illustrates phenomenon of *fixation disparity* (called by them *residual disparity*).

an uncrossed disparity. They called the discrepancy in convergence a *residual* disparity.

For similar observations made in the vertical meridian (test targets rotated 90°) they stated that the maximal disparity (subperceptual) that could be introduced by a vertical divergence of the targets, before diplopia occurred, was 10 to 15 minutes of arc. This disparity was especially evident if the indicator mark and the scale division marks were seen sharply defined.

LAU

Lau[2] in 1921 also used targets in the haploscope (Figure 1–2). He devised experiments to test the hypothesis of Hering that vertical threads in space would appear to lie in the frontoparallel plane when the images of those threads were not disparate. He observed to his surprise that the monocularly seen portions of the targets appeared displaced horizontally with respect to each other; the magnitude of the displacement varied with the degree to which the convergence of the eyes was forced to change. He found that by reducing the con-

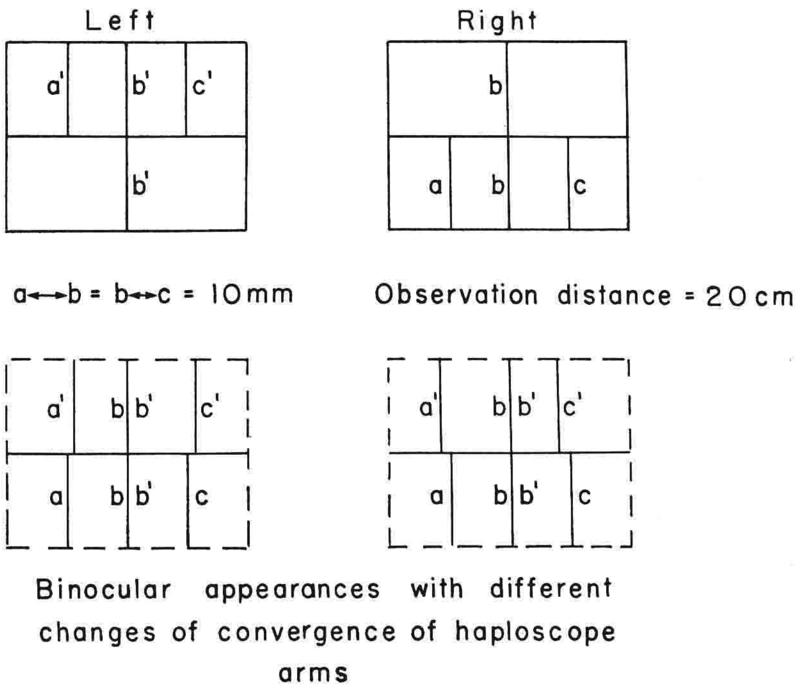

Fig. 1–2. Illustration of type of haploscope targets used by Lau.

vergence to 6° the monocularly seen nonius* lines appeared aligned, but that for a further decreased convergence to 4° the displacement was in the direction opposite to that seen first. He wrote (in translation): "I concluded . . . that the two middle threads (lines) must have stimulated noncorresponding points in order to bring about the plastic impression. Obviously the middle thread (line) was no longer fixated, but neighboring points instead." And again: "This phenomenon is an unequivocal proof that with a great amount of convergence, the lines of regard (to the fixation line) are actually no longer directed to the central lines b and b′ but to nearby points so that fusion of disparate images of the central thread (line) must have taken place to produce a single (binocular) image of bb′ (the fixation lines)."

* *Nonius* is the Latinized form of Nunes, the name of a Portuguese mathematician, and pertains to a device at one time used in graduating instruments. The device subsequently was improved into the vernier. (From Webster's *New International Dictionary*, Second Edition.)

LEWIN AND SAKUMA

In 1924–1925 Lewin and Sakuma[3] also observed this phenomenon with the haploscope, using for the left and right targets playing cards—the four of diamonds for one eye, the five of diamonds for the other. They observed that, although the images of the corner diamonds were fused, the center diamond did not appear centered with respect to the four corner diamonds. Furthermore, its position changed with sudden movements of the cards. They studied this displacement primarily with respect to movements of the arms of the haploscope and suggested theories to explain the displacement on the basis of the "coupling" of the monocular images with the binocular perception. It is not clear that they ever correctly interpreted the phenomenon.

AMES AND GLIDDON

This phenomenon was studied by Ames and Gliddon[4] (reported in 1928) with special regard to heterophorias. Again in a haploscope a variety of targets were used (Figure 1–3). These investigations also found that the uniocularly seen details of the targets appeared displaced with respect to each other. The small black disk appeared displaced laterally within the larger disk. The displacement (which they called a "retinal slip") was different in various observers; furthermore, it varied in the same observer with the extent to which the convergence of the targets was changed. The magnitude of the displacement itself was not measured, but for each subject they did ascertain that convergence of the eyes for which there was no displacement. This they correlated with the lateral heterophoria of the subject.

The importance of using targets such as shown in A and B of Figure 1–3 is that the displacement occurs either when the letter E is centrally fixated (Fig. 1–3 A), in which case the displacement is observed extrafoveally, or when fusion of the images of extrafoveal contours is maintained (Fig. 1–3 B), the displacement then being observed foveally. Ames and Gliddon correctly interpreted their observations as demonstrating a "misalignment of the lines of sight" or inexactness of fixation associated with a heterophoria, and the consequent fusion of disparate images.

Fixation disparity, the phenomenon of the apparent displacement of the uniocularly observed details of targets whose other details are fused binocularly, occurs commonly. It is found in a variety of types of instruments such as the synoptophore and amblyoscope, and in anaglyphs, and so forth, and it notoriously occurs in eikonometry when the direct comparison test targets are used (Figure 1–4).[5] In fact, displacement of the test nonius (vernier-like) lines not only interferes

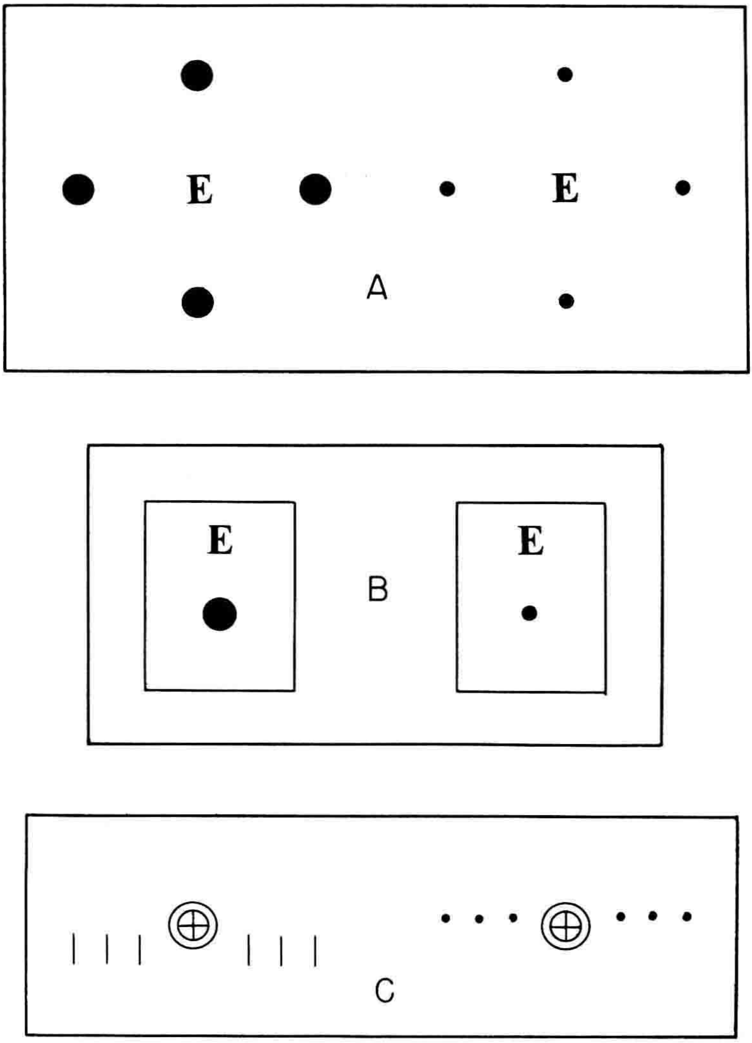

Fig. 1–3. Types of targets used by Ames and Gliddon in their study of fixation disparity (called by them *retinal slip*).

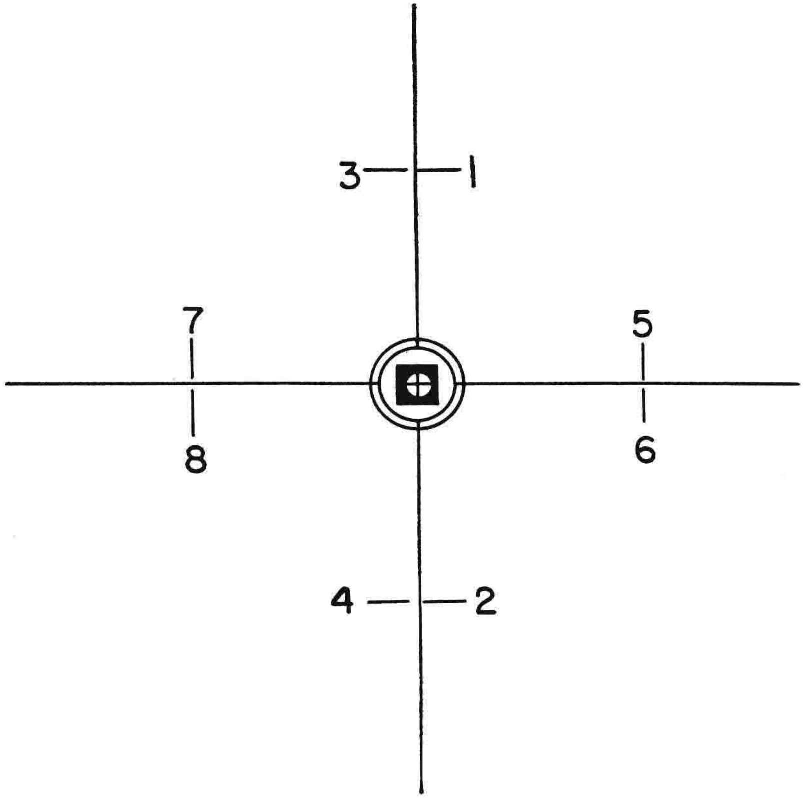

Fig. 1–4. The direct-comparison eikonic target, in which fixation disparity can be observed.

with the precision of the measurements, often leading to spurious results if the subject's phoria is large, but also prevents the measurement of differences in magnification in oblique meridians.

ANALOGOUS EFFECT IN CYCLOPHORIA

In his book on squint, Worth[6] includes a design of targets to be observed in a stereoscope which actually show that this phenomenon can occur also in the sense of a differential cyclotorsion between the eyes (Figure 1–5).

Since 1947, fixation disparity has been investigated by only a few experimenters, both as an interesting effect in itself and as a tool in the investigation of oculomotor imbalances.