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THE CONVERGENCE OF HUMAN BINOCULAR VISION

BY

N. A. STUTTERHEIM

SOUTH AFRICA

IN my work "Indications for the Kinetic Treatment of the Eyes,"¹ I have called the central kinetic factor of human binocular vision "Involuntary Convergence." In available literature I find convergence mentioned only as a voluntary movement.² But *voluntary* convergence is *not* the kinetic factor of binocular foveal-macular vision. Therefore, in order to make it clear that I dealt with the *reflex* motor-co-ordination and not with the other function—the willed movement—I called it Involuntary Convergence.

I trust that this long term will soon make place for convergence, pure and simple. "Voluntary convergence" is really a misconception of voluntary binocular adduction, a movement of considerable importance to make the two visual fields overlap, but it is not the convergence of *bi-foveal vision*.

It appears that some serious confusion exists in the terms and definitions of binocular ophthalmology. One of the causes of this condition is, I consider, the overlapping of ophthalmological science with mechanics or optics on the one side (on account of the ocular media) and with psychology on the other side (on account of the visual fields in the cortex cerebri). This confusion obscures the outlook on the physiology of binocular vision.

Cantonnet complains that binocular vision is neglected³ "mais qui s'occupe de la vision binoculaire?"

Some definitions in binocular ophthalmology are veritable stumbling blocks to the scientific layman. Recently, an eminent anthropologist remarked to me that he could make neither head nor tail of many of the ophthalmological terms. Our conversation was on the comparative anatomy of the skulls of man and the primates in connection with binocular movements.

Before going any further, therefore, I want to make clear what meaning I attach to some important terms.

Fusion

Fusion of the two ocular images is a psychological phenomenon. Experimental investigation has proved that there is no actual fusion, either in an optical or in a physiological sense.⁴ The ophthalmologist, therefore, should avoid using the word fusion in the terms describing binocular movements. The terms fusion-range, fusion-movements, fusion-compulsion (*Fusions-zwang*), etc., wrongly suggest physiological relations. Not fusion but reflex-convergence—a measurable function and not a psychological phenomenon—is responsible for the bringing together of the two foveal images.

Convergence and Divergence

The motor-co-ordination of human binocular convergence is more than an optical or a mechanical movement; it is a *functional* one. Definitions should be clear on this point, but they are not.

Convergence is a *visual* binocular movement—a movement in connection with an *object of vision* for the biunial—or dual—eye. By this definition the well-known “convergent squint” and “strabismus convergens” are condemned as devoid of sense, a contradiction *in adjecto*. In every squint necessarily one of the ocular axes *deviates* from the object of vision, consequently every squint is *di*-vergence.

In ophthalmology a *position* of *con*-vergence does not occur. Convergence is always movement⁵ and always active movement, even when the dual eye is fixing an object.

A position of divergence is *every* binocular position where the two visual axes do *not* meet in an object of vision, e.g., the natural position of binocular rest—in sleep, in deep narcosis, probably even in staring.

The motor-co-ordination of divergence is not a *visual* movement; it is not even a function in ophthalmology, but it is either a relaxation of convergence, or a voluntary act of disturbing the convergence (in voluntary squint).

Centres for convergence have been found in the brain; one of considerable phylogenetic importance in the mid-brain.⁶ But the quest for a centre of divergence has been in vain, so far.⁷ It

will probably remain so, for could one expect to find a brain centre for the relaxation of the action of a function?

It must be borne in mind that, contrary to the confused common conception, the motor-co-ordinations of convergence, as well as of divergence, consist of the same component movements of the individual eyes. Both convergence and divergence can be composed of adductions or abductions or sursum- or deorsum-ductions or any possible combination of these. If, for instance, while looking at an object straight ahead I start squinting by voluntarily *ad*-ducing the eyes, then this should be called a movement of divergence just as well as when, by closing the eyes, I allow them to be *ab*-duced towards the position of rest.

The point is that convergence always is a *visual* movement and that divergence never is a visual movement.

Equally important is that every visual movement of the human binocular organ is convergence. The resulting motor-co-ordinations may—or may not—have other components—upwards, or downwards, to the right or to the left—as well, *but the basic movement is convergence*. Without convergence no binocular foveal single vision is possible, and this can be said of no other kinetic factor, of no other movement. This convergence is the obligatory factor of every visual binocular movement. It is, therefore, more than a function; it is the kinetic principle of binocular vision.

This Convergence as the Kinetic Principle of Binocular Vision

For a pair of eyes which have no fovea, a movement of convergence has no meaning. There are no visual axes that can converge. Such eyes may have the power of adduction which makes the two visual fields overlap more than in the primary position. This, however, should not be called convergence.

Only an eye possessing a fovea is equipped for distinct vision in one line. Such an eye is an organ which is physiologically equipped with the strong tendency to bring one single visual line into such a direction that a specialized central spot of the retina can—and must—receive the most important rays. The rays of greatest importance are those which emanate from the object of visual attention. If these rays are not in the visual axis, then a reflex-movement sets in, in order to change the direction accordingly. I have called this movement the *stimulotrope* movement of the fovea.⁸ Within narrow limits the strength of the stimulus for this movement seems to increase in inverse ratio with the distance of the fovea from the stimulated para-foveal spot. For every eye there is a distance where the stimulus ceases to be effectual; then a voluntary duction can bring the fovea within the working range for the reflex of the stimulotrope movement.

An approximately parallel position of the visual axes is the anatomical position for the mammals equipped with a fovea. This position has brought the foveal visual line of either eye within easy distance from every object of foveal vision of the other eye. It enables the dual eye to perform every normal visual movement

FIG. 1. (HUNTER-BROUWER)

Scheme of oculomotor nuclei in various mammals, all except Tarsius after Brouwer . . . (Edinger-Westphal nucleus is represented in black; nucleus of convergence is stippled).

through the reflex for the stimulo-trope movements; by this favourable position interference by voluntary duction has become superfluous.

In the mammalian line the fovea begins with the felines, and is developed to its highest degree of perfection in man. Parallel with this development another development has occurred, viz: that of a centre for convergence in the mid-brain. I give here a schema by Brouwer to illustrate this occurrence⁹ (Fig. 1). These two phylogenetic happenings prove that convergence is phylogenetically a very young function in contradistinction to ancestral functions, like accommodation. Young functions are plastic, in contradistinction to ancient ones which show more ease of performance, more machine-like fatality than young reflexes. Another characteristic of convergence is its great complexity. The same twelve

muscles, which are involved in the motor-co-ordinations of convergence, are—often even at the same time—involved in quite different movements as well.

It is evident that the centre for this young reflex has to assert itself; it has still to battle for the supremacy which is its birthright. On account of its youth and complexity a considerable individual plasticity could *a priori* be expected. For the same reason much individual difference in range and even insufficiency of the function are found. Both insufficiency and plasticity have been established by me in the diagnosis and the treatment of hundreds of eyestrain cases. By kinetic therapy the existing insufficiency in such patients can always be dealt with and the convergence brought to full range and power.¹⁰

The insufficiency of convergence I have called *astheno-vergence*.

Method of Testing

I give here photographic pictures of the implements used by me in many thousands of tests. Every person was tested while sitting opposite a black cloth, 4 feet square, at a distance of 5 or 6 metres. In the centre of the cloth an oblong strip of white cardboard 7 cm. by 0.5 cm. was fixed in the middle. The white strip served as the object of vision. It was placed in the vertical position in the tests

OBJECT—VERTICAL POSITION.

OBJECT—HORIZONTAL POSITION.

for horizontal convergences, and in the horizontal position in the tests for vertical convergences. The head of the tested person was supported by a rest for the chin and one for the forehead. Into the rest for the forehead a trial-frame was fixed for the prisms. The test was done by successively placing prisms of increasing strength (no revolving prisms!) in front of the eyes, until the images were no longer merged, but remained apart. The difference between the separate prisms I use for horizontal convergence is one degree, for vertical convergence it is one-quarter of a degree of prism. When the images were no longer merged, the preceding number of prism degrees was taken as the result of the test.

The Significance of the Test

When looking at a distant object straight ahead, the two lines traversing the foveae and the main focal points—the visual axes—although actually converging are nearly parallel. This, in contradistinction to the anatomical position, should be called the functional primary direction.

I speak of direction and not of position in order to remain on physiological ground and so to avoid the prevailing confusion. The almost parallel direction is *not* a position, but it is a function of visual activity. That direction can never be parallel—nor for practical purposes parallel—because it *is* convergence.

When prisms are placed in front of the eyes, the visual axes change their direction in order to let the broken rays, which come from the object, hit the foveae as before. In other words, notwithstanding the action of the prism on the direction of the rays, convergence is performed all the same. It is immaterial whether the prism be placed with its base out, or in, or up, or down, or in whatever combination of these positions, *the dual eye which overcomes the difficulty of the deviation and performs single vision, performs this by the power of convergence.*

I know this is an entirely new conception of convergence, but the above considerations forced me to its adoption.

Consequently the several movements of this convergence could be differentiated according to the different directions the front part of the visual axis takes in relation to the *primary* direction. Two main directions during convergence are the intra-primary and the extra-primary direction. Two other main directions are the two sursum-deorsum directions of convergence.

The point is that all these motor-co-ordinations are performed by the function of (involuntary) convergence. The degree to which a person by his or her involuntary convergence is able to overcome the action of the prism varies. That degree is the measure of such a person's power of involuntary convergence.

Examination of Bantu natives of South Africa

In preparing my thesis¹ I dealt exclusively with persons belonging to the white races, officially called "Europeans" in this country. My interest at that time was fixed on the difference between the patient with healthy eyes but with complaints of eyestrain and the normal person with no such complaint.

It appeared now of interest to examine another human race. By the courtesy of Dr. Orenstein, Chief Medical Officer of the Rand Gold Mines, I received facilities for testing healthy young persons of the Bantu race. At a dressing station on a gold mine, where about sixty natives were detained daily for minor injuries, I had at my disposal a room with suitable light and distance for the test. The officer in charge of the station and two of his orderlies assisted me daily for about two hours for more than three weeks. This, combined with the almost military discipline at the station, created an atmosphere which rendered possible an investigation of such delicate nature on such a scale. Superstition, fear and other disturbing factors would have precluded even an attempt at such a test on similar natives in their own homes in the native territories or even in the mine compounds. But as it was, a happy spirit prevailed amongst these natives and they showed great interest in the proceedings.

Diagrams

I attach hereto a chart showing three groups of three diagrams. The groups are marked I, II and III.

Group I deals with normal Europeans.

Group II „ „ European eyestrain patients.

Group III „ „ normal Bantu natives.

Each person was tested on three different days. Therefore a test-result of every person appears in every one of the three diagrams constituting the group.

All groups are on the same abscissa, and on this abscissa I have set out the degrees from 0° — 90° of prism principal angle.

Each square represents the result of the test on one person on one particular day. Thus the one square on the extreme left in the left bottom corner means that on the first day of testing Bantu natives, one individual had 6° as his test result. In the same way the 14 squares on top of one another in Group I, third testing day, mean that 14 individuals reached the convergence of 84° on that day. This last result is somewhat inaccurate as higher degrees cannot be scored with the present apparatus. Some of these 14 squares should really be distributed over an area beyond 84° .

DIAGRAM: INVOLUNTARY CONVERGENCE (Stutterheim)

GROUP I.
EUROPEANS. NORMALS. GROUP II.
EUROPEANS. PATIENTS. GROUP III.
BANTU NORMALS.

Conclusions

The conclusions that can be drawn are:—

(1) On comparing normal Europeans (I) and Bantu (III) it will be seen that the Bantu results are distributed round a lower average than those of the Europeans. This difference would appear to be about 15° . In other words: the Bantu race evidently has a less developed centre of involuntary convergence.

(2) It will be seen that in the normal Europeans there is a great shifting of the squares to the right on every succeeding day. In the Bantu this shifting to the right is much less pronounced, and hardly ever does an individual reach as high a degree of improvement as the European normals frequently do. In other words, the Europeans are nearly all capable of reaching a high degree of this convergence, either on the first test day or on one of the following days. It must not be forgotten that three days is a short time for achieving great improvement. I know from experience that normal Europeans will keep on improving day after day and that, with very rare exceptions, all of them can reach about 80° . It seems quite unlikely that such a thing would be possible in the majority of the Bantu.

I had an opportunity to put two young natives to the test to see how native convergence would respond to more prolonged treatment identical to that I had given to Europeans. One of the natives hardly made any progress, and remained below 30° . The other, a keen intelligent man, who did much of the administration of the station, I could not bring higher than 42° .

(3) Comparing the data for patients and for normal Europeans, it strikes one that the shifting to the right during these three days is very much slower in the patients. The patients also start at a very much lower average level than the normals. From experience I know that, although the shifting to the right is slow in patients, it is very consistent. Practically all patients can by methodical treatment be brought to a level of 70° — 84° .

(4) Throughout all the diagrams I have indicated by means of horizontal lines, which together produce the impression of a ladder, the range of degrees of convergence necessary for reading. I consider this reading-distance as the minimum distance of most of the near work of binocular vision, and for that reason of very great importance in binocular economy. It is evident that the bulk of the patients are below the range of convergence required for that distance, that the normals are chiefly well above it, and that the Bantu are somewhat evenly distributed on either side. This, to my mind, gives the most suitable explanation of the eyestrain complaints arising in patients when doing near work, of the absence of eyestrain in normals in similar circumstances, and of the apparent

unsuitability of the Bantu as a race for following pursuits which entail much accurate, frequent and persevering near work.

Summary

A new conception of convergence is proposed. This conception does away with current ophthalmological opinion on convergence.

The new conception of convergence affects the diagnosis of asthenopia. It displaces the centre of gravity in that diagnosis from the static factor of monocular refraction in the direction of the kinetic factor of functional binocular ability.

An important physiological difference was found in this function between the Bantu and the European.

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TWO RARE CORNEAL CONDITIONS

- I. Acute Conical Cornea
- II. Keratoconus Posticus Circumscriptus

BY

T. HARRISON BUTLER

BIRMINGHAM

Case I

FUCHS (*Lehrbuch der Augenheilkunde*, 14th Ed., p. 408) mentions a condition which he calls *acute conical cornea* and describes it in the following words:—"The alteration in the curvature of the cornea sometimes causes spontaneous rupture of Descemet's membrane and its endothelial lining. Then the aqueous seeps into the corneal parenchyma causing it to swell and become cloudy.