THE DIVERGENCE OF THE PRIMARY POSITION OF THE EYES

BY

N. A. STUTTERHEIM, M.D.

FROM THE DEPARTMENT OF PHYSIOLOGY, UNIVERSITY OF THE
WITWATERSRAND, JOHANNESBURG

I HAVE previously pointed out¹ why the text-book conception of the Primary Position is wrong. It is essential to establish the actual physiological Primary Position, because it is the basis of kinetic binocular ophthalmology.

My view is that the anatomical position is the PRIMARY POSITION of the bi-unial eye.

This position is slightly *divergent*. I propose to call this divergence the "PRIMARY DIVERGENCE." The consequences of Primary Divergence will now be considered.

The visual axis of the eye connects three points, *viz*: the fovea, the nodal point of the dioptric system, and the fixation point of the visual object. The intra-ocular part of this line is practically straight. The course of the extra-ocular part is determined by the refracting surfaces it passes through between the cornea and the fixation point. If there are no refracting surfaces, this part is also a straight line.

In bi-foveal single vision there are four possibilities, illustrated by the Figs. 1, 2, 3 and 4. Text-books call Fig. 4 the "negative convergence."

Fig. 1

Fig. 3

Fig. 2

Fig. 4

Divergence of the visual axes precludes bi-foveal single vision. *Co-ordinated action*, therefore, *of the Adductor musculature is essential* for visual activity of the bi-unial eye.

The angular displacement from the primary position, *e.g.*, in reading, consists of two parts. The one, reckoned from the parallel position of the visual axes, is known as the angle of convergence. This, for the average reading distance, and the average pupillary distance, can be taken as 10.5° (angle of deviation). The second part is the angle of divergence of the primary position. This angle is unknown and cannot be measured *directly*. I have tried an *indirect* method: I tested the negative convergence in two groups of young persons without eye complaints, (100 Europeans, and 100 Bantu natives).

The Method

The negative convergence was estimated by placing the usual prisms in front of the eyes—the base of the prism towards the middle line—and recording the degree of prism that the eyes could overcome in single vision. (See Fig. 4.) The object to be looked at was placed at 6 metres.

It must be noted that no amount of practice was ever observed to increase the range.

The Europeans had a negative convergence ranging from $2-12^\circ$ of prism, and the mean was 5.5° (equivalent to 2.88° of angular deviation). The Bantus ranged from $2-24^\circ$ of prism, and the mean was 10.88 (equivalent to 5.17° of angular deviation).

Can this amount of negative convergence of 2.88° angle of deviation (5.5° of prism) be regarded as identical with the amount of primary divergence?

If the negative convergence is larger, its range would then go beyond the primary divergence, in which case even full inhibition of the Adductor musculature would be insufficient for the movement, but contraction of the muscoli Recti Externi would, in addition, be required.

The Nucleus Abducens

The Nucleus Abducens is very distinct from the other ocular mid-brain nuclei. Far away from the others it forms the *Pontine centre* for conjugate deviation by its connection with the nucleus for the musculus Rectus Internus of the opposite side. This connection is established by a comparatively long nerve tract, the Fasciculus Longitudinalis Posterior. But the Nucleus Abducens does not participate in—is, in fact, at a great distance from—the unpaired raphe group of nerve cells, belonging to the Nuclei

Oculomotorii, which group Brouwer has established as the centre for convergence in the mid-brain.²

Further, the range of action of the musculus Rectus Externus is 45° towards the temporal side. If, therefore, the muscoli Recti Externi functioned to increase the range of negative convergence, they could produce an angle, open towards the front, of 90° . But the average negative convergence for Europeans is only about 3° .

Authors agree that in the anatomical position (in death, in deep narcosis, or in complete ophthalmoplegia) the ocular axes show *slight* divergence. If it were much less than 3° it would not be perceptible by available methods.

The CONCLUSION is that the range of negative convergence is the same as the amount of divergence of the Primary Position. The *average primary divergence* in Europeans, therefore, is, according to my investigations, nearly 3° *angle of deviation*.

Force of Convergence

The angle of convergence for ordinary reading is 10.5° joint angular displacement, reckoned as is customary, from the parallel position of the axes. As, however, the primary divergence is already about 3° , the total displacement is 13.5° .

In actual experiment I have found that in animals of *circa* 25 lbs. weight (monkeys and baboons) the force for one millimetre tangential displacement is between 1 and 2 grammes, for two millimetres between 2 and 4 grammes, and so on. In man (with an ocular radius of 12 millimetres) 13.5° means 2.82 millimetres tangential displacement.

In man the force required will possibly be greater than in my experimental animals. If it were the same, then the force for reading convergence would be 5 grammes (to be exact 5.05 grammes). For the dimensions of the muscles even this is a very considerable effort, especially as civilisation requires such expenditure of energy for many hours each day.

Tenseness

The divergence of the Primary Position producing an elastic pull as soon as the bi-unial eye is in function, *procures a uniform tenseness*, even when looking at a distance, with the axes nearly parallel.

This tenseness forms a suitable basis for the delicate accuracy of the movements of the eyes. It is somewhat comparable to a musical instrument, properly tuned.

The European, with his slight primary divergence of only 3° , seems to have a more delicate tuning, more appropriate to his high standard of stereoscopic perception, than the Bantu.

This difference in primary divergence between Bantu and European fits in with another difference between these racial groups, viz.: the average range of convergence.³

Following up these racial differences, I measured fifty European and fifty Bantu skulls. The skull being placed in the Frankfurt plane, two points on each orbital rim, near the insertion of the palpebral ligaments, were projected on a horizontal surface. The angle formed by the two lines connecting these two points for each rim, was measured. In the European skulls it ranged from 133° to 157° , with a mean of 143.64 . In the Bantu skulls it ranged from 131° to 155.5° , with a mean of 141.08° . As the difference, 2.56° , is less than twice the standard error, it is not significant statistically. One must conclude that the racial difference in primary divergence is not caused by a difference in the shape of the bony orbits. I suggest that it is due to a racial difference in the development of the mid-brain centre for convergence.

Lateral Range of Reading Movement

The primary divergence also makes it possible to cover an extra amount of bi-foveal vision, *without* assistance of the Abducens. The activity of the Abducens appears to be characterized by speed rather than by endurance. Looking sideways becomes accompanied by a feeling of strain. One never looks sideways persistently, but rather turns one's head. The primary divergence increases the range at reading distance from, say, 60 millimetres to 77 millimetres, without calling in the action of the Abducens.

Popular publications are as a rule printed in lines not exceeding 7.5 centimetres, and thus can be read without strain or turning of the head.

Summary

The degree of *Primary Divergence* (divergence of the Primary Position)—hitherto unknown—is measured by the indirect method of testing the range of negative convergence.

The displacement from the Primary Position for bi-foveal vision, e.g., reading, can now be found by adding the angle of primary divergence to the angle of convergence.

The force required for overcoming the elastic pull of the Primary Position can now be calculated for every bi-foveal visual movement.

The primary divergence by its elastic pull during bi-foveal single vision causes a uniform tenseness as a basis for the delicate accuracy of human binocular movement.

A difference in average amount of primary divergence is established between Bantu and European.

The primary divergence enlarges the range of comfortable binocular movement, *e.g.*, in reading.

I would like to acknowledge with gratitude the practical help given me in connection with this work by Professor Raymond A. Dart and Professor J. P. Dalton, of Johannesburg, and by Professor M. R. Drennan of Cape Town.

REFERENCES

1. Stutterheim, N. A.—The Primary Position of the Eyes. *Brit. Jl. of Ophthal.*, July, 1933.
2. Brouwer, B.—Klinisch-anatomische Untersuchung ueber den Oculomotorius-kern. *Zeitschr. f.d. ges. Neurol. Psychiatrie*. Bnd. XL, Heft. 1/3, 1918.
3. Stutterheim, N. A.—The Convergence of Human Binocular Vision. *Brit. Jl. of Ophthal.*, January, 1932.

THE USE OF ARTIFICIAL SUNLIGHT FOR ILLUMINATING TEST APPARATUS AND THE GENERAL LIGHTING OF EXAMINATION ROOMS

BY

LT.-COL. R. E. WRIGHT, C.I.E., I.M.S.

MADRAS

OPHTHALMOLOGISTS in the East are, for the most part, enabled to work in bright rooms, where artificial light is unnecessary for illuminating test types and testing apparatus, or for the naked eye examination of patients. Occasionally where adequate provision for efficient daylight illumination has not been made, artificially lit test types, perimeters, etc., have been used. The disadvantages of such methods did not strike me until in 1931 it became necessary to mount a Bjerrum's screen in an ill-lit room. I then determined to develop the idea of flood lighting and proposed to meet the difficulty of uniform screen illumination by having two suitable lamps mounted in paraboloid reflectors set on stout movable stands with vertical telescopic columns capable of being placed in any position on the floor of the examination room so as to flood the screen with an even light of known intensity.