Decompensated heterophoria and its effects on vision

Helmut Goersch

The following paper, translated from the German, describes a sequence of adaptations to heterophoria which are not usually recognised in this country. It suggests that when heterophoria is decompensated, fixation disparity as we know it is the first result, but as the case becomes more long-standing, further sensory adaptations take place which result in changing the symptoms and also a loss of visual functions in several respects. Suggested remedy is the full correction of the motor anomaly by prescribing prisms.

The paper begins by defining precisely the basic concepts. Although these do not differ from those understood in Great Britain, the latter part of this account of binocular adaptations requires a clear understanding of these definitions.

Work is proceeding at Bradford University using the Zeiss Polatest to compare the German outlook with that usually accepted in this country.

D. Pickwell*

1. Some basic concepts

AS there is yet no international standard glossary of terms for the concepts of binocular vision and all monocular concepts have not yet been standardised either, some expressions must be first defined and described, in order to avoid misunderstanding in the use of these terms. The reader is also referred to the German Standard DIN 58 208[1] and to the chapter 'The Pair of Eyes' (*Das Augenpaar*) in the *Zeiss Handbook for Eye Optics.*[2]

a Fixation

The monocular concept of fixation refers to the condition in which the object of attention is imaged in the middle of the fovea (definition of the fixation point). Correspondingly in DIN 58 208 the concept of 'fixation line' is laid down for a free eye.

The fixation line is the principal ray of that bundle of rays in the object space which images the fixation object in the middle of the fovea. If there is a spectacle lens in front of the eye and if the eye is looking through the optical centre of this, then this principal ray is not deviated in any way by the lens, and thus continues to be identical with the fixation line. If, however, the eye is not looking through the optical centre, then there is a prismatic effect and the principal ray is deviated at that point. Its direction in front of the lens then no longer coincides with direction of the fixation line. Consequently, the standard definition of the fixation line can be completed in the following way.

> 'If there is a lens in front of the eye, the fixation line is the straight line connecting the image of the fixation object produced by that lens and the middle of the entrance pupil of the eye.'

There arises for the image of the fixed object point the sequence of separate parts of the principal ray as shown in Fig 1 (in the direction of light):

1 Principal ray in the object space with reference to spectacle lens.

2 Principal ray in the image space with reference to spectacle lens—is at the same time the principal ray in the object space for the eye and thereby identical with the fixation line.

3 Principal ray in the image space for the eye (this ends in the middle of the fovea in a real image of the fixation point).

So only part 2 of the principal ray indicates the direction of the fixation line. This determination is important in connection with the vergence of a pair of eyes behind prismatic spectacles. If the fixation point in the case of monocular viewing is not imaged in the middle of the fovea, then 'eccentric fixation' occurs. *This abnormal condition is expressly excluded for further reference in this paper.*

b Visual direction in monocular vision

Every element of the retina is associated with a visual direction learned during the development of vision[9] which transmits the impression of direction in space for the

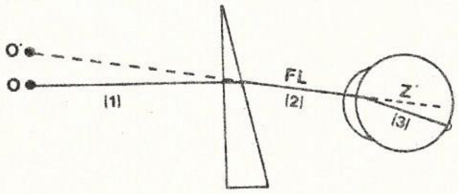

Figure 1. The definition of the fixation line

object point imaged on that particular retina element. In normal central fixation, the centre of the retina has the visual direction 'straight ahead'. The fixation point imaged here is experienced as lying in space straight ahead in front of the eye. All other visual direction refers to this central reference localisation: it is, so to speak, the zero point of the co-ordination system for the experience of direction

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In Fig 2 this idea is expressed schematically. In the lower part of the figure the retina is seen from behind and all those retina elements whose visual directions convey the same height perception as the centre form the 'horizontal retinal meridian'. The 'vertical retinal meridian' is defined similarly. All retina elements above the horizontal retina meridian have the visual direction of below and vice versa; all retina elements to the right of the vertical retinal meridian have the visual direction of 'left' and vice versa.[6]

c Retinal correspondence

The binocular concept of 'retinal correspondence' refers to the co-ordination of both eyes in binocular vision for the purpose of determining visual direction. A test of this correspondence must be carried out with different objects for each eye.[10] Retinal elements of both eyes, which have the same visual direction in binocular vision are called 'corresponding retinal points', retinal elements of both eyes with different direction evaluations are called 'disparate retinal points'.

Those points of both retinas which, in binocular vision, have simultaneously the visual direction of 'straight ahead', are called 'correspondence centres'. As long as the two foveas represent the correspondence centres, or only temporarily relinquish their learned capacity to do so, but have not lost it, 'normal correspondence' is present. In normal correspondence the fixation point is imaged in both eyes within the foveal Panum's area and is seen singly. In this normal correspondence, one must distinguish between bifoveal (ideal) and disparate (no longer ideal) correspondence. In the case of 'bifoveal correspondence' the two foveal centres are the correspondence centres. If, however, one correspondence centre has shifted out of the foveal centre of one eye, but still lies within the foveal Panum's area, then 'disparate correspondence' exists.[7]

If the image of the binocular fixation point in one eye falls outside the foveal Panum's area, then 'abnormal correspondence' occurs. *This abnormal condition is excluded from further reference in this paper.*

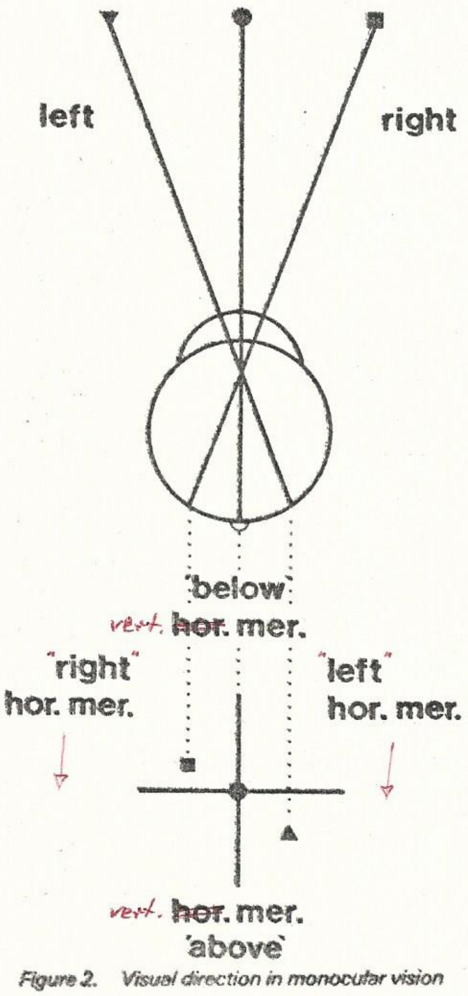

Figure 2. Visual direction in monocular vision

d Fusion

The concept of 'fusion' incorporates all procedures that lead to the blending together of the two monocular images, thus to binocular single vision. Here we must distinguish between motor and sensory fusion.

Motor fusion usually assures that, with the help of the extrinsic ocular muscles, a binocular fixation point is imaged on the correspondence centres of both eyes. Then all object points lying on the phoropter are likewise subject to motor fusion. Through *'sensory fusion'* even disparate images are blended together into binocular single vision, provided the disparity is not greater than Panum's area. In other words, if the visual directions of two points of the two retinas in which the same object is imaged do not differ too much from each other, then the object is seen singly through sensory fusion. The sensory fusion of object details imaged disparately in the Panum's area is the necessary prerequisite for a stereoscopic awareness of depth.[9, 13] Prerequisite for *any* fusion is a sufficient equality of both retinal images (fusion stimulus). Fusion occurs unconsciously (fusion compulsion).

e Heterophoria

A pair of eyes is in the 'position of rest', when the fixation lines of both eyes form the angle with each other at which the eyes are in muscular relaxation. In the case of a position error of the eyes this rest position does not coincide with the 'work position' (also called the ortho-position) in which both fixation lines must be directed at the binocularly offered fixation point. If there is a position error which in the presence of a fusion stimulus, as in natural vision, is overcome by fusion, this condition is known as 'heterophoria' (latent position error). In the case of orthophoria, rest position and work position are identical.

2. Motor fully compensated heterophoria

In every heterophoria its size and direction determine the fusional vergence requirement, and thus the vergence alteration necessary from the rest position, in order to obtain ideal correspondence with bifoveal images of the fixation point (work position), *eg* if there exists an esophoria of 8Δ, then there is a fusional divergence requirement of 8Δ, and so on. At first every heterophoria receives full motor compensation; the eye muscles turn the eyes from their rest position into the work position. This complete motor fusion of the fixation point is the prerequisite for the ideal correspondence with bifoveal fusion which is learned during the development of vision. So in any motor fully compensated heterophoria, the fusional vergence requirement is completely covered by fusional vergence, and this represents a constant effort always going in the same direction of the vergence system.[8, 12] This constant effort will continue as long as possible, because only in this way can a sensory relationship between the two eyes equivalent to orthophoria be achieved.

3. Decompensated heterophoria

In the case of some fully motor compensated heterophoria a time comes when, for some reason or other (*eg* sickness, increased stress, age), the constant motor effort cannot be maintained; the heterophoria begins to decompensate.[8,12] When this occurs the vergence of the eyes deviates somewhat from the work position in the direction of the position of rest. In general, one of the two fixation lines remains directed towards the binocular fixation object (directionally leading eye), but in the other eye, this object is imaged no longer in the centre of the

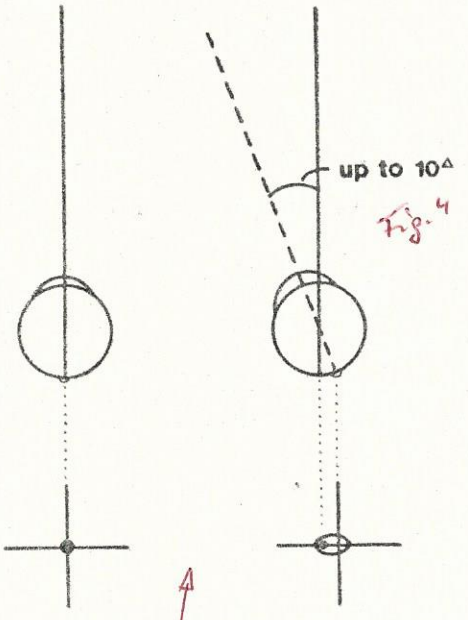

Figure 3. Decompensated esophoria with disparate fusion within normal Panum's area

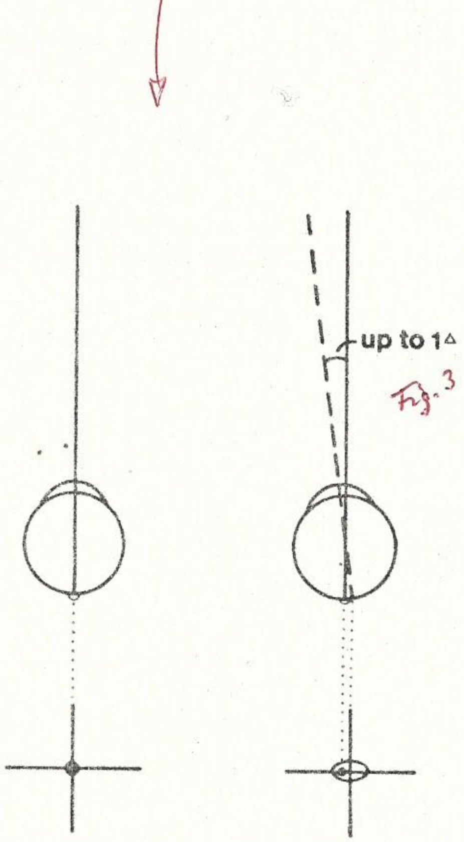

Figure 4 Decompensated esophoria with disparate fusion and nasal enlargement of Panum's area

fovea (ideal correspondence centre) but somewhere in the foveal Panum's area, even as far as its edge (not to be confused with eccentric fixation). The direction of this deviation is determined by the nature of the heterophoria. In esophoria, (see fig 4), the eye turns nasally, etc. The eyes can alternate in taking a leading role. Thus, in the early stage of decompensation of a heterophoria the binocular fixation point is no longer imaged in exact correspondence but disparately within the foveal Panum's area of the deviated eye, *although the bifoveal correspondence at first remains.*

Now the capacity of sensory fusion for objects disparately imaged in Panum's areas is also applied to the fixation point and thus it continues to result in single vision. This is the first type of sensory adaptation to a decompensated heterophoria (first kind of fixation disparity), which is called 'disparate fusion' by H. J. Haase, as it is a matter of a sensory fusion of the disparately viewed fixation point. A prerequisite for "disparate fusion" is, as for any fusion, a sufficient equality of the retina images in both eyes. Only for binocularly fusionable fixation objects, the corresponding disparate retinal element of the deviated eye takes on the same visual direction as the foveal centre of the leading eye (in the deviated eye the fusion centre is moved in relation to the foveal centre, but the correspondence centre remains central!).

At first the decompensation of a heterophoria goes only as far as the edge of the normal foveal Panum's area, about the size of which widely varying references are to be found in the literature. In this 'decompensation within the normal Panum's area' deviation of about 1Δ from the work position is probably possible.[11] If, however, the heterophoria is greater, then the foveal Panum's area follows to some extent the trend towards further decompensation. It enlarges itself in the direction of the position of rest, *eg* in an esophoria like that in fig 4 towards the nose, etc. This enlargement of the foveal Panum's area is possible to an astonishingly high degree. As measurements with the Zeiss Polatest over a number of years on more than 1,000 pairs of eyes have shown, enlargements of the foveal Panum's area have been found as an adaptation to decompensated distance heterophoria often up to 4Δ in the direction determined by the heterophoria; in individual cases even up to 10Δ! In other words, this means that heterophorias up to the size of 10Δ can possibly completely adapt: they are fully compensated sensorily, and there is no additional requirement from *motor* fusion. In the case of a 'decompensation with enlarged Panum's area' the image of the binocular fixation point in the deviated eye (with continued binocular single vision) can have reached as far as a point in the perifovea at which the acuity is only about 30 per cent of maximum central acuity. If decompensated heterophoria is left in the stage of disparate fusion long enough (there is no answer to the question 'how long is that?'), in other words, not corrected prismatically, in the course of time the disparately positioned fusion centre in the deviated eye changes into a correspondence centre. This second condition of the sensory adaptation to a decompensated heterophoria (second kind of fixation disparity) is called, after H. J. Haase 'disparate correspondence' because in this case the disparately imaged fixation point in the deviated eye has led to a genuine shift of correspondence.

The newly obtained correspondence centre lies within the normal or enlarged foveal Panum's area and is classified as a 'disparate correspondence centre' (not to be confused with an abnormal retinal correspondence where the correspondence centre lies *outside* the foveal Panum's area). In a correspondence test (with differing objects for both eyes) it is shown that this disparate image point, in the deviated eye, has acquired the visual direction of 'straight ahead' in binocular vision (but not in monocular vision) regardless of the object seen: it has, in fact, become a correspondence centre. The changeover of the other visual directions follows in the course of time. The longer the disparate correspondence exists, the further away from the correspondence centre the directional change has become established: peripheral retinal points change over later than central ones.

If a full prismatic correction is worn by a patient with disparate correspondence to restore the eyes to the position of rest while the fixation point is imaged in the centre of both foveas, then the centres of correspondence again become foveal (as originally learned): there is a reversion to ideal correspondence with bifoveal fusion. In 'recent disparate correspondence' this

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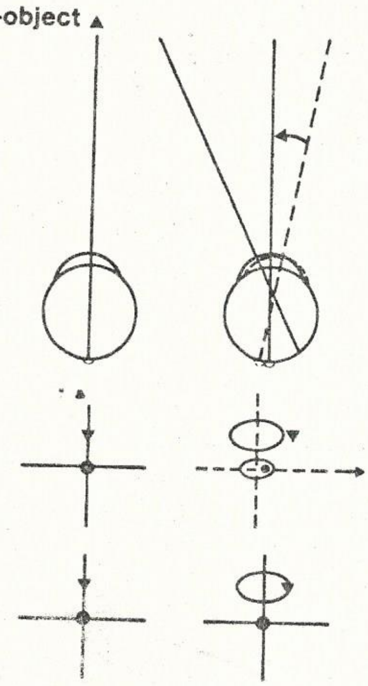

Figure 5. Stereoscopic perception in decompensated exophoria showing reduced stereo-acuity in disparate fixation

reversion to bifoveal fusion occurs spontaneously: in 'long-standing disparate correspondence' it may not be spontaneous. The older a disparate correspondence, the more slowly it reverts to the originally learned binocular visual direction of ideal correspondence with bifoveal fusion.

4. Visual disturbances and symptoms

As a result of uncorrected heterophoria there can ensue effects on the vision and on the general well-being of the patient. In further explanations a distinction is made between visual disturbances and strain difficulties creating symptoms. In the case of reduced visual performance the following detectable visual disturbances may be present:

1 decreased or only with a time lag attainable binocular full acuity
2 decreased monocular acuity in one or both eyes
3 difficulties of monocular fixation in one or both eyes
4 delayed stereo-awareness of objects occurring before and/or behind the fixation point (stereo-delay)
5 false stereoscopic direction awareness of objects lying before and/or behind the fixation point (stereo-prevalence)
6 decreased depth perception
7 lack of stereopsis
8 decreased fusional reserve
9 occasional onset of double image (intermittent diplopia)

In many situations the patient is conscious of some of these vision disturbances, and this causes him to seek the advice of an experienced optician. Often, however, existing visual disturbances are not noticed, if they have developed relatively slowly, and as a result the reduced visual ability is considered as *normal* by the patient.

The symptoms which can occur as a result of constant motor stress of the vergence system (headaches, burning sensation of the eyes, etc) have been exhaustively described in the literature.[3,5]

5. Effects of decompensated heterophoria

As long as a heterophoria receives full motor compensation, the vision disturbances referred to above cannot occur, as the eyes in this condition are in ideal sensory co-operation. Only the decompensation of a heterophoria can lead to various visual disturbances.

a Disparate fusion in the normal Panum's area

In the case of disparate fusion in the normal Panum's area the image of the binocular fixation point in the deviated eye lies a little outside the centre of the fovea and thus no longer at the point of the greatest resolution potential. Binocular full acuity which in the case of ideal sensory co-operation of both eyes is *appreciably* higher than monocular acuity, is no longer achieved where there is a deviation from the work position of the eyes. Binocular acuity is, in this case, at best a *little* higher than the monocular acuity of the leading eye: only when the eyes achieve 'full motor fusion' as far as bifoveal images of the fixation point can full binocular acuity again be achieved: visual disturbance (1) above. If the image of the binocular fixation point in the deviated eye lies on the edge of the foveal Panum's area, then the results are difficulties in the stereoscopic recognition of objects lying before and/or behind the fixation point. When the image is on the temporal side of the fovea as in the example of the decompensated exophoria of fig 5, these stereoscopic difficulties will arise for objects with crossed disparity and vice versa. For perfect stereo awareness of such objects 'full motor fusion' must likewise be achieved to result in bifoveal images of the fixation point. This full motor fusion occurs in appropriate visual tasks and requires a certain amount of time: visual disturbance (4) above.

Thus in exophoria a delay can occur for objects *in front of* the fixation point, in esophoria for objects *behind* the fixation point and in vertical phoria for objects *before and behind* the fixation point. Visual disturbances (1) and (4) have a particularly unfavourable effect in connection with eye movements and with the estimation of speed. If only a part of an existing heterophoia is sensorily compensated, then for binocular single vision the remainder must have motor compensation. If in the case of extreme tiredness (especially for near vision) this motor compensation becomes temporarily too difficult, an intermittent diplopia occurs: visual disturbance (9) above.

b Disparate fusion with enlarged Panum's area

In the case of disparate fusion with enlarged Panum's area, the visual disturbances described under (a) are even more evident, especially in near vision. In addition, suppression areas can develop in the deviated eye (in both eyes where there is alternating dominance), in the centre of the fovea and the fusion centre. As a result of these suppression areas, the fusion stimulus is weakened: full motor fusion is much more difficult for the vergence system which must now bring about a greater change of vergence anyway. In addition a decrease in the fusional reserves is observed: visual disturbance (8) above.

c Recent disparate correspondence

If a disparate correspondence has developed from a disparate fusion, the visual disturbances described under (a) and (b) present themselves to a more marked degree. Stereo-delay is particularly evident, as in recent disparate correspondence full motor fusion resulting in bifoveal images of the fixation point (optional bifoveal correspondence) may still occur with particularly difficult visual tasks. It can then take longer than 30 seconds until a suddenly presented stereo object can be *correctly* localised in space. Often stereo objects are perceived even *constantly* in a too small spatial distance from the binocular fixation point: visual disturbance (6).

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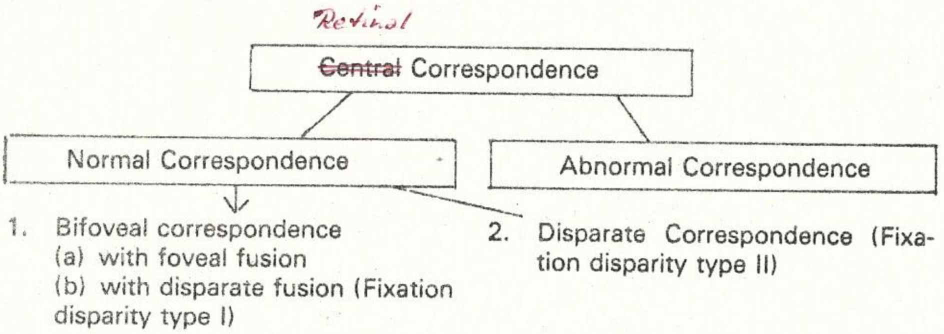

Figure 6. Types of correspondence

d Long-standing disparate correspondence

As a disparate correspondence becomes more long-standing, the capacity for full motor fusion to obtain befoveal images of the fixation point is gradually lost. Therefore a situation finally arises when the visual disturbance (1) is a *constantly* diminished binocular acuity, and visual disturbance (4) (stereo-delay) is no longer present. Either there still exists stereopsis with incorrect perception of direction and decreased depth perception (visual disturbances 5 and 6), or the capacity for binocular spatial perception on the basis of disparate images is forgotten: visual disturbance (7).

If long-standing disparate correspondence lies in the enlarged Panum's area, then the suppression areas in the deviated eye gradually become so consolidated that they increasingly have an effect on monocular vision.

Already in the determination of refraction, reduced vision and a hesitant and jerky reading of the optotypes will be noticeable visual disturbances (2) and (3).

Sensory fully compensated heterophoria with long-standing disparate correspondence is not accompanied by symptoms for distance vision, as, in this condition, the eyes are constantly in the rest-position whereas at least in the presence of suppression areas appreciable symptoms usually arise for near vision. A full prismatic correction usually eliminates all visual disturbances caused by the decompensation.

6. Effects of prismatic correction

Just as spherical and cylindrical corrections do not affect the refractive error of the eyes, prismatic corrections do not alter the position of rest. Exactly as a full refractive correction images a distant fixation point at the eye's far points, binocular fully correcting prisms, by deviating the light, provide bifoveal images for the eyes in the position of physiological rest.

Expressed in general terms, prismatic corrections bring about a changed work position in contrast to uncorrected vision. Binocular fully correcting prismatic lenses produce this work position in which the eyes are in a state of muscular relaxation. So the effect of prismatic corrections, for the full correction of heterophoria, consists in producing 'orthophoria with correction', (just as full refractive corrections produce 'emmetropia with correction'): in viewing a distant object the eyes are then, (without accommodation) in their distant position of rest. By this means the natural accommodation and convergence relationship for near sight is recovered. Therefore the prismatic full correction of distance heterophoria is advisable.

7. Summary

By way of introduction certain concepts of optometry were explained: in fig 6 the most important expressions of retinal correspondence are again summarised. Then the basic points of the theory, developed by H. J. Haase, of decompensated heterophoria were presented.[8] In the course of twenty years this theory has been authenticated in practice, and not only at the Higher Technical College, Optics Department, in Berlin.[4, 7, 12] On the basis of this practical experience, the visual disturbances connected with the various stages of the sensory adaptation to decompensated heterophoria are presented. From experience in correction of decompensated heterophoria, the recommendation is made to correct prismatically, to the full extent at least, all decompensated heterophoria for distance vision.

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† The concept of 'disparate correspondence' is vital to understanding the later sections of this paper. D.P.