HOW USEFUL IS ANOMALOUS CORRESPONDENCE?

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SUMMARY

In anomalous retinal correspondence (ARC), retinal points in the right and left eyes which receive stimuli from one object in space have the same visual direction despite a manifest motor deviation. The mode of cooperation of these anomalously corresponding retinal points depends on their relative eccentricity or their relative functional level. If there is a great difference, as for the most part in large angle strabismus, the retinal point with less eccentricity and better resolution will prevail, while the other will be suppressed. This leads to a second area of high resolution in the binocular visual field with a possibly irritating effect. In microtropia, anomalous corresponding retinal points have functionally different levels only in the very centre of the visual field. ARC provides in this case a binocular cooperation very similar to normal fusion. To an individually different degree, ARC can adapt to new squint angles, which makes squint surgery possible without postoperative diplopia, but a change to normal binocularity with stable interocular connections can not be achieved. ARC enables the heterotropic patient to see with both eyes simultaneously without diplopia by a regionally changing use of inhibition and anomalous fusion in the interest of the best possible perception.

The frontal placement of human eyes leads to an overlap of major parts of the right and left monocular visual fields; most visible objects therefore stimulate both eyes simultaneously. For an undisturbed visual orientation, retinal points which are stimulated by the same object in the plane of visual attention (the horopter) must be perceived in the same visual direction. In other words, within the limits of the binocular visual field, each retinal point of one eye must have a partner in the other eye with an identical local sign. Those retinal points are called corresponding. Together they establish a directional coordinate system in which the bifoveal percept of the image of regard lies in the centre, providing the principal visual direction as reference. In this way retinal areas are coupled with nearly identical visual functions (such as resolving power, light sensitivity or colour sensitivity), which is a prerequisite for building a new and optimal binocular percept from the two monocular images of an object with normal sensory fusion.

The retinal point-to-point relationship between the right and left eyes is the classical concept of normal retinal correspondence (NRC) in which monocular and binocular visual directions are identical and stable. This holds true only under artificial interocular dissociated conditions of seeing, in which the stimuli cannot be fused. But the moment fusion is permitted, disparate images which come from slightly different directions, and therefore stimulate non-corresponding points, can also be combined sensorially to a single binocular percept which is localised in the middle of the two monocular directions (Allelotropie, after Tschermak, or fusional shift[1,2]).

If the disparity of the fused images occurs horizontally, the new binocular percept gives the additional visual impression of relative depth or stereopsis. Taking stereopsis as a parameter for the maximal disparity at which two monocular images can still be combined to form a new binocular percept, values up to 20 degrees of disparity and more have been found in normal observers under experimental conditions.[3,4]

As well as the proven ability to combine images of different eccentricities, the point-to-point relationship exists simultaneously and competes with sensory fusion when the disparity of images increases. Up to a certain degree of disparity the fusion system prevails and there is binocular single vision (Panum's area). At larger disparities, the different visual directions for the images cannot entirely be combined and the image of the same object is seen at two places or double without losing a certain degree of stereopis in the case of horizontal disparity.[5]

For an unambiguous visual orientation, normal

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sensory binocularity demands, therefore, an exact and fast working motor system, the vergence system, to direct both visual axes to the object of regard. The benefit of this type of binocularity, which we diagnose as 'normal binocular vision' in our patients, is mainly binocular stereopsis with its extremely low threshold. The disadvantage is that it requires very complicated sensori-motor systems in the brain. As a consequence, the system is in many ways susceptible to disturbances, as the orthoptic and motility departments in each eye clinic demonstrate. The most common disorder of binocularity in these departments is so-called concomitant strabismus in its congenital or infantile form and in acquired forms up to the third year of life. The incidence is about 5%. Almost none of these cases with childhood eso- or exotropia experience double vision under natural conditions of viewing, in spite of the ocular motor misalignment. A few of them are just not aware of the second image which originates in the deviated eye. Such cases should be classified as late onset strabismus or phorias. Bright stimuli together with appropriate attention of the patient will produce diplopia corresponding to the angle of squint, which indicates normal retinal correspondence. In the majority of cases, a change of visual directions in the deviated eye can always be measured, which compensates for the motor deviation. This change of interocular relationship is called anomalous retinal correspondence (ARC; from the Greek word *nomos*), because it does not follow the normal laws of physiology. ARC is only demonstrable under binocular viewing conditions and it shifts in alternating strabismus back and forth to the respective deviated eye. The monocular local signs are not involved.

To answer the question as to how useful ARC is in a patient with strabismus, we have to examine how the stimuli of the fixating and the deviated eye are processed to build up the binocular visual field (for a more detailed review, see Herzau[6]). This depends largely on the amount of motor deviation and to some extent also on the direction of squint.

Fig. 1 shows schematically the condition of a very simple examination in a common case: an esotropia of 20 degrees with good visual acuity. Both eyes look at a frontoparallel screen with a fixation light in the centre for the left fixating eye. The central retina of the deviated eye is directed at the black optotype '4', at 20 degrees eccentricity to the left. After occluding the deviated eye the patient sees a black blob at the location of the '4' but cannot recognise the number, because it falls too peripherally on the retina of the fixating eye. Without the occluder, the patient discerns the '4' immediately in spite of steady fixation of the central light with the left eye, and localises it at the same place where the black blob was. In the same

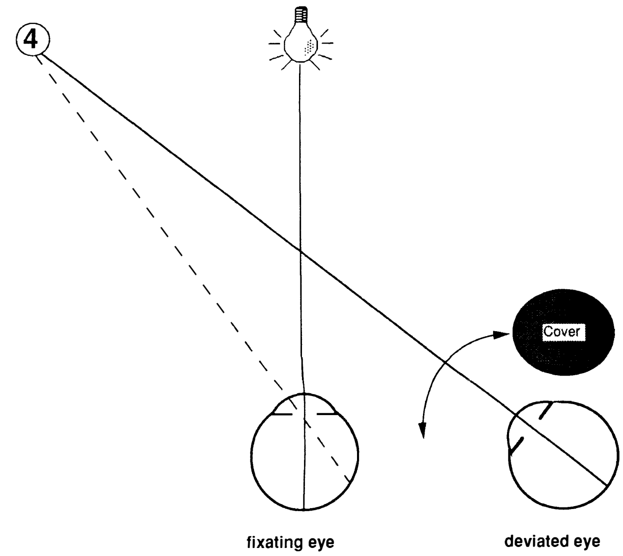

Fig. 1. *Examination of foveal vision and visual direction of the deviated eye in large angle strabismus (see text).*

sense, we will find with a moving stimulus the perimetric isopters enlarged to the left in this patient when the deviated right eye is not occluded. If we use the '4' as an intermittent stimulus and measure the simple reaction time, it will be shorter without an occluder in front of the left eye.[7,8] These and other tests show that, irrespective of the direction of squint, the deviated eye and particularly its fovea participates in building up the binocular visual field and that it is even superior to the fixating eye in that part to which it is deviated. The ARC enables the patient to localise the foveal stimuli of the deviated eye correctly, because its central retina has taken over the visual direction of that retinal point in the fixating eye at which the same image is projected. Clinicians cells this 'harmonious anomalous correspondence'. In disharmonious ARC the amount of the anomalous shift of the deviated eye's visual directions does not compensate for the angle of squint. Disharmonious ARC is mostly a product of an inadequate method of examination and will not be discussed here. In NRC an esotropic patient would also see the '4' better without occlusion, but superimposed on the central fixation light.

With rivalry patterns or Bagolini's striated glasses, patients with ARC demonstrate a division of their binocular visual field into areas of dominance of the fixating and the deviated eye respectively. The border of dominance lies almost exactly between the visual field centres of the two eyes when there is no amblyopia.

It seems, therefore, as though the anomalous connections between different eccentricities of the right and left retina in ARC bring only that image to consciousness which originates from the less eccentric retinal point. This implies that from the retinal points in the right and left eye with the same image, the less eccentric point suppresses the more eccentric one in the other eye. And indeed, with the Aulhorn extinction phenomenon it can be shown that rivalry-caused suppression in ARC is regional as in NRC, but the suppressed area is much larger.[9]

A view of the profile of light difference sensitivity or visual acuity (Fig. 2) in the horizontal meridian of an esotropic patient may show that processing in this way is teleologically very economic. While in a normal observer the peaks of sensitivity are binocularly superimposed and images of the same object stimulate functionally similar retinal areas, in a strabismic person the two peaks are separated by the angle of squint. The graph shows an example of the perimetric findings from a patient with a left esotropia. Monocularly there are two overlapping curves. The curve with the central peak belongs to the fixating right eye; the sensitivity peak of the deviated eye is shifted to the right, corresponding to the motor deviation. The binocularly measured curve of sensitivity (bold line) is also elevated on the side of the squint direction. The thin lines represent the monocular continuation of the respective sensitivity. If the patient wants to have the best possible information, for example about the imge of the fixation point, a combination of the monocular right and left images would be a bad idea. He should rather suppress the coarse resolved image of the deviated eye, and this is exactly the way he processes visual information at that location (fixation point scotoma[10,11]). But on the right side of the binocular visual field the deviated left eye has the higher sensitivity and there it is the fixating eye which is suppressed. Between the sensitivity peaks (around 10 degrees to the right in this example) the function of retinal points with the same image is largely equal and suppression makes no sense. In this area normal-like binocular perception can be demonstrated with striated glasses or with classical rivalry patterns and, at least in esotropia, a gross perception of motion-in-depth may be demonstrable.[12] The size of this zone

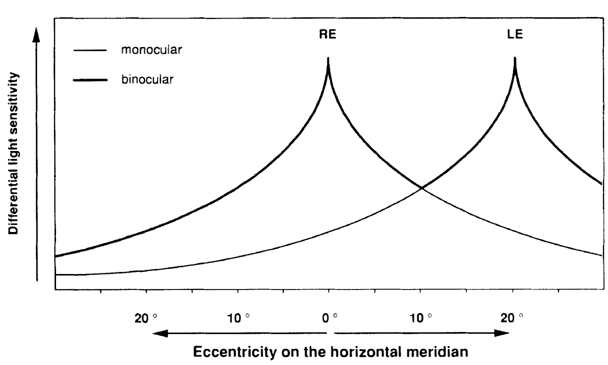

Fig. 2. *Monocular and binocular differential light thresholds in left esotropia of 20 degrees without amblyopia (schematic). RE, right eye; LE, left eye.*

of anomalous binocular vision increases with the brightness or contrast of the stimulus and can reach up to the visual field centre of the deviated eye.[13] ARC in large angle strabismus seems therefore to be very useful as it enables the patient to profit from the visual function of both eyes, without diplopia. Compared with a normal observer his visual field has an even higher sensitivity in that part which corresponds to the visual field centre of the deviated eye. But this superiority can mostly not be used in daily life, because we are not able to direct our attention to two things – the foveal images of the right and left eye – simultaneously. To avoid irritation from the second island with higher visual function in the binocular visual field, the patient has to ignore it. Most often this happens unconsciously and the better resolution in the dominant area of the deviated eye is used only for warning functions. But I know many patients with problems in concentrating on the fixation point area only.

In special rare cases the development of ARC is of particular use. These are strabismic patients with a homonymous hemianopia in which the residual visual field of the deviated eye compensates for the visual field loss of the leading eye. The anomalous visual directions provide here a partial but functionally important enlargement of the binocular visual field.[14]

The described filtering action of ARC by which the too peripheral retinal stimulus is regional suppressed is also applicable to small deviations. But here retinal areas with the same image in the right and left eye have mostly identical function. The overwhelming part of the binocular visual field is therefore binocular in a way comparable to normal binocularity, particularly in cases of primary microtropia without amblyopia. Only in the very central visual field may small areas of ocular dominance be found when stimuli of high spatial frequency are used. Stereoacuity is therefore always reduced in microtropia.

The better possibility for positive binocular cooperation in patients with microtropia is also expressed by their ability to fuse prisms.[15] This anomalous fusion holds the inconspicuous motor deviation stable.

In contrast to NRC the anomalous common visual directions in ARC are not fixed and can adapt to spontaneous or post-operative changes of the angle of squint, at least to a certain individually very variable degree. This enables us to correct unsightly ocular deviations in most patients satisfactorily without anomalous diplopia. Nevertheless, the anomalous substitute of binocularity can never be converted to that of the normal. It always needs a very strong ability to suppress, especially in the fixation point area. From earlier efforts we know that orthoptic training can indeed bring about normal visual directions during binocular vision but no normal fusion. Without the ability to suppress, those patients are often left with intractable diplopia and they can find help only when they learn to be unaware of the double image. A similar situation may develop after surgical overstrain of the flexibility of ARC, particularly after a change of the primary direction of squint in adults. A careful preoperative prism adaptation test informs the surgeon about the amount of deviation which can safely be corrected.[16]

In summary, ARC enables the patient with early onset strabismus to use the visual functions of both eyes at their best during binocular vision. According to the described psychophysical data ARC allows a combination of the two monocular images of an object as long as the respective retinal points have similar functions or similar eccentricity, as in microtropia. This interocular cooperation resembles normal binocularity and is probably processed on the basis of normal disparity channels which match the individual motor deviation; all other disparity channels are deprived or suppressed. When, on the other hand, in large angle strabismus one object stimulates retinal points with very different eccentricities in the two eyes, an anomalous cooperation also exists but in a negative sense: only the more useful, i.e. less peripheral image comes to consciousness and the other will be suppressed. This anomalous cooperation could also use existing normal pathways of higher visual areas which work nevertheless spatially with minor precision.

Key words: Anomalous retinal correspondence, Suppression, Strabismus, Diplopia.

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