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Relevance of the AC/A ratio

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It is obvious that a symposium of this kind on the subject of strabismus is concerned to a large extent with the growing-points of the specialty, and this is entirely appropriate when the meeting is held within the confines of St. John's College, Cambridge, a University centre of learning and academic progress for centuries, and abundantly emphasized by the link of this particular building with Pythagoras. The concept of the AC/A ratio, that is, the amount of accommodative-convergence (AC) which is induced by a change in accommodation (A), is a relatively recent one, but it must be appreciated that the justification to regard it as a growing point is essentially a measure of emphasis, not one of uniqueness, because the close link which exists between accommodation and convergence has been acknowledged since the time of Donders (1864).

It should be mentioned at this stage that the use of the term "convergence" is a composite one because it includes true convergence (positive convergence) and divergence (negative convergence). It should also be mentioned that a discussion on the AC/A ratio is concerned with only one aspect of reflex convergence, and that other reflex mechanisms—tonic, proximal, and fusional—play important roles in the vergence of the eyes, particularly the fusional mechanism which controls the amount of convergence which may be exerted or relaxed during the maintenance of a constant amount of accommodation (the relative convergence) and this has positive and negative components (positive relative fusional convergence and negative relative fusional convergence). In this description of relative convergence, it is logical to take note of the concept of relative accommodation which implies the amount of accommodation (positive and negative) which may occur without any apparent change in convergence. It is evident that something akin to relative accommodation must take place to some extent in the presence of an uncorrected refractive error, except in the rare event when the amount of accommodative change is equal to the amount of vergence change required to control an underlying heterophoria, but it has been suggested that there is no true relative accommodation because any change in accommodation inevitably initiates a change in vergence, although this is immediately blocked by the influence of the positive or negative fusional convergence mechanism in order to maintain bifoveal fixation. It must be conceded, however, that this somewhat controversial point is largely of academic interest.

The concept of the AC/A ratio arose out of an attempt to obtain a precise understanding of the relationship between the two components of the ratio—accommodative-convergence and accommodation—but this has proved to be a difficult task because of the complex nature of the relationship and it is scarcely surprising that several methods of determination have been put forward.

(1) The convergence requirement

It is obvious that the amount of convergence required for a particular distance of fixation provides a measurement of the AC/A ratio, provided account is taken of the interpupillary distance of the particular individual. In this way (I and II), 6 Δ of convergence are required for each 1 Δ of accommodation, on the assumption that the interpupillary distance is 6 cm., so that the AC/A ratio is 6 Δ (with a slightly higher figure when the inter-pupillary distance is greater than 6 cm. and a slightly lower figure when it is less), but this determination is of limited practical value because it is valid only in the so-called normal individual who is emmetropic and orthophoric so that it is largely of a theoretical nature.

I

$$C = \frac{IPD}{F_1}$$

Where: C = Convergence requirement in prism dioptres.
IPD = Interpupillary distance in centimetres.
F_1 = Fixation distance in metres.

For example: C = 6/1 = 6

II

$$C = IPD \times F_2$$

Where: C = Convergence requirement in prism dioptres.
IPD = Interpupillary distance in centimetres.
F_2 = Fixation distance in dioptres.

For example: C = 6×1 = 6

Convergence requirement with fixation distance in metres (I) and in dioptres (II)

(2) The heterophoria method

This is of great significance because it may be carried out readily without any elaborate equipment. Indeed the heterophoria method is a "face-saver" as far as Great Britain is concerned because it was adopted in many centres as a routine method in the evaluation of a squint at a time when the AC/A ratio as such was unknown and subsequently largely neglected, in sharp contrast to our American colleagues who have endorsed the concept of the AC/A ratio with typical enthusiasm.

The heterophoria method is concerned simply with a comparison of the measurements of the latent deviations of the eyes on distant (6 m.) and on near (1/3 m.) fixation, by the prism and alternate cover test, while the appropriate amount of accommodation is maintained by the use of a target which contains detail (such as a letter of the Snellen's test types). As a general rule this determination is made during the use of the appropriate spectacle correction, but in certain circumstances it is of interest to note the changes in the measurements which may occur in the absence of the spectacle correction. When the measurements of an eso-deviation or exo-deviation are more or less equal on near and distant fixation, the AC/A ratio is regarded as normal; when the measurements of an eso-deviation are greater on near than on distant fixation, the AC/A ratio is high, and when this is reversed it is low; and when the measurements of an exo-deviation are greater on distant than on near fixation, the AC/A ratio is high, and when this is reversed it is low (Parks, 1958). It is evident, however, that this simple, but none the less valuable, method suffers from the disadvantages that it fails to provide any precise measurement of the AC/A ratio or to take into account the variation in the necessary convergence for a particular distance of fixation which is determined by the lack of uniformity of the interpupillary distance in different individuals. These difficulties may be overcome in two ways:

(*i*) The AC/A ratio may be regarded as the interpupillary distance in centimetres plus the difference between the latent deviations in prism dioptres for near (1/3 m.) and for distance (6 m.) with a division of the difference by the distance of the near fixation in dioptres (III) or with a multiplication of the difference by the distance of the near fixation in metres (IV).

III
$$AC/A = IPD + \frac{\Delta_2 - \Delta_1}{F_1}$$

Where: AC = Accommodative convergence in prism dioptres.
A = Accommodation in dioptres.
IPD = Interpupillary distance in centimetres.
Δ_1 = Latent deviation for distance (6m.) in prism dioptres.
Δ_2 = Latent deviation for near (1/3 m.) in prism dioptres.
F_1 = Distance of near fixation in dioptres.

For example: $AC/A = 6 + \frac{(-10-(-4))}{3} = 6 + \frac{(-6)}{3} = 6 - 2 = 4$

IV
$$AC/A = IPD + (\Delta_2 - \Delta_1) \times F_2$$

Where: AC = Accommodative convergence in prism dioptres.
A = Accommodation in dioptres.
IPD = Interpupillary distance in centimetres.
Δ_1 = Latent deviation for distance (6 m.) in prism dioptres.
Δ_2 = Latent deviation for near (1/3 m.) in prism dioptres.
F_2 = Distance of near fixation in metres.

For example: $AC/A = 6 + (-10-(-4)) \times 1/3 = 6 + (-6) \times 1/3 = 6 - 2 = 4$

AC/A ratio as determined by heterophoria methad with near fixation distance in dioptres (*III*) *and in metres* (*IV*)

(*ii*) The unit of accommodative-convergence may be measured in terms of the metre angle (MA) and this use of the metric system, in contrast to the use of the prism dioptre, permits a measurement of the amount of convergence when the eyes are directed to an object a known distance from them so that the interpupillary distance is automatically taken into account.

This method provides a 1:1 relationship for the AC/A ratio in contrast to the 6:1 relationship obtained by the assessment of the convergence requirement (in the emmetropic and orthophoric person), but despite its advantages it has received scant attention.

(3) The gradient method

This is concerned with a determination of the difference in the deviations of the eyes, by the prism and alternate cover test, for a given distance of fixation (with the use of a target which excites the appropriate amount of accommodation), after placing concave or convex spherical lenses in front of the eyes so that there is a change in the accommodation (positive or negative) and, therefore, a corresponding change in convergence (positive or negative). In this way the AC/A ratio is the difference between the deviation after placing the spherical lenses and the original deviation in prism dioptres, with a division of the difference by the power of the lenses used in the determination (V).

V
$$AC/A = \frac{\Delta_2 - \Delta_1}{D_1}$$

Where: AC = Accommodative-convergence in prism dioptres.
A = Accommodation in dioptres.
Δ_1 = Original deviation in prism dioptres.
Δ_2 = Deviation after placement of spherical lenses in prism dioptres.
D_1 = Power of spherical lenses in dioptres.

For example: $AC/A = \frac{6-2}{1} = 4$

AC/A ratio as determined by gradient method (*V*)

(4) The graphic method

This is carried out on the synoptophore, and the subjective angle is measured first using slides which induce a simultaneous foveal perception (a reduced test-type slide before one eye and a black vertical line before the other eye) with care to induce the correct amount of accommodation and then during the use of the spectacle correction. Subsequently, further measurements are made after the introduction of −1 D, −2 D, −3 D and −4 D spheres, and these measurements are compared with the normal convergence which accompanies each dioptre of accommodation with the maintenance of binocular single vision in the emmetropic and orthophoric person. In this way a normal, a low (or slow), or a high (or fast) response is recorded (Fig. 1).

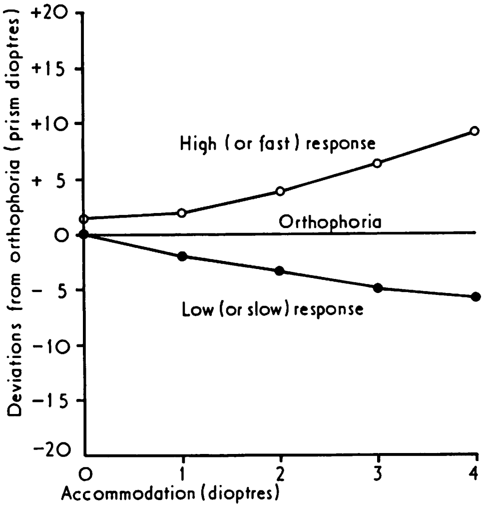

FIG. 1 *AC/A ratio as determined by graphic method showing high (or fast) or low (or slow) response in comparison with normal response of orthophoria*

(5) The fixation disparity method

This makes use of the phenomenon of fixation disparity (Martens and Ogle, 1959). It is evident that, when targets with mainly identical features are presented to the eyes in a haploscopic device, fusion (bifoveal fixation) occurs even in the presence of a heterophoria provided this remains controlled; dissimilar features become displaced relative to one another according to the direction of the phoria, although this shift is exceedingly small, being represented by minutes of arc because it is occurring within Panum's fusional areas. This shift, which was originally described as a "retinal slip" (Ames and Gliddon, 1928), illustrates the fact that dissimilar features which are appreciated within Panum's fusional areas are projected in a strictly correct fashion, so that in the presence of a phoria they suffer a relative displacement in contrast to similar features which are projected in the same direction because they share a common visual direction. This phenomenon of fixation disparity is illustrated readily by the creation of an eso-disparity (Fig. 2, overleaf) or an exo-disparity (Fig. 3, overleaf) by objects which are in certain parts of Panum's fusional areas.

It should be appreciated that the term "fixation disparity" is used here in its strictly correct sense, as defined by Ogle (1950), and it is unfortunate that the same term has been applied incorrectly to the clinical condition of small-angle esotropia (microtropia).

In the application of fixation disparity to an assessment of the AC/A ratio, fusion is maintained over a large field but prevented at its centre where two vertical lines which are oppositely polarized are apparent with the lower one visible only to the right eye, and the upper one only to the left eye. The extent of the fixation disparity is measured by the

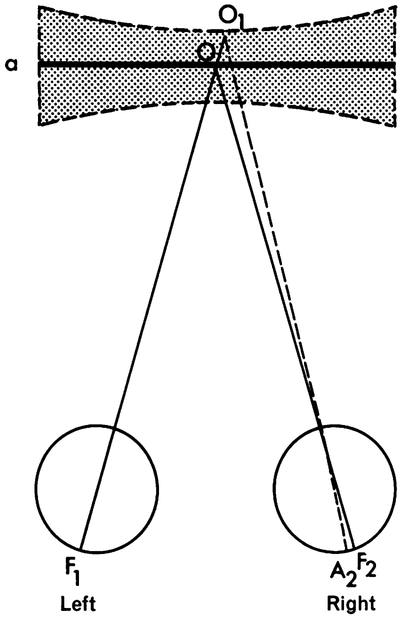

FIG. 2 *Object of fixation (O) at centre of horopter (a) is fixed by fovea of left eye (F_1) and by fovea of right eye (F_2), but another object (O_1) in horopter lying beyond O is fixed by A_2 of right eye on nasal aspect of the fovea (F_2) with creation of an eso-disparity, although O_1 is fixed by fovea of left eye (F_1)*

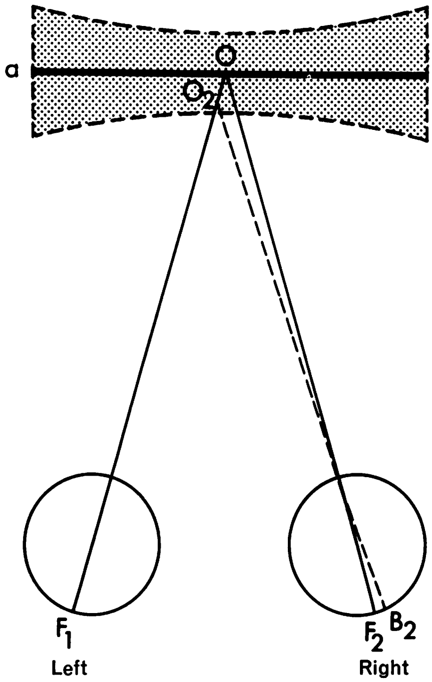

FIG. 3 *Object of fixation (O) at centre of horopter (a) is fixed by fovea of left eye (F_1) and by fovea of right eye (F_2), but another object (O_2) in horopter lying nearer than O is fixed by B_2 of right eye on temporal aspect of fovea (F_2) with creation of ane xo-disparity, although O_2 is fixed by fovea of left eye (F_1)*

amount of movement of the upper line which is necessary to secure its alignment with the lower one. Subsequently the state of the phoria is changed by altering the vergence of the eyes in two different ways:

(*i*) By the use of varying prisms, base-in to create an eso-disparity and base-out to create an exodisparity, and these induced changes in the fixation disparity may be represented in the form of a curve (the curve for prisms) which is modified in its central part according to the original nature of the fixation disparity before the use of prisms; an eso-disparity (Fig. 4), an exo-disparity (Fig. 5), or an absence of fixation disparity in orthophoria (Fig. 6).

(*ii*) By the use of varying spherical lenses, concave to create an eso-disparity and convex to create an exo-disparity, and these induced changes in the fixation disparity may be represented in the form of a curve (the curve for lenses); a typical curve is shown (Fig. 7).

Finally, it is possible to obtain derived data from the curves for the prisms and lenses which illustrate the relationship between the change in the stimulus to accommodation and the equivalent deviation; this is a measurement of the AC/A ratio.

The fixation disparity method of assessing the AC/A ratio has the great advantage that fusion is maintained throughout the examination without any true dissociation of the eyes. It is, however, a somewhat complicated and time-consuming procedure demanding detailed subjective responses, so that it is scarcely appropriate for routine clinical purposes, particularly in the young child.

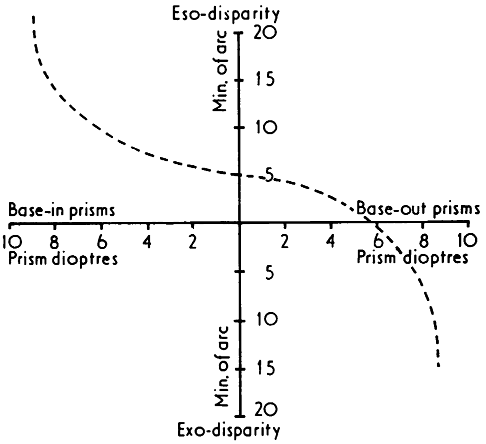

FIG. 4

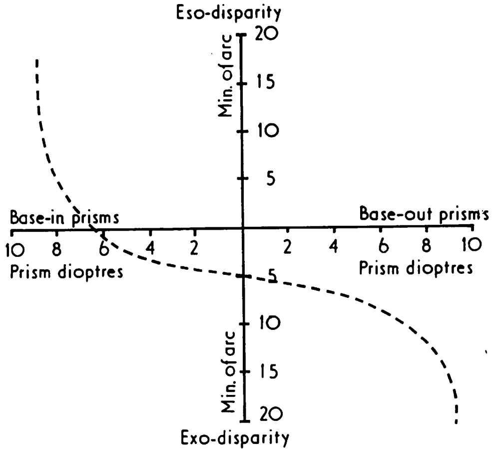

FIG. 5

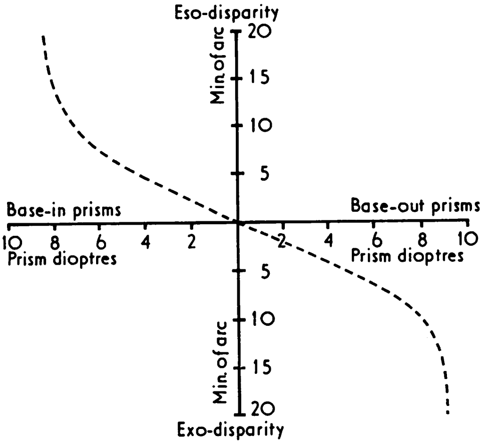

FIG. 6

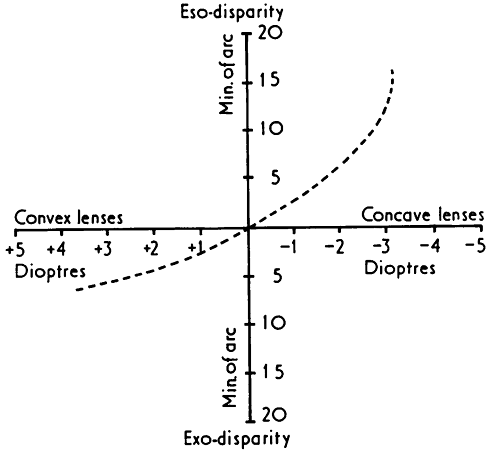

FIG. 7

FIGS 4–6 *AC/A ratio as determined by fixation disparity method; curves for prisms in presence of an eso-disparity (Fig. 4), an exo-disparity (Fig. 5), and orthophoria (Fig. 6)*

FIG. 7 *AC/A ratio as determined by fixation disparity method; curve for lenses*

(6) The oculographic method

Finally, it is of interest to make brief mention of the method of obtaining an objective recording of the AC/A ratio by measuring the inward rotation of the occluded eye, by direct current electro-oculography, which follows an accommodative stimulus (varying concave spherical lenses) presented to the uncovered eye because this inward rotation is essentially a movement of accommodative-convergence (Hermann, 1971). A significant feature of this method is the fact that the electro-oculographic curve so obtained sometimes shows distinctive qualitative characteristics which differ from case to case even in the presence of a fairly uniform AC/A ratio, and these are regarded as patterns of pace which show three forms—isokinetic, hyperkinetic, and hypokinetic.

Conclusions

It is evident that a determination of the AC/A ratio provides fairly precise information about the close relationship which exists between accommodation and accommodative-convergence, and as a general rule the AC/A ratio in the normal individual is about 3·5 to 4·0. It is obvious that the AC/A ratio must become adapted to the presence of an underlying phoria and to the presence of an uncorrected refractive error if binocular single vision is to be retained. For example, in the convergence excess type of esophoria it must be low, whereas in the convergence weakness type of exophoria it must be high; and in uncorrected hypermetropia it must be low, whereas in uncorrected myopia it must be high. It follows that an abnormal AC/A ratio is an important factor in the production of a squint, as in the high AC/A ratio which fosters the development of certain forms of esotropia.

It is not possible in the scope of this paper to discuss in detail all the variations of the AC/A ratio, but it should be stressed that the fundamental nature of the AC/A ratio is little altered by most of the therapeutic methods which are available in the treatment of squint, such as spectacle lenses, orthoptic procedures, and miotics, but the ratio is modified during their application so that binocular single vision may be achieved and established to such an extent that the abnormal AC/A ratio is no longer capable of exercising its adverse influence. In contrast surgical procedures are effective in altering the AC/A ratio in a favourable way provided the operation is appropriate for the particular type of squint.