Sensory anomalies in strabismus

B. BAGOLINI

Modena, Italy

Suppression and anomalous correspondence

In cases of concomitant strabismus of childhood onset, areas of suppression develop in the visual field of the deviating eye in binocular vision (see this subject reviewed by DuBois-Poulsen, 1952; Mackensen, 1959; Ravalico, 1971). There also develops in binocular vision, a variation of the directional localization of the retinal elements of the deviating eye which is called "anomalous retinal correspondence". A certain degree of binocular vision may be acquired if this anomalous correspondence is "harmonious". This "harmony" in fact, indicates that an extrafoveal retinal area in the deviating eye, where the image fixed by the fixing eye is formed, has acquired the same directional localization as the fovea of the fixing eye.

Recent studies (Bagolini 1961-1967) have demonstrated that suppression prevails in cases of large-angle strabismus, while in cases of small-angle deviation, anomalous correspondence of the harmonious type tends to prevail. This latter mechanism has very probably a true antidiplopic effect because the two retinal images may be superimposed in spite of the fact that they stimulate originally non-corresponding retinal areas.

It has also been demonstrated that, in cases of harmonious anomalous correspondence, a type of anomalous binocular vision may be achieved with the development of areas of binocular vision bearing close resemblance to Panum's areas in normal subjects (pseudo-Panum's areas). This type of binocular vision remains, however, quite weak in comparison to normal binocular vision so that it can be demonstrated only with tests (such as the striated glasses test*) which do not alter casual seeing conditions. Other tests which do alter casual seeing conditions, usually by making the two retinal images unequal, easily disrupt this weak state of binocularity (the so-called dissociating tests).

It has also been demonstrated that, after surgical correction of a large angle of strabismus, a sensory reorientation of the retinal elements in the deviating eye may occur quite rapidly (Bagolini, 1967). A new harmonious retinal correspondence then develops which is adapted to the smaller residual angle of deviation. If we succeed in completely eliminating the strabismic deviation, correspondence rapidly becomes normal with the striated glasses test. With the more dissociating tests, correspondence may eventually become normal if we succeed in keeping the eye straight for a sufficiently long period of time.

It is because of these new findings on the postoperative behaviour of retinal correspondence that prism therapy has been revived. Prisms, in fact, have been used for a long time in strabismus, but the idea of treating sensory anomalies with prisms is rather recent (Bagolini, 1962). This approach, which I have applied only to convergent strabismus, appeared only rarely to be successful. This is because the optical elimination of a residual convergent strabismus by means of base-out prisms tends to elicit an increase in the deviation which frequently compensates for the prismatic correction. These convergent movements are an

* See Appendix, p. 317.

expression of a variation in the muscle tonus when a displacement occurs in the position of equal retinal images induced by base-out prisms. We may call these sensory-motor effects "anomalous movements".

Anomalous movements

The interpretation of anomalous movements is a matter of speculation. Halldén (1952) and Bagolini (1970) tend to consider these convergent movements as a sort of fusional movements.

From a clinical point of view they have a common feature with normal fusional movements in that, in both cases, there is a variation in muscle tonus when one of the retinal images is displaced; *e.g.* an increase in the tonus of the medial rectus muscles is produced by base-out prisms.

They also have, however, important differences (Bagolini, 1970):

- (a) Anomalous movements are very slow if compared to normal fusional movements (Fig. 1 A and B). It may take several minutes, hours or even days for the final ocular deviation to be reached. Unlike normal fusional movements, they can never be observed by the naked eye because they are too slow. They can only be detected because a variation in the angle of strabismus is observed by means of the cover test some time after the prisms have been applied.
- (b) Anomalous movements are much less precise than normal fusional movements (Fig. 1B). In the latter a base-out prism is fully compensated by an angular movement of the same prismatic amount. Instead, anomalous fusional movements have an angular displacement which is frequently lower than the prismatic power of the base-out prisms applied.
- (c) As was observed by the combined use of prisms and the striated glasses test, in anomalous movements there may be not only a variation of the muscle tonus, but also a concomitant variation in correspondence (the spatial value of the retinal elements of the deviated eye may change) under the prismatic correction, while in normal fusional movements the state of correspondence remains unchanged. This covariation may easily be revealed in many patients with residual postoperative esotropias (or primary small-angle esotropias). When the deviation is corrected by prisms, it may maintain superimposition of the two retinal images in the striated glasses test, while at the same time, the angle of deviation slowly increases until partial or total compensation of the prismatic correction is achieved. There is, therefore, a covariation between the objective angle (due to the anomalous movements) and the subjective angle (anomalous retinal correspondence) under the effect of the prisms. This covariation has the evident aim of maintaining anomalous single binocular vision in spite of variations in the angle of strabismus. Variations in the objective angle of strabismus are, as we know, quite common: *e.g.* in the case of total or partial accommodative squints and in cases of up and down gaze when an A or V pattern is present.

Anomalous movements may vary in strength. The use of progressively stronger prisms may offer a simple clinical indication of the strength acquired by anomalous movements: cases of residual postoperative esotropia, where overconvergence cannot be prevented even by strong prismatic overcorrection, indicate deeply rooted movements; cases that do not overconverge or may even diverge (Fig. 1 C and D) have weak movements and offer the best possibility for sensory and sensory-motor treatment. We may then hope completely to eliminate the postoperative residual ocular deviation with the aid of appropriate prism therapy.

FIG. 1 Diagrams to show the four possibilities of response to a prismatic overcorrection of 20 base-out dioptres in four cases of a small postoperative residual angle of esotropia. All four cases invariably increased the angle of deviation when it was exactly corrected by prisms. The ordinate represents, in prism dioptres, the variations of the angle of strabismus before, during, and after the prismatic overcorrection. The abscissa represents the time of observation. The arrow at on and off represent respectively the moment at which prismatic overcorrection was applied and removed; the various spots represent measurements of the objective deviation (by the cover test) after various lengths of time.

CASE A almost completely compensated for the overcorrection in about 5 minutes by overconvergence. After the removal of the prisms, the angle of deviation returned to the initial state in about 30 minutes.

CASE B slowly and only partially compensated for the prismatic overcorrection by overconvergence. The original deviation returned in a non-measurable period of time.

CASE C The angle of deviation was not modified by prismatic overcorrection.

CASE D reacted to prismatic overcorrection by divergence.

It should be realized that, if a residual esodeviation remains, a new anomalous correspondence, readapted to the new residual esodeviation, will invariably develop. Major amblyoscope exercises are of little benefit in this situation; even if correspondence becomes normal with the use of this instrument, the day-long stimulation of casual seeing when esodeviation is present will annul the benefit of the exercises. To have some chance of success we have to find a way of eliminating the esodeviation.*

Anomalous movements are, therefore, a handicap to the restoration of normal binocular vision because they tend to restore an esodeviation postoperatively. Two approaches have been proposed in an attempt to remove this anomalous sensory-motor obstacle:

(a) This is based on the observation that anomalous fusional movements may often take a long time to develop. In other words, when we place base-out prisms over the eyes of an esotropic patient, the angle of deviation may take from a few minutes to several hours to increase.

(b) This is based on the observation that it is often possible to find a prism strong enough to prevent the patient from converging and even to induce him to diverge (Fig. 1D).

The former approach was proposed by Bagolini (1966–1969) under the name of “prism temporization”. The lowest possible prismatic overcorrection of the residual postsurgical esodeviation is given by means of clip-on prisms. The time needed for the patient to overconverge is calculated as well as the time taken to relax convergence when the dominant eye is patched afterwards. Binocular vision through clip-on prisms is allowed several times a day for a length of time not exceeding the time previously found. Then the dominant eye is kept patched. If the time taken for the patient to overconverge is very short, the power of the prisms is increased so as to find a convenient length of time of at least 30 minutes in which binocular vision can be allowed. The tendency to overconverge is frequently hampered by these exercises. Prisms are then lowered in an attempt to stimulate strictly corresponding retinal points.

The second approach, which has been followed by various authors, has been clearly outlined mainly by Adelstein and Cüppers (1969) and has been greatly facilitated by the introduction of Fresnel prisms. The aim is to find prisms strong enough not to be overcome by anomalous movements and possibly to make the patient diverge as in Fig. 1 D.

Both systems can be combined to discourage anomalous movements. The patient's eye after the elimination of the anomalous movements (which sometimes cannot be eliminated and at best require many weeks) can be placed in a position as parallel as possible, while carefully avoiding the relapse of small residual esodeviations.

These therapeutic approaches may still be considered as at an experimental stage. Never the less, one can say that anomalous movements can be more easily eliminated when they are not too strong, that is, when they can be discouraged by the least possible amount of prismatic overcorrection.

Finally, it is important to realize how anomalous movements may interfere with surgery. When a case of esotropia is operated upon, an undercorrection may be obtained either because an insufficient amount of surgery was planned or because strong anomalous movements increase the tonus of the medial rectus muscles in an attempt to restore the preoperative sensory-motor situation.

If we break the system and the amount of surgery is such that anomalous movements can no longer be active, we may end with an overcorrection. We obtain more or less the

* Divergent fusional movements when the eyes are in a condition of total relaxation are normally extremely limited. It would, therefore, be unrealistic to expect elimination of an esodeviation by those divergent fusional movements lacking even in normal subjects.

effect seen in Fig. 1 D, where rather weak anomalous movements were not able to compensate for a strong prism, and the angle of strabismus decreased. In these cases an important factor raising the tonus of the medial rectus muscle is eliminated, and a positive angle of strabismus may tend to become negative postoperatively.

Anomalous movements are an unpredictable element in surgery. Different patients with approximately the same amount of deviation react in different ways to the same amount of surgery. It is also well known that the same amount of surgery (*e.g.* an equal degree of medial rectus recession) produces a greater degree of correction when the angle of esotropia is large than when it is small. The unreliability of a mathematical approach to the correction of the angle of squint is largely due to the strength acquired by anomalous movements which are possibly less strong in a large angle of deviation.

Unfortunately, as far as we can now understand, it is not easy to determine preoperatively what is the strength of anomalous movements by prisms because the prismatic overcorrection needed to study the strength of this phenomenon preoperatively should be so strong as to create a great distortion and a difference between the two retinal images. This difference weakens both anomalous retinal correspondence and the strength of anomalous movements that we want to investigate.

Appendix

STRIATED GLASSES TEST (Bagolini, 1958)

A pair of plano glasses having almost invisible striations are placed in a trial frame.

FIG. 2 Possible clinical findings by the striated glasses test. The right eye (RE) is the one which deviates

When the subject looks at a spotlight, he sees with each eye a faint luminous stripe. These stripes are seen at right angles to the striations in each glass, so that, when the axes of the striations are orientated at 90° (for example at 45° and 135°), a normal subject sees two luminous stripes crossing at right angles, and the light appears exactly at the point where the stripes cross (Fig. 2B).

With a similar arrangement of the striated lenses, a strabismic patient may see:

(1) The light crossed by two luminous stripes as in a normal subject (Fig. 2B). This indicates that, in spite of the squint, the patient has a type of anomalous binocular vision. Although the image of the fixation light falls upon an extramacular area in the deviating eye, it is perceived in exactly the same visual direction as that falling on the macula of the fixing eye (a condition called *harmonious* anomalous correspondence). This phenomenon usually occurs only with small angles of strabismus, in which the stimulated extramacular area is close to the true macula.

(2) The luminous stripe may not be perceived by the deviating eye (Fig. 2C). This indicates complete suppression of the deviating eye, a condition almost invariably found with large angles of strabismus.

(3) The light may be crossed by two luminous stripes; but the stripe corresponding to the deviating eye may not be seen immediately around the light (Fig. 2D). This indicates a small suppression scotoma in the deviating eye in the region stimulated by the fixation light.

(4) The patient may see two lights, each crossed by a stripe (Fig. 2E). This is a rather rare occurrence and indicates that the sensory collaboration of the two eyes is very weak. Though the striated glasses introduce only a weak dissociating effect, this is strong enough to produce diplopia.

Discussion

PARKS Regarding your concept about the deepening of Panum's fusional space: Is this similar to what Jampolsky previously suggested to explain the normal retinal correspondence that probably exists in small esodeviation angles recently termed either microtropia or the monofixation syndrome?

BAGOLINI I have not heard of Jampolsky's ideas on this subject. In my experience, in small-angle strabismus—and I suppose this is also true for what is defined as microtropia—, there may be binocular anomalous vision. With proper techniques it is possible, in these cases of small-angle strabismus, to demonstrate areas of anomalous binocular vision resembling Panum's areas in normal subjects. These areas are however much larger than normal Panum's areas and I have called them pseudo-Panum's areas, not knowing what they really are from a physiopathological point of view. This finding is closely connected to anomalous binocular vision and thereby to anomalous retinal correspondence.

I am therefore reluctant to accept the previous statement of Miss Mein, which is shared by many. If I understood her correctly, she said that in microtropia there is a central scotoma, normal peripheral fusion, and an enlarged Panum's area. In my opinion, if a patient has an enlarged Panum's area, he must have anomalous binocular vision and anomalous correspondence; he cannot therefore have normal peripheral fusion.

REINHART Does the variation in accommodation when fixing on the target light using striated lenses, account for the deepening of Panum's fusional space? Does the light provide sufficient fixation to control accommodation when using the striated lenses?

BAGOLINI Of course I always use a horopter apparatus when measuring these things. In these circumstances accommodation does not interfere, but when I use a light just to assess the results from anomalous retinal correspondence, the effect of the glass is to search Panum's area.