# Evaluation of Compensatory Torsion by Blind Spot Mapping.

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## Abstract

Blind spot mapping is a non contact and relatively simple method to evaluate rotation of the eye in response to head tilt. Any displacement of the blind spot during head tilt indicates the concurrent rotation of the eye, ie that which has not been compensated by a torsional movement.

This method was used to evaluate the extent of intorsion and extorsion induced by head rotation from 0° to 30° in 22 normal subjects. Results confirm previous studies that full compensation to head tilt does not occur, even at small degrees of head tilt. The mean responses of compensatory intorsion ranged from 32% to 41% and those of compensatory extorsion from 20% to 25%. This difference between intorsion and extorsion (ie, a more effective intorsion response) was statistically significant ($p<0.00001$) at each position of head tilt. This unequal response must be accompanied by a sensory and/or motor cyclofusion to prevent torsional diplopia from occurring. Although these results do not directly contradict the theoretical basis of the Head Tilt Test, they do suggest that a negative or inconclusive result may be due to poor cyclotorsion.

*Keywords:*
cyclofusion, intorsion, extorsion, head tilt, counter torsion.

## Introduction

Ocular torsion is defined as rotation of the eye around the Y axis of Fick. It needs to be differentiated from 'false torsion' which routinely occurs when the eye moves to a tertiary, or oblique position, moving around an axis on Listing's plane, but without rotation around the Y axis [1] (see Figure 1).

Most commonly normal torsion occurs as a vestibular response to tilting of the head (counter torsion or counter rolling [2]), supposedly to maintain the correct horizontal retinal meridian [1] (although Jampel [2] argues that this does not occur). In this context, responses initiated by static tilt and dynamic head movements are often differentiated [2,3].

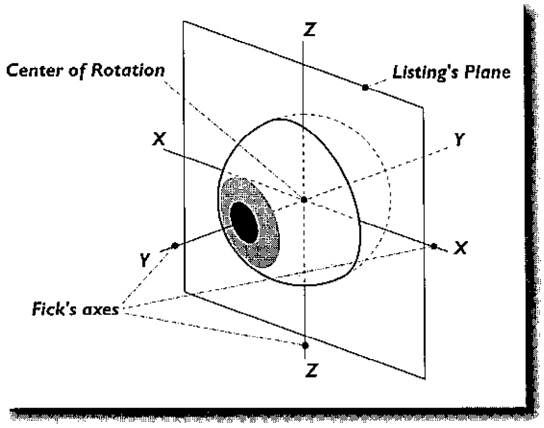


***Figure 1***

Fick's Axes and Listing's Plane. (from Adler's Physiology of the Eye, 7th Ed 1981 CV Mosby)

### *Subjective and objective torsion*

Rotation of the eye around the Y axis is now defined as objective, or anatomical torsion, as many studies have shown [4,5,6,7,8] that the perception of a tilted image (subjective torsion) does not always accompany, or is much less than, that which would be predicted from the anatomical position of the eye. For example, Guyton [8] has shown that subjective torsion is rarely experienced in cases of congenital cyclovertical muscle anomalies, yet considerable objective torsion may be demonstrated by observation of the fundus.

### *Assessment of Torsion*

Evaluation of torsion dates back at least 200 years. Subjective methods have included blindspot mapping [8,9,10] the use of an after image [9,11], the Maddox Rod [11,12], the Maddox Wing [12], the Maddox Double Prism [11], the Synoptophore [11,12] and the recently developed Torsionometer (Georgievski) [12,13].

Subjective torsion, whilst perhaps being a good indication of a patient's symptoms, does not necessarily indicate the full amount of anatomical torsion. For this reason, objective methods are now usually used as a measure of anatomical torsion. These methods include direct viewing of external landmarks of the eye [2,4,9], special contact lenses [4,11,12], evaluation of fundal torsion by fundus photography [8,10,11] or indirect ophthalmoscopy [8,11], infra red video oculography [15,16] and the scleral search coil [3,4,17]. Blindspot mapping (see description below), whilst being essentially a subjective method, reflects the detection of an anatomical landmark and is not influenced by perception of a normal environment. It is therefore more likely to reflect the true anatomical position of the eye.

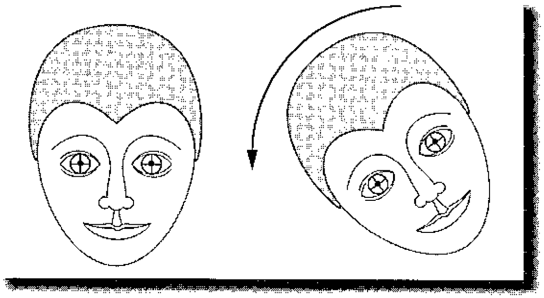

**Figure 2**

*No compensation is occurring, eyes (and optic discs) passively rotate with head tilt.*

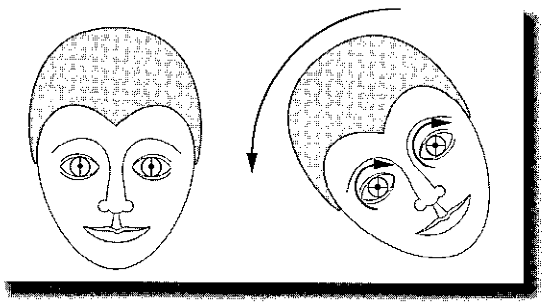

**Figure 3**

*Full compensation is occurring, eyes rotate against head tilt, optic discs remain on horizontal plane.*

### *Effectivity of countertorsion*

Studies of the effectivity of counter torsion to passive head tilt have yielded varying values, but tend to show that the response is usually much less than the actual amount of head tilt (see Table 1). The fact that a perception of an upright image is still maintained when the head is tilted, despite the relative motor response, is a further example of the differences between subjective and objective torsion.

On head tilt to the right the right eye is said to intort, whilst the left eye extorts [1]. This, of course forms the theoretical basis of the Bielschowsky Head Tilt Test. However some authors (see Table 1 [2,10]) argue that this counter rolling does not occur, and Levine [10] therefore questions the validity of the basis this test.

According to Hering's Law, any response which does occur should be equal. However Linwong and Herman have shown a difference in the intorsion and extorsion responses to passive head tilt, (see Table 1). As torsional diplopia is not perceived in this situation it is likely that subjective cyclofusion (a sensory, rather than a motor response) is occurring allowing perception of a single upright image in the presence of torsional disparity [5,6,7].

As few other studies have reported on the relative input of intorsion and extorsion in this situation, this study was undertaken to further evaluate the responses of each eye to passive head tilt in normal subjects by using the simple method of blind spot mapping.

## Method

Twenty two normal subjects were evaluated, the only criteria for selection being that they had 6/6 (equivalent) visual acuity at the distance of the test (2m), normal binocular vision and no ocular motility problem.

### *Blind Spot Mapping:*

The head position was maintained by a special apparatus incorporating a bite bar which could be rotated to fixed positions in either direction.

With the head thus stabilized, the position of the blind spot was carefully plotted and its long axis recorded. This was carried out with the head tilted from 0° to 30° in both direc-

**Table 1**

*Previous studies on intorsion and extorsion responses to passive head tilt.*

| Researchers | Year | Method | Extent of Response |
|---|---|---|---|
| Levine [10] | *1969* | *Fundus Photography / Blind Spot Mapping* | *Little or none* |
| Linwong & Herman [1] | *1971* | *Fundus Photography / Blind Spot Mapping* | *Intorsion 16% / Extorsion 22%* |
| Petrov & Zenkin [13] | *1973* | *Contact Lens / Light* | *Approximately 25%* |
| Collewijn et al [3] | *1985* | *Scleral Search Coil* | *10%* |
| Vieville & Masse [16] | *1987* | *Infra-Red Video* | *(not tested)* |
| Jampel [2] | *1987* | *Iris Markings* | *None* |
| Cheung et al [17] | *1992* | *Scleral Search Coil* | *16%* |

tions (5 degree steps). An examination of both intorsion and extorsion of one eye therefore involved plotting 14 blind spots during fixed head tilt.

Any displacement of the blind spot during head tilt indicated concurrent rotation of the eye, ie that which has not been compensated by a torsional movement. Conversely, if the blind spot did not move, full compensation was occurring, (ie, a counter torsional movement equal and opposite to the head tilt) (see Figures 2 & 3).

The coordinates of the upper and lower limits of the long axis of the blind spot were recorded, and were calculated as degrees of rotation of the eye, allowing for the original position and tilt of the disc.

The order of testing was randomised. Fourteen subjects had only one eye tested (7 right eye, 7 left eye). Eight subjects had the procedure carried out on each eye, and, in these cases the tests were done on different days, due to the time consuming nature of the assessment.

## Results

Figures 4 & 5 show typical responses from two different subjects. The Y axis represents the calculated torsional response ( not the plotted rotation of the disc) and the X axis the amount of head tilt. Therefore, if it was a full compensation for the head tilt, the response would follow the dashed line. Incomplete responses would fall below this line. In Figure 4 it can be seen that there is a good (although incomplete) response of intorsion, at least up to 25° of head tilt, whilst, overall, the extorsion response is much poorer. In Figure 5 both intorsion and extorsion responses are poor, with, at the most, only 1 degree of response for each 5° of head tilt.

The mean values and standard deviations of the total group are shown in Table 2 and Figure 6. The difference between intorsion and extorsion (ie, a more effective intorsion response) was statistically significant ($p < 0.00001$) at each position of head tilt.

The effectivity of these responses are shown in Figure 7, which shows a 32% to 41% response for intorsion, and 20% to 25% response for extorsion, with decreasing efficiency at the head tilt increases.

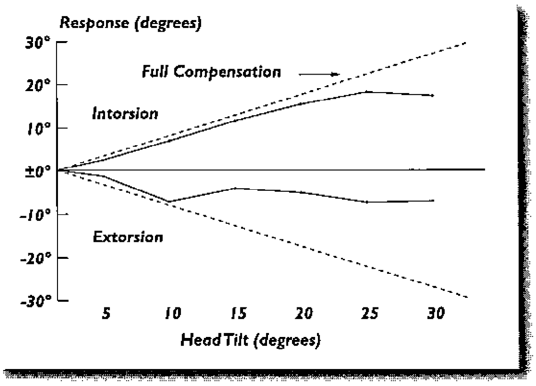


**Figure 4**

*Responses from subject PE. The X-axis represents the amount of head tilt, the Y-axis represents the torsion response. Responses falling on the dashed line would represent full torsional compensation to the head tilt. In this subject there is an almost full intorsion response to 25° of head tilt, but an overall poor extorsion response.*

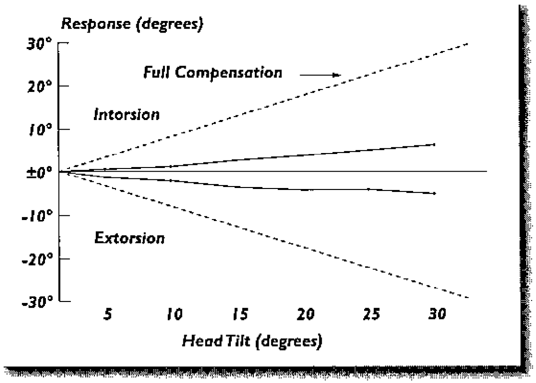


**Figure 5**

*Responses from subject RH. The X-axis represents the amount of head tilt, the Y-axis represents the torsion response. Responses falling on the dashed line would represent full torsional compensation to the head tilt. In this subject there is approximately only one degree of response for each ten degrees of head tilt.*

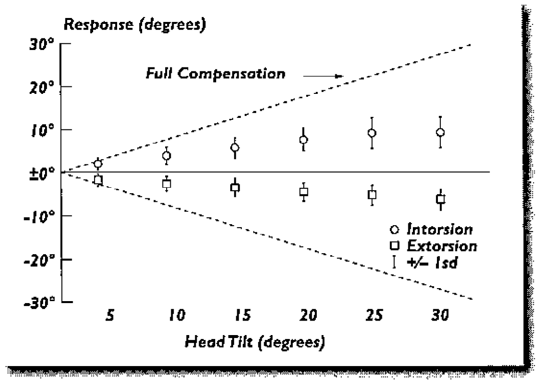


**Figure 6**

*Mean values and one standard deviation for the whole group at each position of head tilt. The X-axis represents the amount of head tilt, the Y-axis represents the torsion response. The dashed line represents full torsional compensation to the head tilt.*

| Head Tilt | Intorsion Mean | Intorsion SD | Extorsion Mean | Extorsion SD |
|---|---|---|---|---|
| 5° | 2.05° | 1.42° | 1.23° | 1.02° |
| 10° | 4.08° | 1.92° | 2.45° | 1.75° |
| 15° | 5.85° | 2.41° | 3.28° | 2.16° |
| 20° | 7.64° | 2.71° | 4.35° | 2.17° |
| 25° | 9.24° | 3.53° | 5.10° | 2.36° |
| 30° | 9.52° | 3.44° | 6.00° | 2.49° |

**Table 2**

*Intorsion and extorsion responses to passive head tilt*

It was noted that in many cases that the amount of tilt of the blind spot was not always consistent with its measured rotation, frequently the disc appeared to be more tilted than that which would be predicted from the amount of rotation in the eye. It is difficult to imagine how this might happen if foveal fixation was maintained, as rotation must occur around the visual axis, and is probably due to testing artefacts from the elevation or depression of the eye caused by the head tilt.

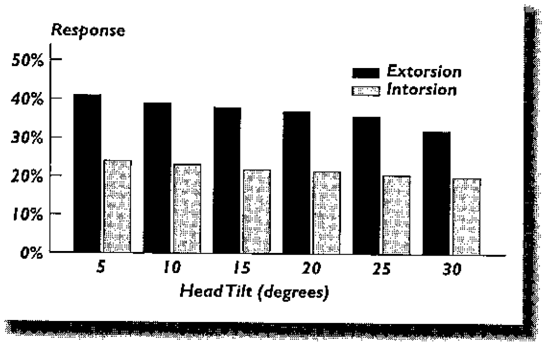


**Figure 7**

*Effectivity of the torsional response. The X-axis represents the amount of head tilt, the Y-axis the percentage of response.*

## Discussion

These results are consistent with previous studies in so far as the torsional response to head tilt is not complete, however they do indicate a greater response than many previous studies. They also indicate a significantly better intorsion response over extorsion (approximately 30%), which differs from Linwong and Hermann's findings of a greater extorsion response [18]. The reasons for this are not apparent, however, Sullivan and Kertesz [19], in studying the motor cyclofusional response to torsional disparity, did find that intorsion was more effective than extorsion.

Blind spot mapping does not permit measurement of both eyes at the same time, and, in the eight cases where both eyes were assessed, these were done on different days, so one must be careful in drawing conclusions regarding the contribution of each eye to the binocular response. However, as there were equal numbers of intorsion and extorsion recordings, the overall superiority of the intorsion response does indicate that, on tilting the head to one side, there must be resulting torsional disparity. This would need to be overcome either by a motor cyclofusion response, or, more likely (according to Kertsz [5]), sensory cyclofusion.

Although these results do not directly contradict the theoretical basis of the Head Tilt Test, the inefficiency of the torsional response to head tilt in some cases may explain why this test does not always give clear results.

A negative or inconclusive result may be due to poor cyclotorsion, rather than paresis of a cyclovertical muscle.

## Summary

Results indicate that the counter torsional response to passive head tilt is around 32%—41% for intorsion and 20%—25% for extorsion. These values are higher than previous studies, but confirm that the response is, at best, much less than that required to maintain the horizontal retinal meridian. The superiority of the intorsion response suggests that motor or, more likely, sensory cyclofusion is acting to prevent torsional diplopia. It is possible that the relative inefficiency of the torsional response may affect the results of the Head Tilt Test in some cases.

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