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Visual evoked potentials in dissociated vertical deviation: a reappraisal

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SUMMARY Pattern reversal and flash evoked potentials were recorded in 13 children with dissociated vertical deviation (DVD). No electrophysiological evidence was found to support the notion that patients with DVD have an anomalous (albinoid) projection of visual fibres originating from the temporal retina of each eye. However, DVD patients had significantly smaller monocular and binocular pattern evoked responses than age matched controls. Explanations are given for this finding and for the occipital VEP asymmetries reported by other workers.

Dissociated vertical deviation (DVD) is an unexplained oculomotor anomaly which becomes evident when the optical input to one eye is occluded or severely degraded. The visually debased eye elevates with extorsion, and latent nystagmus, another commonly associated feature, appears in both eyes. The nystagmus is of the jerk type, with a slow phase towards the covered eye followed by a faster temporally directed jerk. DVD is usually found in patients who had esotropia in infancy, though the condition may not be clinically apparent until a few years after birth.

Fitzgerald and Billson[1] presented pattern evoked potential data which supported their hypothesis that patients with DVD have an anomalous projection in which a significant proportion of fibres originating from the temporal retina cross at the chiasm, together with nasal retinal fibres. This abnormal pattern in projection is similar to that reported to occur in albinos.[2-4]

We have recorded both pattern and flash evoked potentials in young patients with DVD and did not find evidence to support Fitzgerald and Billson's hypothesis. However, we found that pattern reversal responses of DVD patients are not altogether normal, and we suggest reasons for this and for the VEP anomalies reported by Fitzgerald and Billson.[1]

Material and methods

Checkerboard reversal and flash evoked potentials were recorded in 13 patients showing dissociated vertical deviation. Six were male and seven female. The mean age of the group was 8·2 years (SD 4·2, range 3–16 years).

All except one patient had developed esotropia within the first few weeks of birth and had had early surgery. In one patient the squint developed at 1 year of age, and although this patient had DVD and latent nystagmus like the other 12 there was no horizontal component to the deviation, and surgery was not required. All patients had had ophthalmological assessment and orthoptic treatment for a number of years prior to the visual evoked potential (VEP) recordings

Three silver/silver chloride electroencephalograph (EEG) electrodes were applied to the posterior scalp with pyroxylin (Collodion). One electrode was sited in the midline above the inion at a distance of 10% (approximately 4 cm) of the nasion to inion separation. The other two were placed 20% (approximately 4 cm) of the left mastoid to right mastoid distance on either side of the midline electrode. The three occipital electrodes were referred to a common reference, 12 cm above the nasion (Fz, 10–20 system).

The patients sat 1 metre from a 26-inch (66 cm) Sony TV and viewed 50-minute black and white checks of 90% contrast in a full field subtending 28° horizontally and 21° vertically. A small, half degree fixation dot was placed at the centre of the screen.

The checkerboard reversal rate was 3 per second, and responses to full-field and half-field stimulation were recorded. Flash stimulation was also performed with a Devices photic stimulator.

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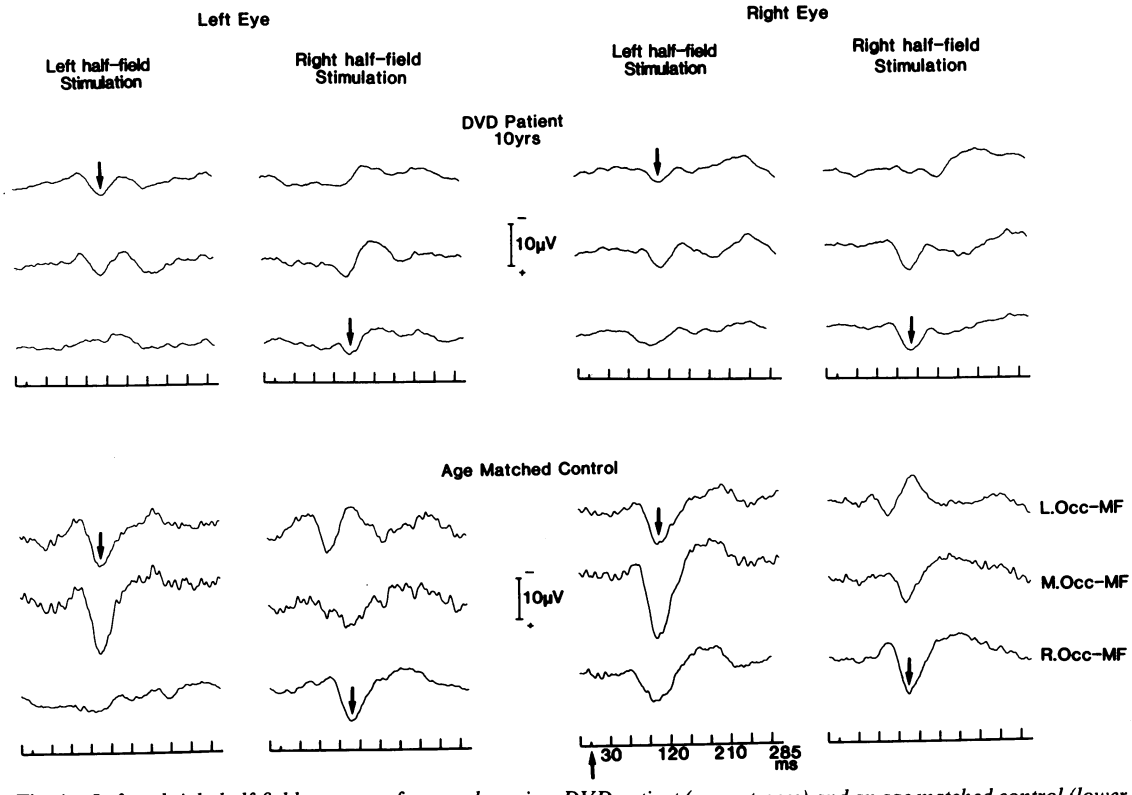

Fig. 1 *Left and right half-field responses from each eye in a DVD patient (upper traces) and an age matched control (lower traces). Note the P100 component (arrows) is seen mainly in the midline and side of scalp ipsilateral to the stimulus field.*

The recording amplifier bandpass was set between 3 and 250 Hz (−3 dB points). The average analysis time was 300 ms, which included a 15-ms prestimulus interval, and 128 trials were averaged with a Medelec Sensor.

Responses from the DVD patients were compared with those of 13 age matched controls (mean 8·3 years, SD 3·4, range 4–15 yr).

Results

There was no consistent nasal/temporal differences in the amplitude of pattern reversal responses to half-field stimulation between patients with DVD and aged matched controls. In both groups the main positive component (P100) elicited by a wide half-field stimulus (0–14° radius) of 50-minute checks, was

Table 1 *Means and standard deviations (in parentheses) of the amplitude of the pattern reversal P100 following full-field and half-field stimulation*

Stimulus	*DVD patients*		*Matched controls*		*Significance level*
	Mean	*(SD)*	*Mean*	*(SD)*	
Binocular full-field	18·1	(7·1)	26·5	(9·8)	<0·05
Left eye full-field	6·2	(2·8)	17·8	(6·7)	<0·01
Right eye full-field	7·2	(4·4)	17·8	(4·9)	<0·01
Left eye left half-field	5·4	(2·3)	9·2	(2·5)	<0·01
right half-field	3·8	(2·2)	9·4	(3·6)	<0·01
Right eye left half-field	4·2	(2·4)	9·5	(2·4)	<0·01
right half-field	5·9	(3·7)	8·9	(2·5)	<0·05

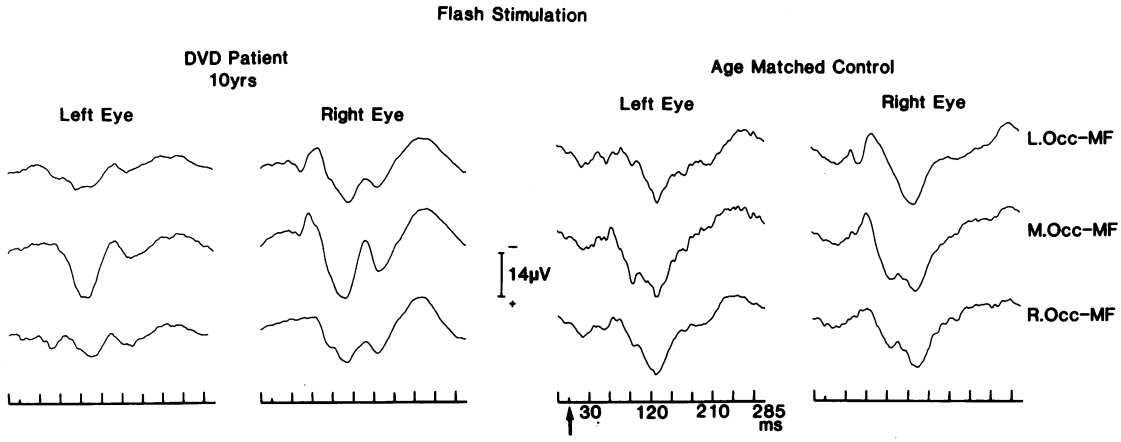

Fig. 2 *VEPs following monocular flash stimulation of each eye. Both the DVD patient (on the left) and the age matched control (on the right) have symmetrically distributed occipital responses.*

recorded in the midline to varying extents, and regularly on the side of scalp ipsilateral to the presented field (Fig. 1). Over the contralateral scalp a positive-negative-positive complex (negativity at around 100 ms) was often evident, though its size varied considerably between individuals and, indeed, in the same individual for left and right half-field stimulation.

Table 1 includes the P100 amplitude values measured at the occipital location ipsilateral to the stimulus half-field. Independent *t* tests gave no significant differences when comparing left and right half-fields of the same eye or the homonymous half-field of each eye.

Fig. 2 shows the flash VEPs from a DVD patient (on the left) and a match control (on the right) for left and right stimulation. Both patient and control had symmetrical occipital distributions for the flash VEP. There were no significant group differences in the mean amplitudes of the midline main positivity for the flash response between the DVD patient group (left eye 19·5 μV, SD 10·5; right eye 23 μV, SD 6·5) and matched controls (left eye 21·8 μV, SD 6·5; right eye 20·1 μV, SD 7·9). There were also no significant differences when comparing the left against the right sided channel for stimulation of each eye, nor for comparison of each eye's response at the same lateral electrode.

No significant latency differences were found between the patient and control groups for either pattern stimulation (Table 2), or flash stimulation.

Thus DVD patients did not differ from matched controls when the occipital distribution was compared either with half-field pattern stimulation or with flash stimulation. However, we did find that DVD patients had significantly attenuated pattern reversal responses. The P100 components both to full-field stimulation and to half-field stimulation were significantly smaller in comparison with those of matched controls (Table 1). Most of the DVD patients (12/13, 92%) were amblyopic in one eye judged on clinical testing. All but one had no demonstrable binocular vision and on orthoptic testing had suppression. The patient who had the

Table 2 *Means and standard deviations (in parentheses) for the latency of the pattern reversal P100 following full-field and half-field stimulation*

Stimulus	*DVD patients*		*Matched controls*		*Significance level*
	Mean	*(SD)*	*Mean*	*(SD)*	
Binocular full-field	103·1	(4·8)	102·8	(2·5)	NS
Left eye full-field	102·4	(5·3)	104·4	(3·1)	NS
Right eye full-field	104·7	(6·6)	105·5	(3·5)	NS
Left eye left half-field	100·7	(7·6)	103·0	(3·3)	NS
right half-field	103·7	(7·2)	106·2	(3·8)	NS
Right eye left half-field	106·6	(5·5)	105·6	(3·0)	NS
right half-field	105·4	(7·9)	105·0	(3·0)	NS

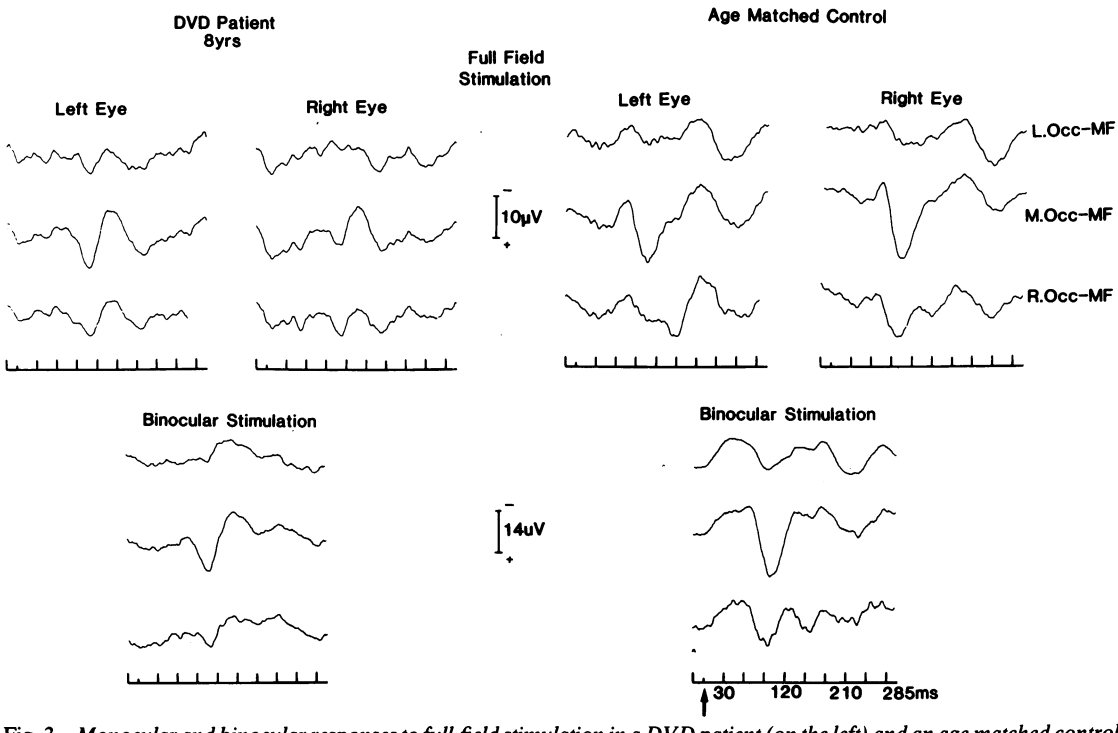

Fig. 3 *Monocular and binocular responses to full-field stimulation in a DVD patient (on the left) and an age matched control (on the right). Note the generally smaller responses from the DVD patient in comparison with the control.*

squint of later onset did show weak binocular vision with abnormal retinal correspondence. The degree of amblyopia was mild (within 2 Snellen lines of normal 6/6 level) in eight patients (62%), moderate (between 6/18 and 6/24) in three patients (23%), and marked (between 6/36 and 6/60) in two patients (15%). The full-field pattern P100 was commonly smaller in the amblyopic eye (mean 5·68 μV, SD 2·5) than in the fellow eye (mean 8·4 μV, SD 4·7), and this in part accounts for the significantly smaller responses in the DVD group. However, the mean full-field P100 amplitude from the non-amblyopic eye of DVD patients was markedly smaller (47% of the size) than the mean monocular amplitude of the control group (17·8 μV).

Fig. 3 shows (on the left side) monocular and binocular pattern VEPs in an 8-year-old boy with amblyopia in the right eye. His acuities were 6/36 for the right eye, 6/12 for the left, and 6/9 when viewing with both eyes. The VEPs from the amblyopic right eye were attenuated compared with those of the better-acuity left eye, but all pattern VEPs from the patient were smaller than those of the matched control (on right). The clear differences between the patient and control groups can be seen in Fig. 4, which shows the left and right eye pattern reversal P100 amplitude values of each patient together with the group mean (circled) and standard deviation.

Predictably, pattern VEPs to full-field binocular stimulation were also significantly smaller ($p<0·05$) than those of matched controls (Fig. 3 and Table 1), but the magnitude of the mean difference (32%) between the two groups was less than that for monocular stimulation conditions, in which the pattern response from the non-amblyopic eye was, on average, 53% smaller in comparison with either of the control eyes.

Discussion

We found no electrophysiological evidence, either from pattern or flash evoked potentials, to support Fitzgerald and Billson's[1] claim that patients with DVD have an anomalous (albinoid) visual pathway projection, in which not only all fibres subserving the temporal field of one eye cross at the chiasm but are accompanied by a significant proportion of fibres subserving the nasal half-field. Marked nasal/temporal half-field differences for the pattern reversal P100 component are reported to occur in both ocular and oculocutaneous albinism.[4] However, in the present study comparisons for the P100 following left

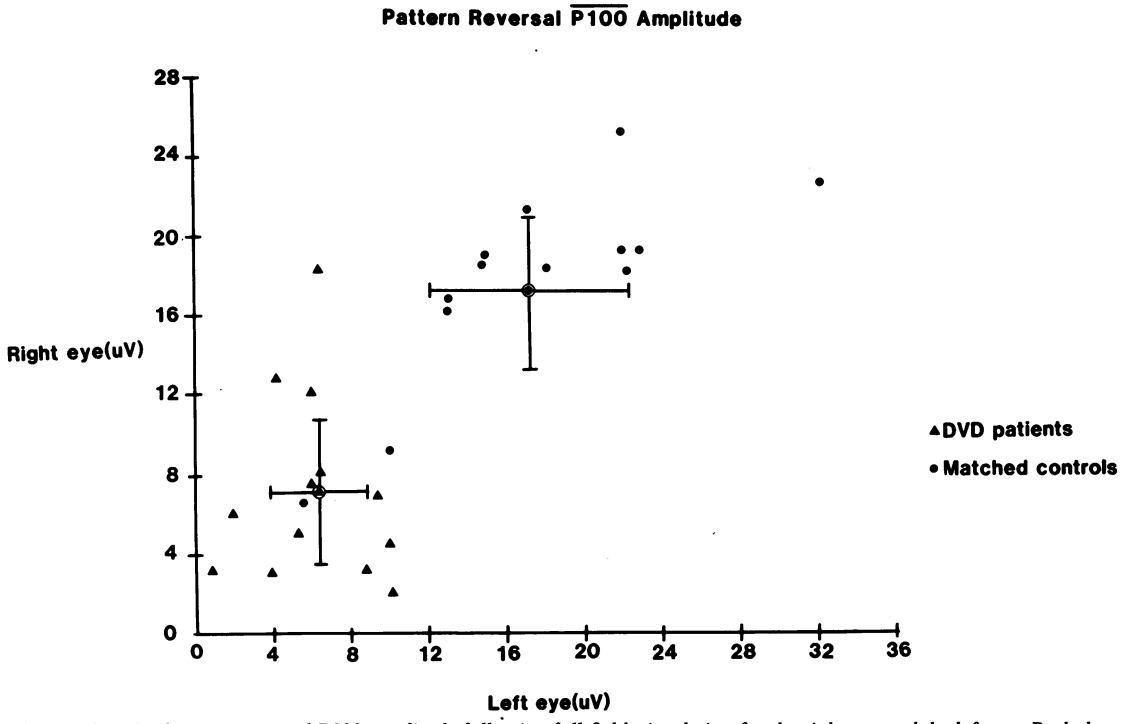

Fig. 4 *Graph of pattern reversal P100 amplitude following full-field stimulation for the right eye and the left eye. Both the individual data and means (circled) +1 standard deviation are shown. Note the DVD patients generally had smaller responses than age matched controls.*

and right half-field stimulation in DVD patients showed no significant amplitude differences. These negative findings were in line with the results following flash stimulation, which did not show differences for the comparison of responses from each eye recorded at the same lateral electrode. Such eye asymmetries are reported to occur in albino subjects.[2]

We also found no significant differences in the latency of the pattern reversal P100 when comparing DVD patients with matched controls. Fitzgerald and Billson[1] reported 'delayed' half-field responses in all patients with DVD. Carroll *et al.*[5] pointed out that it is possible to misidentify the second (commonly the largest) positivity of the paramacular complex (P135 component) as a delayed P100 component. In our study a relatively large half-field (0–14° eccentricity) was used, and this is known to be an effective stimulus size for eliciting not only the macularly derived P100 component, predominantly distributed over the side of scalp ipsilateral to the test half-field, but also in most subjects a contralateral paramacularly derived complex (P75, N105, P135) (see Blumhardt *et al.*[6] for full details). When the pattern reversal P100 component is attenuated, as we have shown for DVD patients, the paramacular complex with its commonly prominent P135 component can spread nearer the midline region and may be misidentified as the P100 component. Fitzgerald and Billson[1] did not address this possibility.

Our study showed that the pattern VEPs of DVD patients were generally significantly smaller than those of age matched controls. Two factors are likely to be involved in this effect. The first is amblyopia, which is known to be associated with conspicuous attenuation of pattern VEPs but not of pure luminance VEPs.[7] In our data the pattern reversal P100 component from the amblyopic eye was on average 70% smaller than that recorded from controls. The better-acuity eye of DVD patients produced larger pattern VEPs than the fellow amblyopic eye. However, responses from the good eyes were significantly attenuated compared with controls (53% smaller). A corollary of this was the significantly smaller binocular response from the patients than the controls. These findings are in line with those of Day *et al.*,[8] who used the swept spacial frequency technique to assess a group of infants with infantile esotropia and found subnormal acuity levels, estimated from VEP amplitude, for both monocular and binocular viewing conditions.

The second factor which is also probably contributing to attenuation of pattern VEPs in DVD is the latent nystagmus which is commonly associated with this condition. There appear to be no published studies of the effects of nystagmus on the recording of visual evoked potentials. We have found that pattern reversal VEPs to a 50-minute checkerboard are attenuated by, on average, 60% when recorded during horizontal vestibular nystagmus induced by a 40-second period of whole body rotation (Kriss A, *et al.*, report in preparation). Thus it is highly likely that latent nystagmus is contributing to the attenuation not only of monocular but also, to less extent, of binocular VEPs recorded from DVD patients. Although manifest latent nystagmus was not seen in any of our patients during binocular viewing, Dell'Osso *et al.*[9] have shown with sensitive eye movement recordings that most patients with monocular latent nystagmus show very small amplitude manifest latent nystagmus on binocular viewing.

It is conceivable that latent nystagmus may also be responsible for the anomalous pattern of asymmetry in the VEP reported by Fitzgerald and Billson.[1] In latent nystagmus there is a slow initial phase which is nasally directed followed by a faster jerk in the temporal direction. Whereas during nasal half-field testing the fovea drifts into the pattern field, for temporal half-field stimulation it drifts into a blank field. Gross *et al.*[10] found that pattern responses were markedly attenuated when elicited during a saccadic eye movement, but pure luminance responses were relatively unaffected. Consequently it is possible that nasal half-field responses may be relatively more attenuated than temporal half-field responses and thus produce a pattern of asymmetry similar to that observed in albinism. In this context it is relevant to note that in the present study both nasal field responses had, on average, smaller P100 components than the temporal half-field responses, though the difference was not significant. These minor nasal temporal differences did not appear in our control group.

References

1 Fitzgerald BA, Billson FA. Dissociated vertical deviation, evidence of abnormal visual pathway projection. *Br J Ophthalmol* 1984; **68:** 801–6.

2 Creel D, O'Donnell FE, Witkop CJ. Visual system anomalies in human ocular albinos. *Science* 1978; **201:** 931–3.

3 Apkarian P, Reits D, Spekreijse H, Van Dorp D. A decisive electrophysiological test for human albinism. *Electroencephalogr Clin Neurophysiol* 1983; **55:** 513–31.

4 Carroll WM, Jay BS, McDonald WI, Halliday AM. Pattern evoked potentials in human albinism. *J Neurol Sci* 1980; **48:** 265–7.

5 Carroll WM, Halliday AM, Kriss A. Improvements in the accuracy of visual evoked potentials in the diagnosis of visual pathway disease. *Neuro-Ophthalmology* 1982; **2:** 237–53.

6 Blumhardt LD, Barrett G, Halliday AM, Kriss A. The effect of experimental 'scotomata' on the ipsilateral and contralateral responses to pattern reversal in one half-field. *Electroencephalogr Clin Neurophysiol* 1978; **45:** 376–92.

7 Halliday AM. *Evoked potentials in clinical testing.* Edinburgh: Churchill Livingstone, 1982.

8 Day SH, Orell-Baxter DA, Norcia AM. Abnormal grating acuity development in infantile esotropia. *Invest Ophthalmol Vis Sci* 1988; **29:** 327–9.

9 Dell'Osso LF, Graccos S, Abel LA. Strabismus – a necessary condition for latent and manifest nystagmus. *Neuro-Ophthalmology* 1983; **3:** 247–57.

10 Gross EG, Vaughan HG, Balenstein E. Inhibition of visual evoked responses to pattern stimuli during voluntary eye movements. *Electroencephalogr Clin Neurophysiol* 1967; **22:** 204–9.

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