Original article:

Study of mechanism of binocular interaction in normal adults using pattern reversal visual evoked potentials

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ABSTRACT

Introduction: Binocular improvement of certain aspects of vision, not involving depth perception is often much understated and elusive advantage of binocular vision. Hence, in an attempt to evaluate such binocular interaction electrophysiologically, the present study was planned to record PRVEP (pattern reversal visual evoked potentials) in normal adults to find out the extent of binocular enhancement and also to search for any gender dependence.

Methods : Transient visual evoked potentials were recorded in eighty normal adults in the age group of 18-55years.Pattern reversal checkerboard was presented, consisting of 15 min and 60 min checks under monocular and binocular conditions. P100 latency and N75- P100 amplitudes were studied. VEPs (visual evoked potentials) in response to monocular and binocular stimulation were compared using t- tests. Binocular summation ratio for two check sizes and for males and females were calculated and compared.

Observation and results : Mean binocular latencies of P100 were shortened and mean N75- P100 amplitudes increased significantly ($p<0.0001$) as compared to mean monocular values, in both the check sizes and in both the sexes. However, the differences between binocular summation ratios were not found to be statistically significant between the two sexes and the two check sizes.

Conclusion : Transient PRVEP exhibit binocular summation in normal adults in terms of both, latency shortening and amplitude enhancement. Gender does not seem to influence the binocular summation. The present data can, further be used to assess the reliability of VEP in defective binocular vision.

Key words : Visual evoked potentials, binocular vision, binocular summation

INTRODUCTION

Binocular vision is a valuable asset for almost all living organisms, from human beings to the lowest, differing mainly in their areas of visual field overlaps. It is the process by which certain aspects of vision like contrast sensitivity, brightness perception, visual acuity etc are improved as compared to the monocular viewing [1]. Previous reports on electrophysiologic and psychophysical evaluation of binocular functions in human subjects have identified different forms of binocular interactions such as binocular facilitation, summation, averaging and inhibition (suppression) [2, 3]. Electrophysiologic studies have used visual evoked averaging potentials to assess these interactions in the visual systems. They provide a sensitive and objective measure of visual functions. However, previous studies have shown that the magnitude of the binocular interactions as reflected in the amplitude of this wave, can vary greatly depending on the stimulus characteristics like spatial and temporal frequency,

luminance, contrast [2,4,5]. Furthermore, the amplitude of PRVEP P100 was shown to exhibit considerable intersubject and intrasubject variability [6].

Most studies refer to it by the equation: 2× (Amplitude of P100 under binocular conditions/Amplitude of Right eye + Amplitude of Left eye) [7]. In stereo- normal adults, if this ratio is more than 1 but less than 2, indicates summation, > 2, indicates facilitation, equal to 1 refers to averaging and less than 1 indicates inhibition (suppression). In this study both amplitude as well as latency have been studied for the extent of improvement from the binocular VEPs. The present study aimed to obtain an objective measure of binocular interactions in normal adult subjects which not only expands the normative PRVEP data base of our laboratory having monocular as well as binocular values for two different check sizes but could further be applied clinically as well as for the research purposes. The study also intends to find out the extent/percentage of binocular summation in terms of binocular summation ratio in normal adults, under our stimulus conditions.

MATERIALS AND METHODS

We studied 80 normal adults (43 males and 37 females) in the age group of 18-55 years with normal or corrected visual acuity. Approval from the institutional ethical committee was obtained to carry out the research work. All the subjects underwent stereopsis testing with synaptophore. None had a history of strabismus or amblyopia. A complete neuro-ophthalmologic examination of each subject was done after obtaining a written informed consent and a detailed clinical history.

Inclusion criteria

Adult healthy subjects with normal stereopsis, with normal or corrected visual acuity, normal fundus and visual field examinations.

Exclusion criteria

Subjects with metabolic , endocrine or demyelinating pathologies; glaucoma, strabismus, amblyopia, optic neuropathies , inherited or acquired neurological disorders, compressive lesions of anterior visual pathways, HIV infections, history of drug- abuse and history of cerebro-vascular accidents.

Pre-test evaluation

For the best results of VEP testing, subjects were advised to come without applying oil or any hair chemical to the scalp, asked to put on their usual glasses or corrective lens. Subjects were instructed to have an adequate sleep, the previous night to prevent the effect of drowsiness on the responses. Subjects were explained about the test to ensure full cooperation and to avoid subject's inattention and defocussing during the test procedure. Subjects were also instructed to avoid any mydriatic or miotic drug 12 hours before the test. Preparation of scalp skin was done before electrode application.

VEP recording

VEP was recorded with Allengers- scorpio system in a specially equipped electrodiagnostic procedure room made dark and sound attenuated for the test. Subjects were seated comfortably about 85 cm away from a video-monitor with a 23×25 cm screen. The video-monitor presented a black and white checker-board pattern with a fixation spot in the center of the screen (mean luminance 50cd/m^2 and contrast 70%). The checks/pattern elements reversed alternately at the rate of 2 Hz. Two check sizes were used for the stimulation .The visual angle subtended by the larger checks was 1° (58min× 63 min) and that by the smaller checks was 15 min (14.5min× 15.8min) and the screen subtended a visual angle of 16 degrees (15.5°×16.85°). The signals were amplified (gain 20,000), filtered with a system band pass filter of 2-100 Hz and 100 responses were averaged. Standard disc surface electrodes were placed according to the International 10/20 system of

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electrode placement with active electrode at Oz, reference electrode at Fz and ground electrode at Fpz [8].Volunteers were instructed to fix the gaze on a small red square at the center of the screen of video-monitor. Subject's fixation at the screen center was continuously monitored during the recording. Monocular stimulation was done by testing each eye separately with an eye-patch covering the other eye and binocular stimulation was done with both the eyes open and fixating at the target simultaneously. With the preset stimulus and recording conditions as mentioned above and keeping the electrode impedance < 5 kΩ, the recording procedure was started. To verify the reproducibility of the waveform, two responses were recorded and superimposed. The replicated response measurements with P100 latency within 2.5 ms difference and N75-P100 amplitude with <15 % difference was accepted [6].

Statistical analysis: All the data was expressed as mean ± S.D. Mean P100 latency and amplitude were recorded under monocular conditions and inter-ocular latency differences calculated. The mean values of P100 latency and amplitude for two different check sizes under monocular conditions were compared with those of binocular VEP using paired t test. Binocular summation ratio was calculated as: 2× [Amplitude of P100 under binocular conditions/Amplitude of Right eye + Amplitude of Left eye] and compared in two check sizes and between males and females. The gender and age dependence of VEP latency and amplitude in both monocular and binocular VEPs was measured .The statistical significance of the data was assessed by t-test and p values <0.05 was considered as statistically significant.

RESULTS

The study was conducted in 80 healthy adults (43males and 37females). Subjects were classified into 2 different age-groups (table 1). P 100 latencies and N75-P100 amplitudes were recorded under monocular and binocular conditions (figure 1 and 2). The difference between the P 100 latency for right and left eye was not statistically significant with mean inter-ocular difference of 0.48 ms ± 0.2(60 min checks) and 1.29 ± 0.5ms(15 min checks). Hence, mean of P100 latency for right and left was calculated as mean monocular latency. Similarly, mean monocular amplitude was calculated. When mean monocular and binocular N75-P100 amplitudes were compared between males and females, a statistically significant increase in amplitude in females was found (table 2) with p value<0.01(mean monocular amplitude: 4.93 µv ±1.64 in males vs. 6.62 µv ±1.99 in females in 18-35 years and 4.7 µv ± 1.74 in males vs 6.92 µv ± 2.43 in females in > 35 years age group, similarly, binocular N75-P100 amplitudes :5.46 µv ±1.62 in males vs. 7.69 µv ±2.2 in females and 5.78 µv ±2.04 in males vs. 8.09 µv ±2.43 in females in the two age-groups) (unpaired t-test). Regardless of age also, similar results were found in males and females (table 4). Contrary to this, when the mean monocular and binocular P100 latencies were compared with those between males and females, no statistical significance could be obtained in both the age groups as well as regardless of age (table 3 and 4) with P100 latency slightly shorter in females but not significant statistically(p >0.05) (unpaired t test). In the two age groups, neither P100 latency nor amplitude was found to be statistically significant) (unpaired t test) (table 2 and 3).

Binocular VEP P100 latency decreased as compared with the mean monocular latency with highly significant difference (p<0.0001) (table 5) with 60 min (98.53 ms± 6.08 vs. 101.9 ms ± 5.57) as well as 15 min check sizes(104.87 ms ± 5.44 vs. 110.4 ms ± 5.84) (paired t test). Similarly, binocular N75-P100 amplitude increased significantly (6.6 µv ± 2.32 vs. 5.65 µv ± 2.12) with 60 min checks as well as for 15 min checks (9.5 µv ± 3.83 vs. 7.68 µv ± 3.03) in comparison with mean monocular amplitude

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(p<0.0001). Binocular summation ratio for 60 min checks was 1.215± 0.29 while that for 15 min checks was 1.254± 0.25, but no statistically significant difference could be obtained between the ratios with the two check sizes (paired t test). P value < 0.0001(highly significant) for binocular latency and amplitude vs. monocular values (99.11± 5.57 vs. 102.24± 5.38 and 5.61± 1.81 vs. 4.82± 1.67) in males and for a similar comparison in females, but, for binocular summation ratio in males (1.2± 0.308) and females (1.19 ± 0.24),the difference was not statistically significant (table no.4).

Table no. 1- Age and sex distribution of the subjects

Age group (years)	No. of subjects		
	Males	Females	Total
18-35	23	20	43
>35	20	17	37

Table no 2- Mean monocular and binocular N75-P100 amplitudes in males and females in different age-groups (check size of 60 min).

Age-group (years)	N75-P100 amplitude(μv)	Males (23)	Females (20)	Total (43)
18-35	Mean monocular amplitude (μv)± SD	4.93±1.64	6.62±1.99	5.716±1.98
	Mean binocular amplitude (μv)± SD	5.46±1.62	7.69±2.2	6.498 ±2.2
>35	**N75-P100 amplitude(μv)**	**Males(20)**	**Females(17)**	**Total(37)**
	Mean monocular amplitude (μv) ± SD	4.7± 1.74	6.92±2.43	5.72±2.22
	Mean binocular amplitude (μv)± SD	5.78±2.04	8.09±2.43	6.75±2.38

P value<0.01, when **mean monocular** (4.93 μv ±1.64 in males vs. 6.62 μv ±1.99 in females and 4.7± 1.74 in males vs. 6.92±2.43 in females) and **binocular N75-P100 amplitudes** (5.46 μv ±1.62 in males vs. 7.69 μv ±2.2 in females and 5.78 μv ±2.04 in males vs. 8.09 μv ±2.43 in females) were compared in both the age groups , but **p>0.05** for slight difference in the same **between the two age-groups** (6.498 μv ±2.2 vs. 6.75 μv ±2.38 and 5.716 μv ±1.98 vs. 5.72 μv ±2.22)

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Table no 3- Mean monocular and binocular P100 latencies in males and females in different age-groups (check size of 60 min).

Age-group (years)	P 100 latency	Males (23)	Females(20)	Total (43)
18-35	Mean monocular latency(ms) ± SD	101.82± 5.98	101.94± 6.26	101.88± 6.04
	Mean binocular latency(ms) ±SD	98.69± 5.84	98.34± 7.48	98.53± 6.57
>35	**P100 latency**	**Males (20)**	**Females (17)**	**Total(37)**
	Mean monocular latency(ms) ± SD	102.69± 4.72	101.88± 6.13	102.02± 4.89
	Mean binocular latency(ms) ± SD	99.59 ± 5.37	96.92± 5.43	98.45± 5.17

P > 0.05 for **both monocular and binocular P100 latency compared between males and females** in both the age groups. And also, **p>0.05** for slight difference in the same **between the two age-groups** (101.88± 6.04 vs.102.02± 4.89 and 98.53± 6.57 vs. 98.45± 5.17).

Table no.4- Mean monocular and binocular P 100 latency and amplitude in males and females (check size of 60 min).

	Mean monocular P100 latency (ms) ± SD	Mean binocular P100 latency (ms) ± SD	Mean monocular N75-P100 amplitude(µv) ±SD	Mean binocular N75-P100 amplitude(µv) ± SD	Binocular summation ratio
Males (43)	102.24± 5.38	99.11± 5.57	4.82± 1.67	5.61± 1.81	1.2± 0.308
Females(37)	101.62± 5.7	97.78± 6.69	6.74± 2.17	7.84± 2.22	1.19± 0.24

P value < 0.0001(highly significant), when **mean monocular and binocular N75-P100 amplitude between the two sexe**s compared (mean monocular amplitude in males: 4.82± 1.67 vs. mean monocular amplitude in females: 6.74± 2.17 and mean binocular amplitude in males: 5.61± 1.81 vs. that in females: 7.84± 2.22). **P value>0.05** for similar comparison for latencies between males and females**.** But, **when binocular summation ratio compared between the sexes, p>0.05.**

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Table no.5- Mean monocular and binocular P 100 latency and amplitude and binocular summation ratio with two different check sizes (60 min and 15 min)

	Mean P 100 latency(ms) ± SD		Mean N75-P100 amplitude(µv) ± SD	
	60 min checks	15 min checks	60 min checks	15 min checks
Monocular VEP	101.9± 5.57	110.4± 5.84	5.65 ± 2.12	7.68± 3.03
Binocular VEP	98.53± 6.08	104.87± 5.44	6.6 ± 2.32	9.5± 3.83
Binocular summation ratio			1.215± 0.29	1.254± 0.25

P value <0.0001 for the difference between **monocular and binocular P 100 latency** (101.9 ± 5.57 vs. 98.53 ± 6.08 and 110.4 ± 5.84 vs.104.87± 5.44) **and N75-P100 amplitude** (5.65 ± 2.12 vs. 6.6 ± 2.32 and 7.68 ± 3.03 vs. 9.5±3.83) in both the check sizes, but when binocular summation ratio compared between the two check sizes, p value >0.05.

DISCUSSION

Binocular summation/facilitation, a comparatively less emphasized advantage of binocular vision, can be assessed by visual evoked potential studies in subjects with normal stereovision by the amplitude increase and latency shortening in binocular viewing conditions. The degree of enhancement, however, may vary, depending on the stimulus conditions. In the present study, both P100 latency and N75-P100 amplitude were evaluated with two different check sizes used for stimulation, in normal adults by means of PRVEP. A binocular summation ratio was calculated and compared between the two check sizes. Also, any gender dependence for the differences in the latencies and amplitudes in monocular and binocular VEPs have been measured and compared in the two viewing conditions.

Gender dependence of latencies and amplitudes in monocular and binocular VEPs

In both the age-groups, monocular and binocular N75-P100 amplitude increase in females was extremely significant as compared to those in males, with p value< 0.0001 (table no 2 and 4)). In other previous studies also a significant amplitude increase has been found in females [9-11]. The amplitude increase in females as compared to males has been

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attributed to the hormonal differences [9]. No influence of anthropometric differences has been suggested to play role in the same [10]. Amplitude change has been found to persist even after head and body size adjustments [12]. However, the monocular and binocular P100 latencies in males compared to females was not statistically significantly different ($p>0.05$) (table no 3 and 4). A previous study by Mitchell et al also reported no gender difference in P100 latency studied in 31 males and 37 females [13]. The sample size of which was comparable to ours. It has been documented that when body size adjustments were applied, regardless of gender, latency differences could not be obtained [12]. The studies reporting increased latencies in males have also explained the difference on the basis of head size and body size and [14, 15].

Age dependence of latency and amplitude in monocular and binocular VEPs

In our study with 80 normal adults classified in two age groups no statistically significant difference in latencies as well as amplitude could be found between the age-groups (table no 2 and 3) However, age has been reported to influence VEP latency in adults after fifth decade [15]. In our study absence of any such change can be partly attributed to comparatively smaller number of adults in > 50 years age-group. As far as, no amplitude changes among the age groups is concerned, most of the similar studies in the past report the same results, with some stating conflicting results in adults>50 years [13, 16]

Binocular VEPs

Binocular enhancement when assessed by comparing the binocular VEP latency as well as amplitude with monocular VEPs for both check sizes i.e. binocular P100 latency vs. monocular P100 latency (mean of two monocular latencies) and binocular N75-P100 amplitude vs. monocular value, compared in 60 min check size as well as in 15 min checks, p value was <0.0001 (table no 5)**.** Binocular summation ratio in the two check sizes did not vary significantly (1.25 ± 0.25 with 15 min checks and 1.21 ± 0.29 with 60 min checks), $p >0.05$ (table no 5).

Latency improvement in our study conforms with other similar studies in the past [17-20]. However, some studies have reported the significant difference in the latency, only when compared with the worse eye (eye with longer latency or smaller amplitude or both) [21]. Amplitude enhancement has been reported in various studies with different degrees of enhancements [21-26]. In line with previous findings, VEP amplitude increase in adults was less than expected after binocular stimulation. In adult recordings, only certain specific conditions will elicit larger binocular than monocular VEP amplitude [2].

Gender dependence for differences in monocular and binocular VEPs

Mean binocular P100 latencies and amplitudes in males varied statistically significantly as compared to their mean monocular values. In females also, the binocular enhancement was found, but when mean binocular summation ratio in males was compared to that in females (1.20 ± 0.3 vs. 1.19 ± 0.24) the slight difference was not statistically significant (table no.4), reflecting that binocular interaction in males and females does not appear to differ.

Regarding researches into binocular interaction of vision, the pioneering works by Hubel and Wiesel (1962) needs to be referred which provided the first insight into this field. In their animal experiments, Hubel and Wiesel introduced a seven group ocular dominance scale in the striate cortex. About 72% of neurones in V1 (striate cortex) responded to visual inputs from either eye [27]. Amongst these binocularly driven cells, some were stimulated equally from both eyes while the others had a corresponding degree of ocular dominance. According to Grusser and Grusser (1965), some cells respond only when both the eyes

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are stimulated simultaneously (Binocular AND cells) [28]. These cells may determine the level of binocular summation. Binocular AND cells respond best to similar inputs from the two eyes. According to a study by Srebro (1978), under binocular viewing conditions normal subjects adjust positions of their eyes to maximize the number of units whose receptive fields exactly corresponds in space, and show binocular facilitation[29] . In adults, however, reduction in binocular summation in visual evoked potential as compared to infants and children with increasing stereoacuity, have been demonstrated by previous studies [23, 26]. It was suggested that with maturation, the proportion of monocularly driven cells is reduced and the binocularly driven cells have more exacting binocular receptive field requirements [26]. This hypothesis may account for the weak summation observed in normal adults.

CONCLUSION

The significant shortening of P100 latency and increase in amplitude by binocular PRVEP in normal adults provides the electrophysiological evidence of summation of visual signals binocularly, enhancing the role of visual evoked potential tests in the evaluation of binocular vision.

The available normative data for monocular and binocular PRVEPs recorded in this study, can now be applied clinically as well as for the research purposes. The present research can, hence, be extended to assess the reliability of transient PRVEP as an electrophysiological method for separating the individuals with normal binocularity from those with defective binocular vision.

REFERENCES

1. David Stidwill, Robert Fletcher. Binocular summation. In: Normal binocular vision: theory, investigation and practical aspects, 2011 (Blackwell publishing): 29-37.
2. Patricia A Apkarian, Ken Nakayama, Christopher W Tyler. Binocularity in the human Visual evoked potential: Facilitation, summation and suppression Electroencephalography and Clinical Neurophysiology, 1981; 51(1): 32- 48.
3. Said CP, Heeger DJ (2013) A Model of Binocular Rivalry and Cross-orientation Suppression. PLoS Comput Biol 9(3): e1002991. doi:10.1371/journal.pcbi.1002991.
4. Bagolini B, Porciatti V, Falsini B. Binocular interaction and steady-state visual evoked potentials Graefe's Arch ClinExp Ophthalmol, 1988; 226(5): 401-406.
5. Katsumi O, Tanino T, Hiros T. Objective evaluation of binocular function using the pattern reversal visual evoked response, II, Effect of mean luminosity. Acta Ophthalmol, 1986; 64(2): 199-205.
6. American Clinical Neurophysiology Society Guideline 9 B: Guidelines on Visual evoked potentials. J Clin Neurophysiol., Apr 2006; 23(2):138-156.
7. Leguire LE, Fellows RR, Rogers GL and Bremer DL Binocular summation and facilitation of latency in flash and pattern VERs in 6-30 month old children Binocular vision, 1987; 2: 15.
8. Odom JV, Bach M, Brigell M, Holder GE, McCulloch DL, Tormene AP, Vaegan. ISCEV standard for clinical visual evoked potentials (2009 update). Doc Ophthalmol 2010; 120:111-119.

9. Celesia GG, Kauufman D, Cone S. Simultaneous recording of pattern electroretinography and visual evoked potentials. Electroencephalogr Clin Neurophysiol, 1987; 68:161.
10. George Fein, Fiona F. Brown. Gender differences in pattern reversal evoked potentials in normal elderly Psychophysiology, 1987; 24(6): 683-690.
11. Klistorner AI, Graham SL. Electroencephalogram- based scaling of multifocal visual evoked potentials intersubject amplitude variability Invest. Ophthalmol.Vis. Sci., August 2001; 42(9): 2145-52.
12. Cynthia L. Darlington. Functional differences. In: The female brain, Dec 2010, 2nd edition (CRC press): 59-89.
13. Mitchell K W, Howe J W and Spencer S R. Visual evoked potentials in the older population: age and gender effects Clin. Phys. Physiol.Meas., 1987; 8(4): 317.
14. Celesia GG, Kaufman D, Cone S. Effect of age and sex on pattern electroretinograms and visual evoked potentials. Electroencephalography and Clinical Neurophysiology, May 1987; 68(3):161-171.
15. Stockard JJ , Hughes JR, SharVough FW . Visually evoked potentials to electronic pattern reversal: latency variations with gender, age and technical factors. Am J EEG Technol, 1979; 19:171.
16. Shaw NA, Kant BR. Age dependent changes in the amplitude of pattern evoked visual potential. Electroencephalogr Clin Neurophysiol, 1981; 51:671.
17. McCulloch DL, Skarf B. Development of human visual system: Monocular and binocular pattern VEP latency. Investigative Ophthalmology and Visual Sciences, July 1991; 32(8): 2372-2381.
18. Johansson B, Jakobsson P. VEP latency- A comparison between normal and defective binocularity. Clin Vision Sci, 1993; 3:245-251.
19. Adachi-Usami E. and Lehmann D. Monocular and binocular evoked average potential field topography: Upper and lower retinal hemiretinal stimuli. Exp Brain Res, 1983; 50(2-3): 341-346.
20. McKerral M, Lachapelle P, Tremblay F, Polomeno RC, Roy MS, Beneish R, Leporé F . Monocular contribution to the peak time of the binocular pattern visual evoked potential. Documenta Ophthalmologica, 1995-1996; 91(2): 181-193.
21.di Summa A, Fusina S, Bertolasi S, Vicentini S, Perlini S, Bongiovanni LG, Polo A. Mechanism of binocular interaction in Refraction error: study using pattern reversal visual evoked potential. Documenta Ophthalmologica, 1999; 98(2): 139-151.
22. Shea SL, Aslin RN, McCulloch D. Binocular VEP summation in infants and adults with abnormal binocular histories. Invest Ophthalmol Vis Sci, 1987; 28(2): 356-365.
23. Mizota A, Hoshino A, Adachi-Usami E, Fujimoto N. Binocular summation in visual evoked cortical potential in patients who have significantly different P100 peak latencies in their two eyes. Graefe's Archive for Clinical and Experimental Ophthalmology, September 2004; 242(9): 762-766.

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24. Heravian J S, Jenkins T C, Douthwaite WA. Binocular summation in visually evoked responses and visual acuity. Opthalmic Physiol Opt., Jul 1990; 10(3): 257-261.

25. di Summa A., Polo A., Tinazzi M., Zanette G., Bertolasi L., Bongiovanni L.G., Fiaschi A. Binocular interaction in normal vision studied by pattern reversal visual evoked potentials (PR-VEPs). The Italian journal of Neurological Sciences, April 1997; 18(2): 81-86.

26. Sloper J J, Collins A D. Reduction in binocular enhancement of the visual evoked potential during development accompanies increasing stereoacuity. J Pediatr Ophthalmol Strabismus, May- Jun 1998; 35(3): 154-8.

27. D. H. Hubel and T N. Wiesel. Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. J. Physiol., 1962; 160(1):106-154.

28 .Grusser O J, Grusser- Cornehls U. Neurophysiological principles of binocular vision. Arch Psychiatr Nervenkr. 1965; 207(4): 296-317.

29. Srebro R.The visually evoked response. Binocular facilitation and failure when binocular vision is disturbed. Arch Ophthalmol, 1978; 96(5):839–844.

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