Scientific Research Publishing

Open Journal of Ophthalmology, 2017, 7, 158-166
http://www.scirp.org/journal/ojoph
ISSN Online: 2165-7416
ISSN Print: 2165-7408

The Effect of Ocular Dominance on Accommodation and Miosis under Binocular Open Viewing Conditions

Fusako Fujimura[1*], Tomoya Handa[1], Takushi Kawamorita[1], Nobuyuki Shoji[2]

[1]Department of Rehabilitation, Orthoptics and Visual Science Course, School of Allied Health Sciences, Kitasato University, Kanagawa, Japan
[2]Department of Ophthalmology, School of Medicine, Kitasato University, Kanagawa, Japan
Email: *f-fujimu@kitasato-u.ac.jp, thanda@kitasato-u.ac.jp, kawa2008@kitasato-u.ac.jp, nshoji@ahs.kitasato-u.ac.jp

How to cite this paper: Fujimura, F., Handa, T., Kawamorita, T. and Shoji, N. (2017) The Effect of Ocular Dominance on Accommodation and Miosis under Binocular Open Viewing Conditions. *Open Journal of Ophthalmology*, **7**, 158-166.
https://doi.org/10.4236/ojoph.2017.73022

Received: May 25, 2017
Accepted: July 7, 2017
Published: July 10, 2017

Abstract

Background/Aims: We investigated the relationship between ocular dominance and accommodation on the pupils of the dominant eye and the non-dominant eye under binocular open viewing conditions. **Methods:** Seventeen healthy young volunteers participated in this study. The dominant eye was determined using the hole-in-the-card test. The objective refraction and pupil diameter were measured under binocular open viewing and monocular single viewing conditions using a binocular open auto-refractor, the WAM-5500 (SHIGIYA MACHINERY WORKS LTD., Hiroshima, Japan). The accommodative response was calculated using the objective refraction, and the rate of miosis was calculated using the pupil diameter. These values were then compared between the dominant and the non-dominant eyes. **Results:** Under binocular open viewing conditions, the accommodative response in the dominant eye was greater than in the non-dominant eye ($p = 0.001$). In contrast, under monocular single viewing conditions, there were no differences in the accommodative response between the dominant and non-dominant eyes. In both binocular open viewing and monocular single viewing conditions, there were no differences in the miosis ratio between the dominant and non-dominant eyes. **Conclusion:** These results suggest that the accommodative response under binocular open viewing conditions is influenced by ocular dominance.

Keywords

Ocular Dominance, Binocular Vision, Open Viewing Conditions, Accommodation

1. Introduction

Under natural viewing conditions, humans demonstrate ocular dominance, and this feature is an important aspect of binocular vision. Usually, the dominant eye plays a controlling role in binocular vision. Ocular dominance can be broadly divided into three aspects: sighting, sensory, and motor ocular dominance [1] [2] [3]. Sighting dominance refers to the preferential use of one eye in different forms of visual alignment and for performing monocular activities, such as looking through a microscope or key hole [4]. Sensory dominance, which is also called interocular imbalance, cannot be equated with motor eye dominance [5]. A similar mechanism has been suggested to occur between binocular rivalry and strabismic suppression. Motor dominance is observed in the asymmetry of the vergence movements [6] [7]. During near reflexes, namely accommodation, miosis, and convergence, eye movements occur at the same time. Accommodation is one of the most basic visual functions. Accommodation occurs when the eye alters the fixation point from one point in space to another point that exists at a different distance from the retina. Past studies have measured the accommodation response under monocular single viewing conditions. In addition, it is widely accepted that the accommodation responses are equal in both eyes [8]. However, there are fewer studies on the relationship between accommodation, miosis, and ocular dominance under binocular viewing conditions.

In the present study, we investigated the effect of ocular dominance on accommodation and miosis under binocular viewing conditions.

2. Materials and Methods

We examined 17 healthy subjects (4 men and 13 women; mean age: 21.2 ± 1.0 (mean ± standard deviation) years) and have publicly invited subjects by poster posting at School of Allied Health Sciences, Kitasato University in 2012. The mean subjective refractive error (spherical equivalent value, SE) of the dominant eye was −0.83 ± 1.62 D, and the SE of the non-dominant eye was −0.83 ± 1.73 D. There were no differences between the SE of the dominant eye and the non-dominant eye ($p = 0.888$, Wilcoxon signed-rank test). All subjects underwent ophthalmology examination. Subjects were excluded from the study if they had any of following: history of ocular surgery, history of strabismus or amblyopia; and presence of any pupil disorders, ocular motility disorders or any binocular vision, or accommodative abnormalities.

The subjects wore soft contact lenses to achieve a distant visual acuity of 20/20 or better in both eyes. The hole-in-the-card test, in which the subject is given a piece of cardboard with a central circular hole 3 cm in diameter, was used to determine ocular dominance. This test was repeated at least three times to confirm dominance.

A binocular open auto-refractor, the WAM-5500 (SHIGIYA MACHINERY WORKS LTD., Hiroshima, Japan) (**Figure 1**), was used to measure objective refraction and pupil diameter under binocular open viewing and monocular single viewing conditions. The high-speed mode of the WAM-5500 can measure the value of objective refraction and pupil diameter every 0.2 seconds. The subjects were asked to fixate on targets located 5 m, 2 m, 1 m, 0.5 m, 0.33 m away during

Figure 1. WAM-5500 (SHIGIYA MACHINERY WORKS LTD., Hiroshima, Japan).

15 seconds. Cross-shaped targets (20/20 size) were used at each respective distance as fixation targets. We recorded the SE and the pupil diameter under binocular open viewing and monocular single viewing conditions. The lighting conditions during measurement were kept 500 lux. We used mean values over six seconds (0.2 second × 30 values) after the start of measurement, with five seconds needed for analysis. We defined the difference between 5 m and each target distance as the accommodation stimulus (0.5 D, 1.0 D, 2.0 D, and 3.0 D). The accommodative response was calculated as the difference between the SE value at 5 m and the SE value at each target distance. The miosis ratio (%) was calculated as the difference between the pupil diameter at 5 m and the pupil diameter at each target distance. Then, we compared values between the dominant eye and the non-dominant eye. All examinations were conducted by an experienced examiner.

The study protocol was approved by our Institutional Ethics Committee. This study followed the tenets of the Declaration of Helsinki for research involving human subjects, and informed consent was obtained from all participants.

3. Statistical Analysis

Statistical analysis was performed using IBM SPSS statistics software (version 23.0; IBM Corporation, Armonk, NY). The two-way repeated measure ANOVA test was used to compare the accommodative response and the miosis ratio between the dominant and non-dominant eyes. Dunnett's test was used to compare the objective refraction (SE) and the pupil diameter at 5 m and each target distance. The level of statistical significance was set at a p-value of less than 0.05.

4. Results

4.1. Objective Refraction and Pupil Diameters

Table 1 and **Figure 2** show the objective refractions and pupil diameters at each distance under binocular open viewing conditions. The object refractions at 5 m were significantly different from other distance object refractions in both the dominant and non-dominant eyes. Pupil diameters at 5 m were only significantly different from the pupil diameters at 0.33 m in both the dominant and the non-dominant eyes.

Table 1. Objective refraction and pupil diameters under binocular open viewing conditions (n = 17).

	Fixation distance				
	5 m	2 m	1 m	0.5 m	0.33 m
DE objective refraction (D)	−0.09 ± 0.42	−0.45 ± 0.53**	−1.00 ± 0.45***	−1.56 ± 0.31***	−2.49 ± 0.41***
NDE objective refraction (D)	−0.25 ± 0.39	−0.44 ± 0.54	−0.90 ± 0.48***	−1.49 ± 0.48***	−2.43 ± 0.48***
DE pupil diameter (mm)	5.6 ± 0.8	5.6 ± 0.7	5.7 ± 0.8	5.4 ± 0.8	5.1 ± 0.9*
NDE pupil diameter (mm)	5.6 ± 0.8	5.8 ± 0.8	5.8 ± 0.8	5.5 ± 0.7	5.2 ± 0.9*

DE: dominant eye; NDE: non-dominant eye; *$p < 0.05$ (Dunnett's test); **$p < 0.001$ (Dunnett's test); ***$p < 0.0001$ (Dunnett's test).

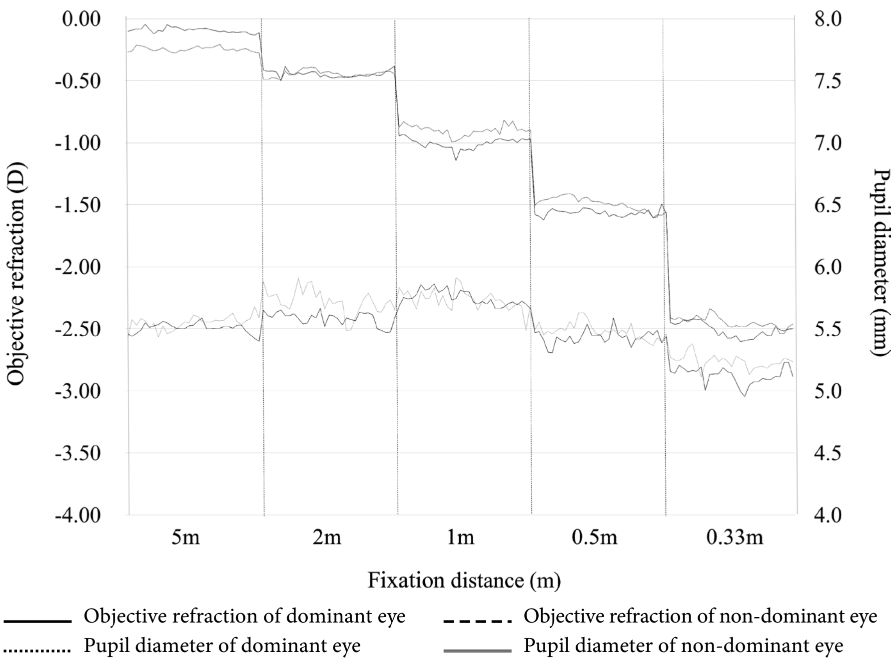

Figure 2. Objective refraction and pupil diameter in binocular open view (n = 17).

Table 2 and **Figure 3** show the objective refractions and pupil diameters at each distance under monocular single viewing conditions. The object refractions at 5 m were significantly different from other distance object refractions in both the dominant and non-dominant eyes. In the dominant eye, the pupil diameters at 5 m were different from the pupil diameters at 0.5 m and 0.33 m. In the non-dominant eye, the pupil diameters at 5 m were different from the pupil diameters only at 0.33 m.

4.2. Accommodation Response Values

The mean accommodation response values (at accommodative stimuli of 0.5 D, 1.0 D, 2.0 D, and 3.0 D) under binocular open viewing conditions were 0.35 ± 0.31 D, 0.91 ± 0.35 D, 1.47 ± 0.38 D, and 2.40 ± 0.49 D, respectively, in the dominant eye, and 0.19 ± 0.34 D, 0.65 ± 0.4 2 D, 1.24 ± 0.36 D, and 2.19 ± 0.48 D,

Table 2. Objective refraction and pupil diameters under binocular open viewing conditions (n = 17).

	Fixation distance				
	5 m	2 m	1 m	0.5 m	0.33 m
DE objective refraction (D)	−0.20 ± 0.34	−0.45 ± 0.43*	−1.00 ± 0.42***	−1.51 ± 0.32***	−2.47 ± 0.34***
NDE objective refraction (D)	−0.29 ± 0.35	−0.35 ± 0.38	−1.00 ± 0.49***	−1.55 ± 0.39***	−2.53 ± 0.35***
DE pupil diameter (mm)	6.3 ± 0.9	6.2 ± 0.8	6.2 ± 0.8	6.0 ± 1.0*	5.8 ± 0.9*
NDE pupil diameter (mm)	6.0 ± 0.9	6.2 ± 1.0	6.0 ± 0.9	5.9 ± 0.9	5.7 ± 1.1*

DE: dominant eye; NDE: non-dominant eye; *$p < 0.05$ (Dunnett's test); **$p < 0.001$ (Dunnett's test); ***$p < 0.0001$ (Dunnett's test).

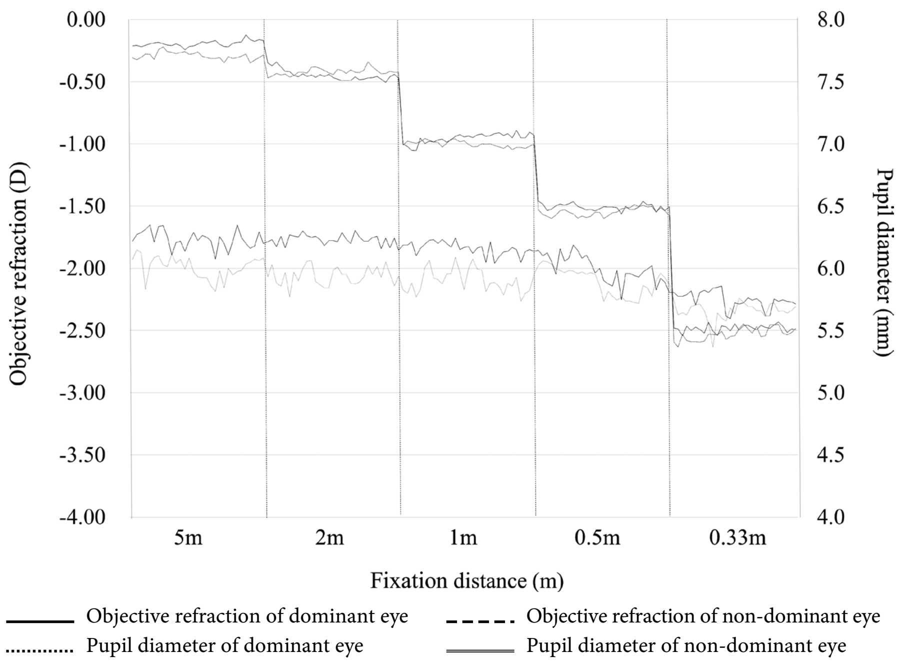

Figure 3. Objective refraction and pupil diameter in monocular single view (n = 17).

respectively, in the non-dominant eye (**Figure 4**). There was a significant difference in the accommodation response values between the dominant and non-dominant eyes under binocular open viewing conditions (p = 0.001). The mean accommodation response values (at accommodative stimuli of 0.5 D, 1.0 D, 2.0 D, and 3.0 D) under monocular single viewing conditions were 0.25 ± 0.21 D, 0.80 ± 0.39 D, 1.23 ± 0.41 D, and 2.27 ± 0.39 D, respectively, in the dominant eye, and 0.05 ± 0.29 D, 0.71 ± 0.52 D, 1.26 ± 0.42 D, and 2.34 ± 0.44 D in the non-dominant eye (**Figure 5**). There were no significant differences in the accommodation response values between the dominant and non-dominant eyes under monocular single viewing conditions.

4.3. Miosis Ratios

The mean miosis ratios (at accommodative stimuli of 0.5 D, 1.0 D, 2.0 D, and 3.0

D) under binocular open viewing conditions were −1.7% ± 9.0%, −4.0% ± 8.2%, 1.4% ± 8.7%, and 7.8% ± 9.8%, respectively, in the dominant eye, and −3.9% ± 8.2%, −3.9% ± 8.2%, −4.2% ± 6.9%, and 0.9% ± 9.8%, respectively, in the non-dominant eye. The mean miosis ratios (at accommodative stimuli of 0.5 D, 1.0 D, 2.0 D, and 3.0 D) under monocular single viewing conditions were 0.6% ± 3.7%, 0.3% ± 5.9%, 4.2% ± 6.1%, and 8.1% ± 8.0%, respectively, in the dominant eye, and −3.6% ± 8.3%, 0.5% ± 8.6%, 1.2% ± 9.1%, and 6.0% ± 10.1%, respect-

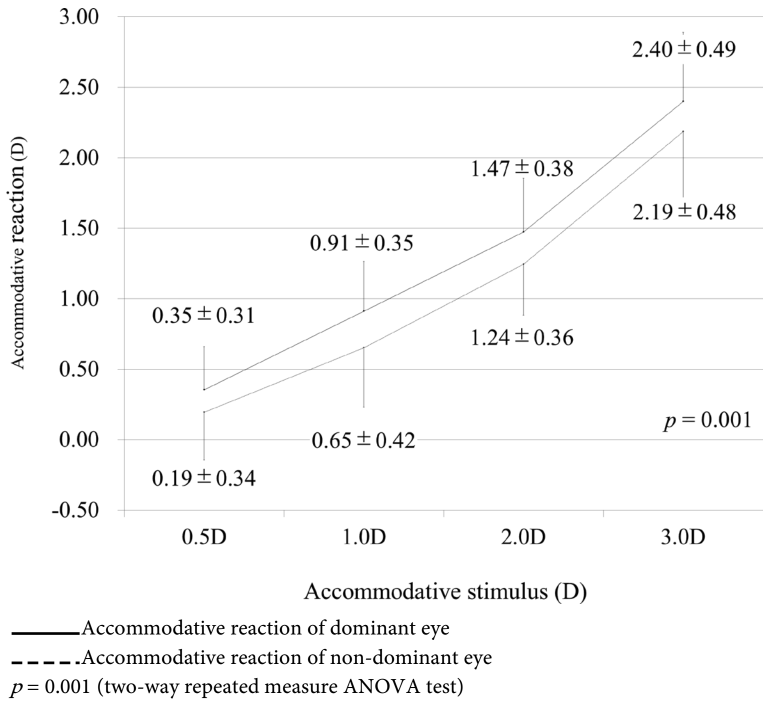

Figure 4. Accommodation reaction in binocular open view (n = 17).

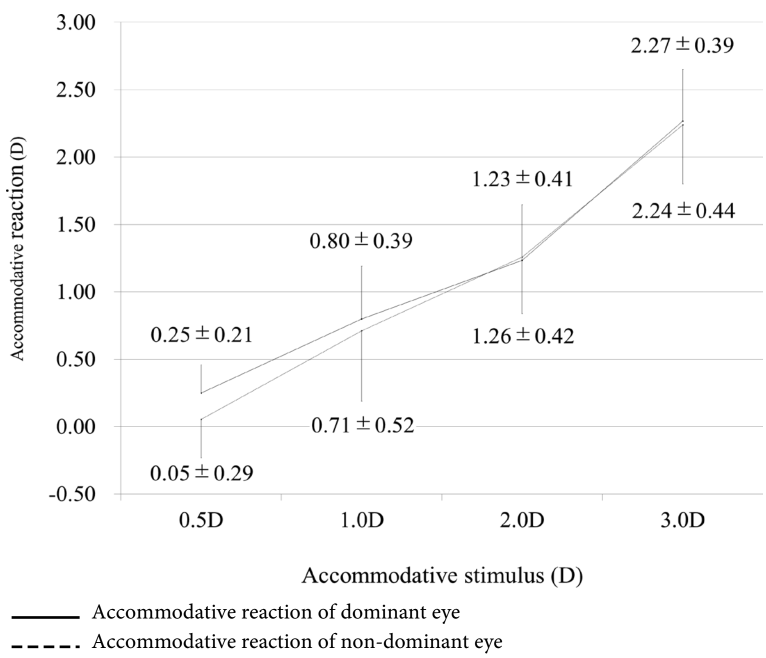

Figure 5. Accommodation reaction in monocular single view (n = 17).

tively, in the non-dominant eye. There were no significant differences in the accommodation response values between the dominant and non-dominant eyes under both binocular open viewing and monocular single viewing conditions.

5. Discussion

This study demonstrates that the accommodation response of the dominant eye was significantly greater than the accommodation response of the non-dominant eye under binocular open viewing conditions in response to all accommodation stimuli. In contrast, under monocular single viewing conditions, there were no significant differences in the accommodation responses between the dominant and non-dominant eyes. This suggests that the accommodative response is influenced by ocular dominance only under binocular open viewing conditions.

A study by Ibi found a lower accommodative lag in the dominant eye in normal subjects. The authors attributed this finding to a potential myopic shift following the change in fixation from far to near in the dominant eye compared to the non-dominant eye [9]. Momeni *et al.* reported that the accommodative amplitude and facility were statistically better in the dominant eye than in the non-dominant eye [10]. In contrast to past studies that measured accommodation responses under artificial binocular viewing conditions, the present study utilized the WAM-5500 to measure object refraction and pupil diameter. This device does not have an internal fixation target, so subjects can see outside targets under natural binocular open viewing conditions. Davies *et al.* reported that the refractive error, as measured by the Shin-Nippon NVsion-K 5001 (Japan), (which is the same type of device as the WAM-5500), was found to be similar to subjective refraction, and that an open viewing arrangement facilitates the measurement of static refractive error to various binocular, real-world stimuli. [11] Therefore, this study demonstrates that a lack of an internal fixation target and enclosed viewing arrangement reduced the risk of proximal accommodation and enabled observation of variables under real-world conditions. Ocular dominance exists under binocular vision conditions, so our results reflect how accommodation functions in a natural visual environment.

In general, ocular dominance reflects functional lateralization, or the tendency to prefer visual input from one eye over the other. It may be defined as the facility whereby one eye commonly dominates or leads the other. Ocular dominance is divided into sighting eye dominance, sensory eye dominance and motor eye dominance. Walls defined sighting dominance as a one-eyed expression of an asymmetric but binocular phenomenon [12]. Sighting eye dominance can be determined using the hole-in-the-card test.

Sensory eye dominance refers to the eye that is preferred for a perceptual visual task that is related to the visual neural system. Berner and Berner defined sensory eye dominance as the controlling eye in binocular perception, for example, that which can be determined by binocular rivalry [13]. Handa *et al.* reported that by using the balance technique based on binocular rivalry, sensory dominance may be quantitatively examined [14]. In the present study, we used the hole-in-the-card test to determine the dominant eye and examined the relationship between sighting eye dominance and the accommodation response through measurements of pupil diameter. Future studies should examine the effect of sensory eye dominance on accommodation and the pupil under binocular open viewing conditions.

Accommodation and miosis are two of the near reflexes. These reflexes are associated with movements controlled by the supranuclear nerve. As such, these movements cannot be consciously separated. However, the miosis ratio was not significantly different between the dominant and non-dominant eyes under either binocular open viewing or monocular single viewing conditions.

The pupil regularly oscillates rhythmically under certain conditions. This oscillation is called "hippus" or "pupillary unrest," and it is caused by activity in the sympathetic and parasympathetic nervous systems. The oscillations occur in both eyes at same time, but there is a difference in physical strength among individuals regarding the frequency and amplitude of these oscillations. These oscillations tend to be most vigorous in young people [15]. However, it is difficult to differentiate between pupillary oscillations and miosis with accommodation. Therefore, in this study, the miosis ratio showed no difference between the dominant and non-dominant eyes under either binocular open viewing or monocular single viewing conditions.

Under both binocular open viewing and monocular single viewing conditions, object refractions at 5 m were significantly different from other target distance object refractions in both the dominant and non-dominant eyes. In contrast, there were few differences between pupil diameters at 5 m and other target distances in either the dominant or the non-dominant eyes. This suggests that accommodation function predominantly than miosis for near vision. It is suggested possibility that this result is applied to any clinical interventions such as spectacle prescription.

A limitation of this study was sample size. The subjects of this study were young people, because we measured accommodation reaction. As a result, the subjects were small. In order to improve the statistical detection rate, it is thought that it is necessary to increase the number of subjects.

6. Conclusion

In conclusion, this study suggests that the accommodative response under binocular open viewing conditions is influenced by ocular dominance.

Institutional Review Board

This study was approved by the Institutional Review Board at School of Allied Health Sciences, Kitasato University (Number 2012-031) and followed the tenets of the Declaration of Helsinki.

Acknowledgements

The authors report no conflicts of interest. The authors alone are responsible for

the content and writing of the paper.

References

[1] Chia, A., Jaurigue, A., Gazzard, G., *et al.* (2007) Ocular Dominance, Laterality, and Refraction in Singaporean Children. *Investigative Ophthalmology & Visual Science*, **48**, 3533-3536. https://doi.org/10.1167/iovs.06-1489

[2] Li, J., Lam, C.S., Yu, M., *et al.* (2010) Quantifying Sensory Eye Dominance in the Normal Visual System: A New Technique and Insights into Variation across Traditional Tests. *Investigative Ophthalmology & Visual Science*, **51**, 6875-6881. https://doi.org/10.1167/iovs.10-5549

[3] Yang, E., Blake, R. and McDonald, J.E. (2010) A New Interocular Suppression Technique for Measuring Sensory Eye Dominance. *Investigative Ophthalmology & Visual Science*, **51**, 588-593. https://doi.org/10.1167/iovs.08-3076

[4] Reiss, M.R. (1997) Ocular Dominance: Some Family Data. *Laterality*, **2**, 7-16. https://doi.org/10.1080/713754254

[5] Sengpiel, F., Blakemore, C., Kind, P.C., *et al.* (1994) Interocular Suppression in the Visual Cortex of Strabismic Cats. *Journal of Neuroscience*, **14**, 6855-6871.

[6] Horng, J.L., Semmlow, J.L., Hung, G.K., *et al.* (1998) Dynamic Asymmetries in Disparity Convergence Eye Movements. *Vision Research*, **38**, 2761-2768. https://doi.org/10.1016/S0042-6989(97)00453-7

[7] Kawata, H. and Ohtsuka, K. (2001) Dynamic Asymmetries in Convergence Eye Movements under Natural Viewing Conditions. *Japanese Journal of Ophthalmology*, **45**, 437-444. https://doi.org/10.1016/S0021-5155(01)00405-1

[8] Ripps, H., Chin, N.B., Siegel, I.M., *et al.* (1962) The Effect of Pupil Size on Accommodation, Convergence, and the AC/A Ratio. *Investigative Ophthalmology & Visual Science*, **1**, 127-135.

[9] Ibi, K. (1997) Characteristics of Dynamic Accommodation Responses: Comparison between the Dominant and Non-Dominant Eyes. *Ophthalmic and Physiological Optics*, **17**, 44-54. https://doi.org/10.1016/S0275-5408(96)00032-4

[10] Momeni-Moghaddam, H., McAlinden, C., Azimi, A., *et al.* (2014) Comparing Accommodative Function between the Dominant and Non-Dominant Eye. *Graefe's Archive for Clinical and Experimental Ophthalmology*, **252**, 509-514. https://doi.org/10.1007/s00417-013-2480-7

[11] Davies, L.N., Mallen, E.A., Wolffsohn, J.S., *et al.* (2003) Clinical Evaluation of the Shin-Nippon NVision-K 5001/Grand Seiko WR-5100K Autorefractor. *Optometry and Vision Science*, **80**, 320-324. https://doi.org/10.1097/00006324-200304000-00011

[12] Walls, G.L. (1951) A Theory of Ocular Dominance. *AMA Arch Ophthalmology*, **45**, 387-412. https://doi.org/10.1001/archopht.1951.01700010395005

[13] Berner, G.E. and Berner, D.E. (1953) Relation of Ocular Dominance, Handedness, and the Controlling Eye in Binocular Vision. *AMA Arch Ophthalmology*, **50**, 603-608. https://doi.org/10.1001/archopht.1953.00920030613007

[14] Handa, T., Mukuno, K., Uozato, H., *et al.* (2004) Effects of Dominant and Nondominant Eyes in Binocular Rivalry. *Optometry and Vision Science*, **81**, 377-383. https://doi.org/10.1097/01.opx.0000135085.54136.65

[15] Loewenfeld, I.E. and Lowenstein, O. (1993) The Pupil: Anatomy, Physiology, and Clinical Applications. Iowa State University Press, Ames and Wayne State University Press, Detroit.