Alternation frequency ranges for stereopsis in patients with strabismus

S I Rychkova, M A Gracheva, M V Zhmurov.
(Institute for Information Transmission Problems, Russian Academy of Sciences, Moscow, Russia;
e-mail: lana.rych@mail.ru)

Earlier, we reported the results of estimating *minimal frequency* (*Fmin*) of alternative left-right stereopair image presentation necessary to obtain stereopsis in subjects without ophthalmopathology (Rychkova, Ninio, 2009, *Perception* **38,** Suppl.,59). The purpose of this study was to estimate the alternation frequency ranges for stereopsis in patients with strabismus. We used 20 different stereograms (created by J.Ninio) displayed on a monitor or presented on a synoptophore. It was found that 30 from 34 patients with strabismus were able to perceive depth with the simple linear stereoscopic images. However, these patients required a higher *Fmin* than normal subjects and, in addition, have an upper limit of alternation frequency (*Fmax*), unlike the normal subjects. Thus, for each patient, the values of *Fmin* and *Fmax* limited the frequency range in which he was able to stereopsis. The widest ranges (7.6±0.6 Hz for *Fmin* and 32.6±0.9 Hz for *Fmax*) were found for simple linear stereoscopic images. Less wide ranges (10.1±1.1 Hz for *Fmin* and 22.9±0.9 Hz for *Fmax*) were found for stimuli containing slanted elements. Only 10 patients demonstrated ability to stereopsis with complex random-dot images in a narrow range of high alternation frequencies (22.3±1,5 Hz for *Fmin* and 30.4 ±1,5 Hz for *Fmax*).

Supported by the Program III.3 of DNIT Russ Acad Sci, 2016.

39th European Conference
on Visual Perception,
Barcelona, 2016

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Svetlana Rychkova, Maria Gracheva, Mihail Zhmurov

Institute for Information Transmission Problems (Kharkevich Institute)
Russian Academy of Sciences, Moscow, Russia;
e-mail: lana.rych@mail.ru

RUSSIAN ACADEMY OF SCIENCES
Institute for Information Transmission Problems (Kharkevich Institute)

INTRODUCTION

The *phase haploscopy* (alternating presentation of images separately to the right and left eye) is believed to be very effective method for the impaired binocular vision functions treatment [1]. Nevertheless, it is still an open question what modes of alternating stimulus presentation are better to use in training of binocular functions.

In view of this, the studying of the threshold frequencies of alternating presentation of stereoscopic images in the case of normal and disturbed visual functions is of a great importance for further development of methods for correction of various binocular disorders.

Earlier, we reported estimates of the minimal frequency (Fmin) of alternative left-right presentations of stereo pairs of images necessary to obtain stereopsis in normal subjects [2, 3]. But practical work shows that patients with binocular disorders have not only lower frequency limit (Fmin), but also an upper frequency limit (Fmax), bounding the range, where stereoperception is possible.

The **purpose** of the present study was to estimate and compare the successful alternation frequency ranges (Fmin and Fmax) for stereopsis in patients with and without strabismus.

SUBJECTS

Group I:
32 subjects (10 to 15 years old) with abnormal refraction without binocular disorders.

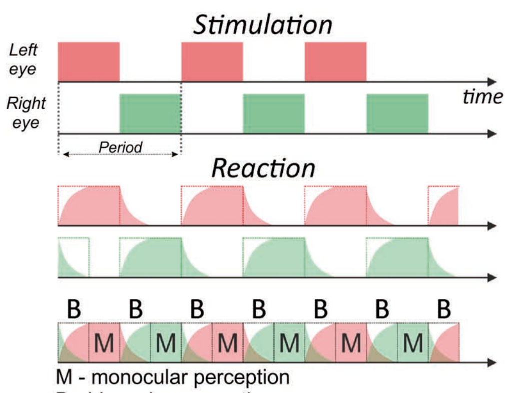
Group II:
34 subjects (10 to 15 years old) with abnormal refraction and impaired binocular functions. 12 subjects had residual microdeviation (squint angle less than 10 degrees) after surgical treatment of concomitant strabismus. 22 subjects have unstable accommodative squint angle.

All patients in both groups had a good visual acuity with the glasses or with the contact lens. In all children with normal binocular vision, the results of examination of stereo vision using the classical stereotests (Lang-test and Fly-test) were positive, and in all children with binocular disorders they were negative.

METHODS

The 20 different stereograms created by J Ninio [4] were used. The stereograms were displayed on monitor situated at the distance of 50 cm from the subject.

The right and left test images of each stereopair were presented on the screen in an alternating mode. The subject observed each stereopair for 2 min through red-green glasses and determined whether the image was flat or have some volume and, in the case of depth perception, which parts were perceived closer and farther than the background. The researcher could change the stimulus presentation frequency arbitrarily without interrupting the procedure. Each change in the frequency was accompanied by an automatic change in the sign of disparity and corresponding change in the volume perception (the closer than background parts became farther then background, and vice versa). This served to reduce guessing possibility in the answers of the subjects. Stereotests were presented in random order. The minimal and maximal (for strabismic patients) frequencies of alternating stimulus presentation at which the subject had the correct (corresponding to the sign of disparity) stereo perception were taken as the threshold frequencies (Fmin and Fmax).



M - monocular perception
B - binocular perception

Graphical explanation of phase haploscopy.
Eyes are stimulated alternatively, one after another, with frequency adjusted.
Frequency = 1/period.
Visual system reaction lasts a little longer than stimulation, forming a binocular perception phase.
Treatment practice shows, that for patient having binocular disorders and some kind of one eye suppression, flickering presentation helps to activate suppressed eye and form binocular perception.

RESULTS

All patients without binocular vision disorders (Group I) were able to perceive the stereo effects in all presented stereograms. They had no upper limit frequencies and were able to perceive depth with flickering and with static version of the same tests. Average minimal limits are presented in table.

Patients with strabismus on average required a higher Fmin than normal subjects and, unlike the normal subjects, had an upper limit of alternation frequency (Fmax), after which depth perception disrupted. Thus, for each strabismic patient, the values of Fmin and Fmax limited the frequency range in which he/she was competent for stereopsis.

The amazing fact of the occurrence of a stereo effect under conditions of alternating stimulus presentation in some patients with binocular disorders, absolutely incapable of stereopsis in tests with static stereograms, can be explained perhaps by the differences in the mechanisms of binocular competition during short-term and long-term stimulation [5].

It can be noted that, in both groups of subjects, the stereograms free of such characteristics as slope, curvature, complexness of form were perceived more easily. The widest ranges of frequencies in strabismic patients were found for simple stereoscopic images (for example, Set 1, a, b).

For stimuli containing slanted elements the ranges were smaller (for example, Set 1, c, d).

All patients experienced the greatest difficulties in perceiving random-dot stereograms, that seems quite natural. Even the patients with normal binocular vision required an alternating presentation frequency more 10 Hz to obtain a stable stereo effect. However, despite the complexity of the interpretation of such stereograms, appoximately 30% patients with binocular disorders achieved stereopsis with complex random-dot images, within a narrow range of relatively high alternation frequencies.

It is most likely that the visual system of the strabismic patients "could not cope" with the perception of stimuli presented at a high alternation frequencies that creates conditions similar to the static presentation of stereograms and beneficial for suppression.

Concerning the lower frequency limit, when the stimulus presentation frequency decreased lower than Fmin, for all subjects the time of storing accurate information about the complex structure of an image received from one eye was insufficient for comparison with the fresh information received from the other eye.

Examples of frequency ranges in different subjects

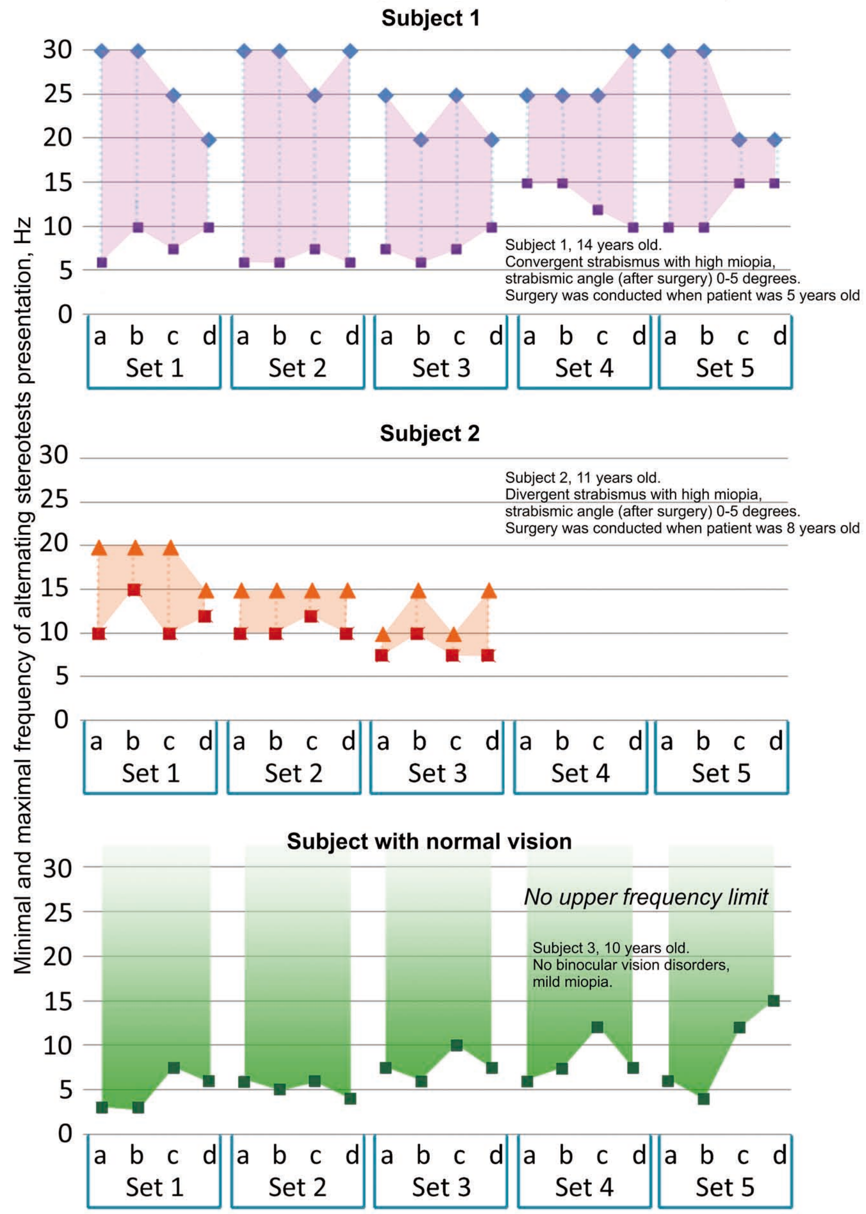


Table. Mean threshold frequency (*Fmin* and *Fmax*) of alternating stereotests presenting. Stereotests		**Children without binocular disorders (32 subjects)** *Fmin*, Hz (M±m)	**Children with binocular disorders (34 subjects)** *Fmin*, Hz (M±m)	*Fmax*, Hz (M±m)	Number of strabismic children capable of stereopsis at alternating stimulus presentation
Set 1	a	**3,4**±0,2	**7,6**±0,6	**33,6**±0,9	30
	b	**3,7**±0,2	**9,6**±1,1	**32,6**±1,9	30
	c	**4,7**±0,4	**9,9**±1,1	**23,3**±1,2	29
	d	**5,2**±0,4	**10,1**±1,1	**22,9**±0,9	29
Set 2	a	**4,7**±0,4	**8,6**±1,02	**32,3**±1,9	30
	b	**5,2**±0,5	**8,5**±1,01	**28,8**±1,9	29
	c	**5,4**±0,4	**9,2**±1,2	**28,6**±1,6	25
	d	**4,9**±0,4	**9**±0,9	**30,6**±1,6	30
Set 3	a	**7,6**±0,4	**11,5**±1,4	**26,4**±2,1	18
	b	**4,6**±0,3	**8,1**±0,7	**27,9**±1,6	27
	c	**7,3**±0,4	**11,6**±1,4	**29,6**±1,3	23
	d	**4,8**±0,3	**9,5**±1,2	**30**±1,6	25
Set 4	a	**9,1**±0,5	**16**±1,1	**25,2** ±2,1	22
	b	**9,9**±0,6	**16,3**±1,1	**27,7** ±1,6	26
	c	**6,7**±0,7	**17,4**±1,2	**23,9** ±1,7	22
	d	**9,6**±0,8	**15,3**±0,9	**24,1** ±1,7	24
Set 5	a	**6,5**±0,7	**27,1**±1,4	**29,5** ±1,4	28
	b	**5,9**±0,3	**25,4**±1,2	**28,1** ± 1,3	27
	c	**12,4**±1,1	**23,4**±1,5	**29,8** ±1,5	10
	d	**11,2**±0,9	**22,3**±1,5	**30,4** ± 1,5	10

CONCLUSION

The possibility of perception of certain stereograms at alternating stimulus presentation even by the patients with binocular disorders opens up the prospects for applying the approach described to studying the problems of stereopsis in ophthalmic practice.

We hope that our results can help to understand more clearly the hierarchy of difficulties in stereopsis depending on the characteristics of stereotests in the alternating mode of their presentation both in subjects without binocular disorders and in patients with impaired binocular functions.

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Supported by the Program III.3 of DNIT Russ Acad Sci, 2016.