BINOCULAR SUMMATION WITHIN THE BINOCULAR VISUAL FIELD

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Abstract

To study the influence of binocular summation on the threshold values of the central visual field in normal subjects, the authors modified the Octopus 201 by combining it with the space synoptophore. They tested ten normal subjects between 20 and 30 years of age. A space synoptophore was built into the cupola of the Octopus 201 so that the authors could confirm the conditions of binocular vision while they measured the visual sensitivity of the visual field under the binocular condition. Sensitivity of the visual field was thus measured while fusional patterns were displayed by the space synoptophore. Forty-seven points in the central visual field were tested with the SARGON program. The mean sensitivity in the central visual field was 30.4dB in the left eye, 30.3dB in the right eye, and 32.0dB in both eyes. The visual sensitivity under the binocular condition was higher than that under the monocular condition. The difference in the foveal sensitivity was 3.7dB between the monocular and binocular conditions. Binocular summation of the visual sensitivity in the binocular visual field was observed, and it was highest in the fovea. Combining the Octopus 201 with the space synoptophore was quite useful for the assessment of binocular summation.

Introduction

One of the important functions in the realization of binocularity is the binocular interaction within the binocular visual field. The increase in the amplitude of the visual-evoked potential by binocular stimulation is well known\(^1\)-\(^4\). However, there have been very few reports on the visual sensitivity of perimetry by binocular stimulation\(^5\),\(^6\). In order to examine the binocular interaction within the binocular visual field, it was necessary to confirm the condition of the binocular vision while the visual sensitivity was measured. To evaluate binocular summation, we modified the Octopus 201 by combining it with the space synoptophore and tested light sensitivity in normal subjects.

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Material and methods

The ten normal subjects were aged between 20 and 30 years. Their corrected vision was 20/20 or better, refraction was within 1.5 diopters of spherical error and 0.75 diopters of astigmatism, and the binocular function was 60 seconds of arc by the TNO stereo-test. None of the subjects had any systemic or ophthalmological diseases likely to affect visual function.

Visual sensitivity was measured with the Octopus 201 (Interzeag) and the space synoptophore (TOPCON) developed by Iwai. Two tubes of the synoptophore were removed, and half mirrors only were installed in the position of the reflection mirrors (Figs. 1 and 2). It was built into the cupola of the Octopus 201 in order to measure monocular and binocular sensitivities in the central visual field. Sensitivities of the central visual field under monocular and binocular conditions were measured, while the fusional patterns were displayed on the space synoptophore. The fusional patterns were a 3° square for both eyes, a 45° diagonal line for the left eye, and a 135° diagonal line for the right eye (Fig. 3).

Octopus perimetry was performed with a stimulus size 3, under the background luminance of 4 asb. The duration of target stimulus was 100 msec. Using the SARGON program, we designed a new program to test 47 points, 37 of which were located in the central 6° visual field and ten on the horizontal meridian subtending 8°, 10°, 12°,
Binocular summation within the binocular visual field

Fig. 2. Schematic drawing of the measuring device. A. The cupola of the Octopus 201; B. the space synoptophore; C. the half mirror.

Fig. 3. Fusional patterns displayed on the space synoptophore.
16°, and 20° (Fig. 4). We measured each double circle twice for the purpose of calculating the short-term fluctuation.

Each measurement was carried out twice, and the mean values were used to evaluate the visual sensitivities under monocular and binocular conditions. Statistical analysis was carried out using the Wilcoxon rank sum test.

Results

Visual sensitivity under monocular condition

Figure 5 shows the mean value of the visual sensitivities of ten normal subjects under monocular condition. The mean sensitivities of the 46 test points (except the blind spot) were 30.4dB in the left eye and 30.3dB in the right.

Under monocular condition, no difference was noted in the visual sensitivity of the left eye or of the right. In three of ten subjects, the dominant eye was the left one. In seven of ten subjects, the dominant eye was the right one. A difference in monocular visual sensitivity between the dominant eye and the non-dominant eye was not found in all subjects.

Visual sensitivity under binocular condition

Figure 5 also shows the mean values of visual sensitivity under binocular condition in ten normal subjects. The mean sensitivity of the 47 test points was 32.0dB in both eyes under binocular condition. The mean values of the short-term fluctuation were 1.3±0.3dB in the left eye, 1.3±0.3dB in the right eye, and 1.3±0.3dB in both eyes. The catch trials with the Octopus 201 were less than 15%.

Comparison between monocular and binocular conditions

We compared the visual sensitivity of either the left or right eye with that of both eyes. We found that visual sensitivity under binocular condition was higher than that under monocular condition in all ten subjects (Figs. 5 and 6).
Binocular summation within the binocular visual field

**Fig. 5.** The average sensitivity of each test point under monocular and binocular conditions.

<table>
<thead>
<tr>
<th>Monocular (left eye)</th>
<th>Monocular (right eye)</th>
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<tbody>
<tr>
<td>30.2 30.4 30.3 30.4 30.1</td>
<td>30.0 30.2 29.6 30.1 29.4</td>
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<tr>
<td>30.0 30.5 30.8 30.7 30.6</td>
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<tr>
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<td>28.8 29.8 30.6 31.3 30.9 30.8 31.2 31.2 36.0 31.4 30.7 30.8 36.2 29.6 29.3 0 28.6</td>
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<tr>
<td>29.8 30.5 30.6 30.6 31.1</td>
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<td>30.3 30.3 30.0 30.2 30.2</td>
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<td>29.5 29.6 29.4 29.8 29.6</td>
<td>29.3 29.3 29.6 30.3 29.7</td>
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**Binocular**

| 31.9 31.8 31.3 31.6 31.5 |
| 31.8 31.9 32.4 32.4 |
| 32.1 32.5 32.8 32.3 |
| 30.3 30.6 31.3 32.1 32.4 32.8 33.0 30.7 33.0 31.1 32.4 32.6 32.0 31.4 29.8 30.2 |
| 31.9 31.8 31.8 32.3 32.0 |
| 31.7 31.9 31.9 32.0 32.6 |
| 31.5 31.0 31.4 31.3 31.3 | (dB) |
These results show that there exists binocular summation of the visual sensitivity in the binocular visual field. There was a statistical difference between the values of monocular and binocular conditions (Wilcoxon rank sum test, \( p < 0.05 \)).

There was an increase in sensitivity in the central 6° visual field under binocular condition. The amount of increase in sensitivity for left and right eyes was 1.7dB and 1.8dB, respectively. The difference between sensitivity in the fovea under binocular condition and that in the left or right eyes was 3.7dB and 3.7dB, respectively (Fig. 7). The increase in sensitivity in the fovea was higher than that in the area outside the fovea in the central 6° visual field (Wilcoxon rank sum test, \( p < 0.05 \)). These results show that the degree of binocular summation was highest in the fovea.

**Discussion**

In our study, visual sensitivity under binocular condition was higher than that under monocular condition. Our results indicated that binocular summation was obtained by projecting the same stimulus onto the responding retinal points on the two retinas.

It was reported that visual-evoked potential recorded under binocular condition showed greater amplitude than under monocular condition\(^{1-4}\). Hater defined this phenomenon as binocular summation\(^8\). Visual sensitivity was found to increase under binocular condition using our device. We detected binocular summation by binocular interaction within the binocular visual field.

Our results also indicated that binocular summation was highest in the fovea.
Binocular summation within the binocular visual field

The foveal area of 1° visual angle overlaps in the temporal-nasal retina. The information from this area is projected onto each side of the visual cortex, and it is important for stereopsis to occur\(^9,10\). It was reported that reduction of the retinal disparity sensitivity by increasing retinal eccentricity was confirmed by visual evoked-potential measurement\(^11\). The foveal area has different anatomical and physiological features compared with other retinal areas. Therefore, we suggest that binocular interaction in the fovea plays an important role in the realization of binocularity.

In our study, we recorded binocular summation of the visual sensitivity using stimulus size 3. We propose that it is necessary to investigate a suitable stimulus size for binocular summation in each retinal area, especially in the fovea. Thus, we concluded that combining the Octopus 201 with the space synoptophore was quite useful for the assessment of binocular summation. On the basis of all these results, we are planning to examine the binocular summation of the visual sensitivity of each eye in amblyopic and strabismus patients.

References


Fig. 7. Difference in the average sensitivity between monocular and binocular conditions of the central 6° visual field.

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<th>Binocular – Right eye</th>
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