INTEROCULAR DIFFERENCES IN THE VERTICAL-HORIZONTAL ILLUSION

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PROBLEM

The monocular visual field is phenomenogically and retinally different from the binocular. The phenomenological shape of both fields is roughly elliptical or oval and extends in the horizontal direction. The horizontal axis of the binocular field is assumed to be greater than that of the monocular.

When a point directly in front of an observer is fixated, the binocular field of vision can be divided into two equal parts by the vertical meridian. The corresponding parts of the monocular fields are, however, not equal. The nasal portions are considerably smaller than the temporal parts (Figure 1).

Thus, in monocular vision with the left eye, as well as with the right, a fixation point is nearer to the nasal boundary than to the temporal; whereas, in binocular vision, it is equidistant from both lateral bound-

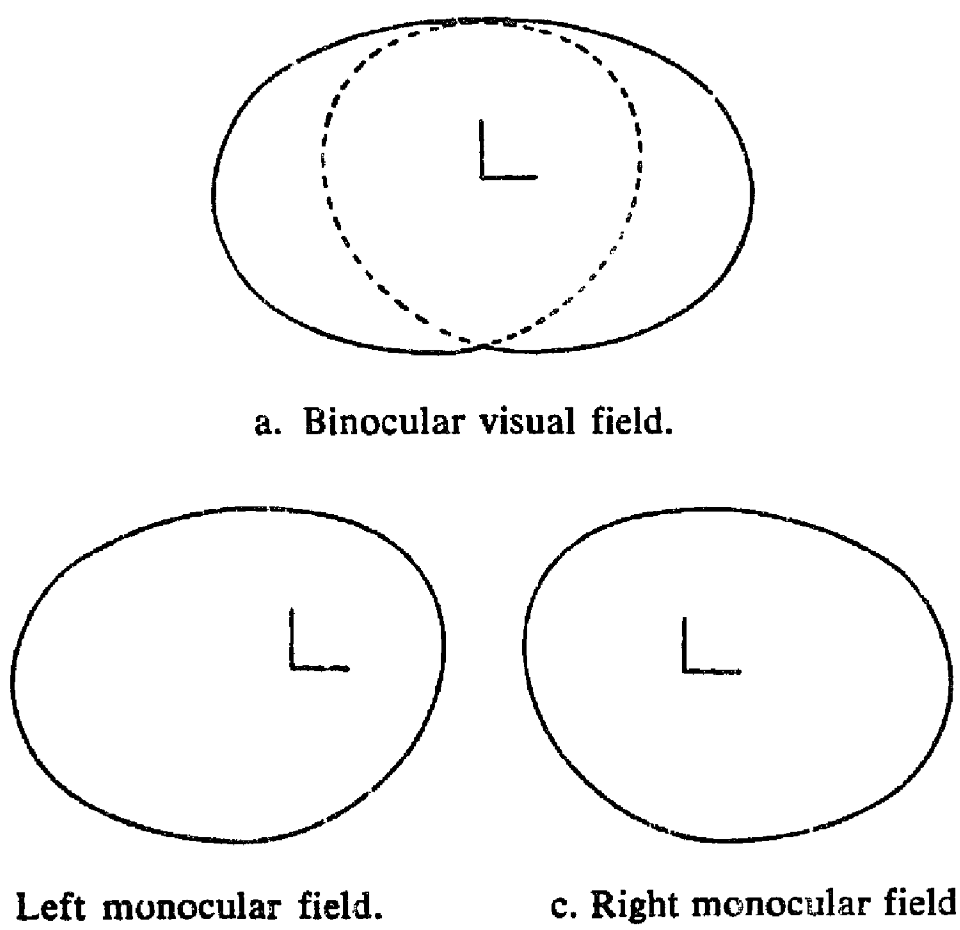

Figure 1. The right-figure in the binocular, and in the left and right monocular fields (cf. 1, p. 102).

aries. When the horizontal line of an L-shaped figure extends to the right of the vertical line and is seen by the left eye it is nearer to the nasal boundary and its relative distance – the relation of the distance of the horizontal line from the boundary to the whole distance of the fixation point from the same boundary – is smaller. When the same figure is seen by the right eye, however, the horizontal line is further from the boundary and its relative distance greater. The reverse is true when the horizontal line is to the left of the vertical. In binocular vision there is no difference between the two. The vertical aspect of the fixation point is identical for both eyes and can be assumed to be the same for binocular vision.

The above mentioned asymmetry of the monocular visual field makes it possible partially to test our hypothesis (2, 3, 4) concerning the overestimation of the vertical line (OV). According to this hypothesis, the subjective length of a line is determined by the relative distance from the line to the boundary of the visual field. It is to be expected that different distances of the equal horizontal lines in the nasal and temporal parts of the monocular visual fields would influence the apparent length of the vertical line, producing different OVs. A similar effect is to be expected from the differences between the shape of the binocular and monocular visual fields.

The purpose of the present study is to provide a partial test of our general hypothesis by investigating in what way differences between the temporal and nasal parts of the monocular visual fields, and the differences between the monocular and binocular fields, influence the OV.

On the basis of our general hypothesis, six testable predictions can be made (cf. Figure 1).

(1) When a vertical-horizontal figure is seen by the left eye, extension of the horizontal line to the left produces a larger OV than when it is extended to the right.

(2) In the case of the right eye, extension of the horizontal line to the right produces a larger OV than when it is extended to the left.

(3) The nasal parts of the monocular visual fields have the same OV.

(4) The temporal parts also have equal OVs.

(5) In binocular vision, extension of the horizontal line to the left or to the right produces no difference.

(6) The OV is larger in binocular than in monocular vision.

METHOD

Apparatus.

A vertical-horizontal figure is exposed in the centre of a rectangular white surface, 72×160 cm. Through a slit 0.5 mm wide, a constant horizontal line of 50 mm can be exposed to the left or to the right of a vertical line. The first figure is called the left and the second the right-figure. The length of the vertical line can be adjusted by the observer. Details are given in a previous paper (3).

Procedure.

The observer sat in front of the apparatus in a fixed position, his head held steady by a chin rest. The distance from O's eyes to the stimulus pattern was 400 mm. The vertical-horizontal pattern was at eye level so that the point where the horizontal and the vertical lines intersect was exactly between O's eyes. In the case of monocular observation, one eye was covered with patch, and Os were told to keep the covered eye open in order to avoid narrowing of the palpebral fissure of the eye in use.

The method of adjustment was employed. O had to compare the length of the exposed vertical and horizontal lines and adjust the length of the vertical line so that it appeared equal to the horizontal line. During the adjustment, O was told to fixate the centre of the pattern where the vertical and the horizontal lines intersected, but a glance along the lines was allowed. The O saw the stimulus figure only while he was adjusting the variable vertical line. After each adjustment, the stimulus pattern was switched off and rearranged by the experimentor before the next exposure.

Experimental conditions.

There were six conditions. (1) The left eye and the left-figure. (2) The left eye and the right-figure. (3) The right eye and the left-figure. (4) The right eye and the right-figure. (5) Both eyes and the left-figure, and (6) Both eyes and the right-figure. In all conditions the fixation point was the same, and the head was held in the same position.

Conditions 1 and 2 were designed to test prediction 1; conditions 3 and 4 prediction 2; condition 2 compared to 3 tested prediction 3; condition 1 compared to 4, prediction 4; and conditions 5 and 6 prediction 5. The comparison of results for conditions 1, 2, 3 and 4 with those for 5 and 6 could be used to examine prediction 6.

Observations were made on two days. On the first day Os worked with the right-figure, and on the second day with the left-figure, or vice

Table 1 Length of the Line Appearing Equal to the Horizontal Line of 50 mm and the OV (in mm) When Seen by the Left, Right and Both Eyes.

Eye	Figure	Length		OV	
		mm	SD	mm	Percent
Left	Left	47.66	1.39	2.34	4.7
	Right	48.55	1.38	1.45	2.9
Right	Left	48.45	1.50	1.55	3.1
	Right	47.38	1.36	2.62	5.2
Both	Left	48.19	1.36	1.81	3.6
	Right	47.80	1.27	2.20	4.4

versa. The sequence of conditions was rotated to equate possible learning and fatigue effects. Os were made familiar with the experimental situation in preliminary trials.

Observers.

Twenty one university psychology students, twelve men and nine women, took part in the experiments. All Os had normal visual acuity. In eight cases, however, sight was corrected by spectacles. Two Os (7 and 17) had weak astigmatism. Eleven Os began with the right-figure, and ten with the left-figure. Each O made 32 adjustments in each of the six conditions: 16 ascending and 16 descending. Thus, each O made 192 adjustments and the group made a total of 4032 adjustments.

RESULTS AND DISCUSSION

The results of the group are shown in Table 1. The vertical line was always overestimated, but not to the same extent in all conditions. In the case of the left eye, OV was greater for the left-figure, and prediction 1 confirmed.

The difference between the mentioned OVs of the left and right figures, seen by the left eye, may be explained as follows. The subjective length of a vertical line as compared to a horizontal line depends on two factors: the vertical direction and the subjective length of the horizontal line. The vertical direction is the same in both cases, but not the apparent length of the horizontal line. For the left eye the distance (relative and absolute) from the horizontal line of the right-figure to the nasal boundary is shorter than that from the left-figure to the temporal boundary. It is, therefore, to be expected that the subjective length of the former horizontal

Table 2. Length of the Vertical Line Appearing Equal to the Horizontal Line of 50 mm and the OV (in mm) in the Nasal and Temporal Parts of the Monocular Visual Fields.

Part	Eye	Figure	Length mm	Length SD	OV mm	OV Percent
Nasal	Right	Left	48.45	1.50	1.55	3.1
	Left	Right	48.55	1.38	1.45	2.9
	Mean		48.50	1.44	1.50	3.0
Temporal	Left	Left	47.66	1.39	2.34	4.7
	Right	Right	47.38	1.36	2.62	5.2
	Mean		47.52	1.38	2.48	5.0

line is greater than that of the latter (3, 4). So the vertical line will appear longer, and will therefore be overestimated less than in the left-figure.

For the right eye one may expect, for the same reasons, that OV will be larger for the right-figure. The results from conditions 3 and 4 (Table 1, rigth eye) confirm this prediction (pred. 2).

In binocular vision the horizontal lines of both figures are equidistant from the corresponding left and right boundaries of the visual field and, therefore, should be overestimated equally. Comparison of conditions 5 and 6 in Table 1 (both eyes) shows that there was only a slight difference between OVs for the figures.

The nasal portions of both monocular visual fields are compared in Table 2. The results for the left eye are similar to those for the right, as was to be expected (pred. 3) because of the distance from the horizontal line to the nasal boundary, which was the same in both cases. The temporal cases gave similar results (pred. 4). The mean for the temporal parts, however, differs considerably from the mean for the nasal parts.

Comparing the results for the binocular conditions with those for the monocular, one may expect OV to be larger in the former. Table 3, how-

Table 3 Comparison of Binocular and Monocular Observations.

Observation	OV mm	OV Percent
Binocular	2.00	4.0
Left Monocular	1.89	3.8
Right Monocular	2.08	4.2
Nasal Monocular	1.50	3.0
Temporal Monocular	2.48	5.0

Table 4. Size (in mm) and Significance of the Differences.
df = 20

Difference between OV of	Size	t	P
Left- and Right-Figure of the Left Eye	.89	2.23	=.05
Left- and Right-Figure of the Right Eye	1.07	3.57	<.01
Nasal Parts of the Monocular	.10	.20	>.05
Temporal Parts of the Monocular	.28	1.17	>.05
Left- and Right-Figure of the Binocular	.39	1.44	>.05
Left-Figures of the Left and Right Eye	.79	3.39	=.01
Right-Figures of the Left and Right Eye	1.17	3.77	<.01
Binocular and Nasal Monocular	.50	2.78	<.05
Binocular and Temporal Monocular	.48	3.00	=.01
Binocular and Left Eye	.11	.58	>.05
Binocular and Right Eye	.08	.42	>.05
Nasal and Temporal Parts of the Monocular	.98	6.13	<.001

ever, shows that there is no difference when binocular results are compared to the mean for the left or right eye. Comparing the binocular results with the means for the nasal and temporal monocular observations, the OV for binocular vision exceeds only the nasal results.

The disagreement between this finding and prediction 6 may be partially explained by two facts. (1) There is a phenomenological difference between binocular and monocular vision which does not affect the comparison of the two monocular fields. In binocular vision, the stimulus figure seems to be clearer and slightly larger than when it is seen monocularly. (2) The binocular field, strictly speaking, is only the central part of the total visual field, where the two monocular fields overlap (Figure 1). To the right and left of this area the binocular field is actually the same as the lateral parts of the monocular fields. Thus, the binocular visual field is, in this respect, compressed horizontally, and this may reduce its OV.

The significance of the differences is shown in Table 4. The differences between the two figures are significant for monocular, but not for binocular vision. Binocular vision does not differ from monocular vision except when it is compared to the nasal and temporal portions of the monocular cases. The difference between the nasal and temporal monocular observations is significant, but not the differences between both monocular nasal, and between both monocular temporal cases.

We may conclude that five of the predictions have proved to be correct. The sixth prediction was not confirmed.

SUMMARY

A further attempt was made to test our general hypothesis that overestimation of the vertical direction is primarily due to the oval form of our visual field with its longer horizontal axis.

Keeping head position and fixation point constant, the left and right-figures were viewed monocularly and binocularly.

The principal findings were as follows:

(1) With monocular vision the overestimination of the vertical line (OV) was different for both figures: when seen by the left eye, the left-figure had the larger OV; when seen by the right eye, the right-figure had the larger OV. With binocular vision, however, there was no significant difference between the figures.

(2) The nasal portions of the monocular visual fields had the same OV; the OV of the temporal parts were also equal; but the OV of the temporal parts was significantly larger than that of the nasals.

(3) OV of binocular vision was greater than that for nasal monocular but less than that for temporal monocular.

Six testable predictions were deduced from the hypothesis. Five of these were confirmed by the experimental results and the one discrepancy is discussed and tentatively explained.

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