The effect of variation of frame shape on the angular function of the rod-and-frame illusion*

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The angular function of the rod-and-frame illusion was studied under conditions of variation in frame shape. The results support predictions arising from the hypothesis that as a frame is varied in tilt, vertical settings of a rod will be in error in the direction of the major frame axis closest to true vertical.

In an earlier study (Beh, Wenderoth, & Purcell, 1971), it was demonstrated that as a square outline frame was tilted from 0 to 90 deg in 15-deg steps, settings of an enclosed rod to the visual vertical were in the direction of the major frame axis nearest to gravitational vertical. A major frame axis is defined as any line which may be drawn such that it passes through the center point of a frame and divides it into two symmetrical parts, one part being the mirror image of the other. This definition may be more clearly understood by reference to Fig. 1. Although a square may be divided by any number of lines passing through the center point, the two segments thus formed may not be mirror images. For this reason, Axis 1 in Fig. 1 would not be regarded as a major frame axis, whereas Axis 2 in the same figure would.

While the results of the study by Beh et al (1971) were consistent with the major frame axis hypothesis, the present study was considered to provide a more rigorous test of this hypothesis by varying frame *shape*. Since variation in frame shape results in variation of the positioning of the major frame axes at various degrees of frame tilt, it follows that predictable variations in the angular function of the rod-and-frame illusion should result as the shape of the outline figure is varied.

In the present experiment, the frames used were a rectangle, a hexagon, and an equilateral triangle (Fig. 2). The selected shapes varied both in the number of major axes and in the *direction of tilt* of the axis nearest to gravitational vertical at various degrees of clockwise frame tilt. Figure 3 shows how the direction of tilt of the major axes nearest to true vertical varies when the triangular frame is tilted clockwise from 0 to 45 deg.

For each of the frames, the direction of the nearest major axis from true vertical (DNA) was calculated for clockwise frame tilts varying in 15-deg steps between 0 and 90 deg. The results of these calculations are shown in Table 1, together with the predicted direction of error (PDE) of rod settings to vertical for each angle of frame tilt.

Since the choice of 15-deg steps led to the prediction of no error in rod settings with the hexagonal frame, it was decided to use finer (5-deg) steps in the hexagonal frame condition. The results of calculations for 5-deg steps from 0 to 45 deg clockwise tilt for this frame shape are also included in Table 1.

METHOD

Subjects

Forty-two students (18 males and 24 females) from an introductory course in psychology acted as Ss. Ss who normally wore corrective lenses were asked to wear them during the experiment.

Experimental Design

Each S made four judgments of the vertical under each angle of frame tilt studied. The judgments were from four different starting positions: ±10 and ±20 deg. Independent groups of Ss were used for each frame shape studied. Ss in the rectangular and triangular frame conditions made judgments at seven angles of clockwise frame tilt—0, 15, 30, 45, 60, 75, and 90 deg—while Ss in the hexagonal frame condition made judgments at 10 angles of clockwise frame tilt—0, 5, 10, 15, 20, 25, 30, 35, 40, and 45 deg.

Each S in each condition made the judgments in a different random order.

Apparatus

The apparatus used in this study was essentially the same as that described elsewhere (Beh et al, 1971), the only difference being that frames of the following shape and dimensions were used under the various conditions in place of the square outline frame:

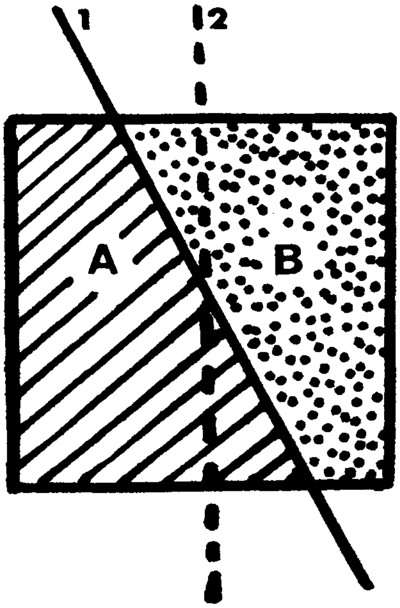

Figure 1

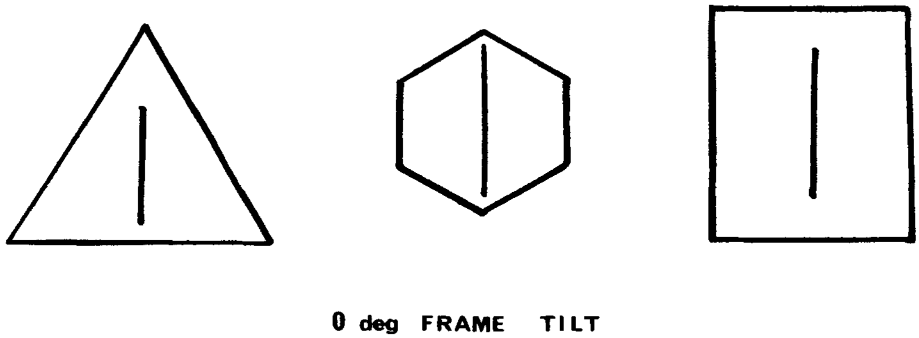

Fig. 2. Diagram showing vertical orientation of frame shapes.

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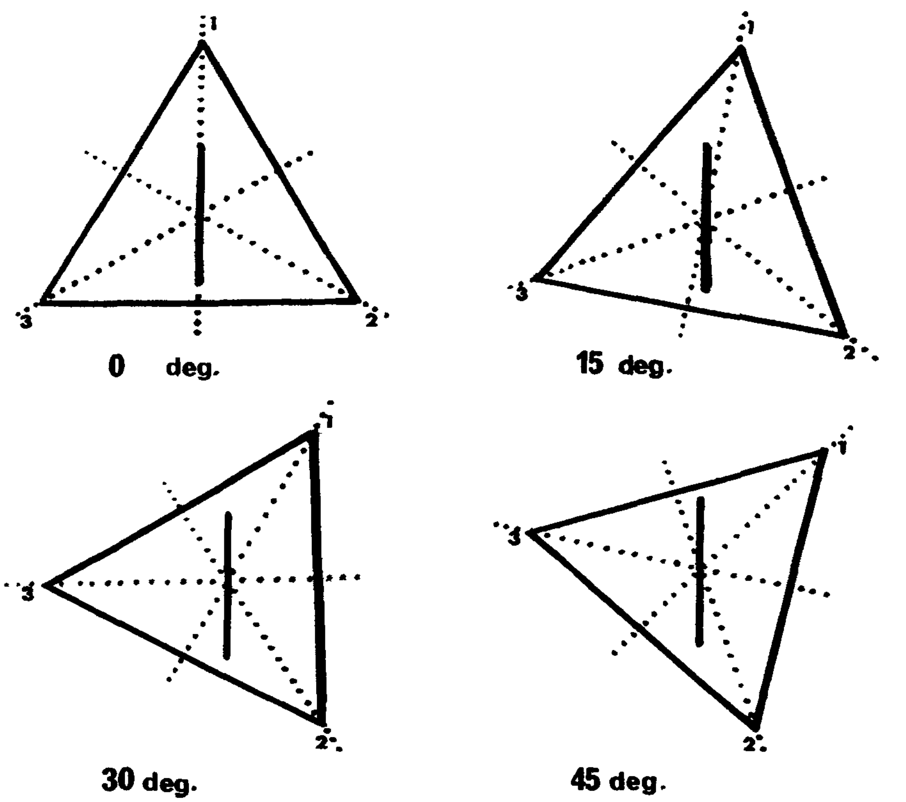

Fig. 3. Orientation of frame axes relative to true vertical, as frame tilt varies from 0 (vertical) to 45 deg clockwise.

(1) a rectangular frame, 8 in. wide, 10 in. high; (2) a triangular frame, 11¼ in. along a side; (3) a hexagonal frame, 4 in. along a side.

Each frame outline was made by placing black insulating tape on a white background, and the above measurements were taken on the inside edges of the respective frames.

Procedure

Upon entering the laboratory, S was seated behind a monocular viewing screen and given the instructions (see Beh et al, 1971). The adjustment method without bracketing was used, with E adjusting the rod until S reported the rod as being truly vertical. S was permitted free inspection of the rod while making a judgment.

Rest periods of 30 sec were given between judgments. Additional rest periods of 2 min were given at the end of each block of 7 trials in the rectangular and triangular frame conditions and at the end of each block of 10 trials in the hexagonal frame condition. S was not permitted to view the apparatus except while making a judgment.

Results

Mean departures of rod settings from true vertical were calculated for each angle of frame tilt for each of the three frames used (Fig. 4).

For each of the frame shapes studied, the departures of rod settings from true vertical as a function of frame tilt were consistent with the predictions set out in the introduction (Table 2). Two-tailed t tests were performed on all means whose values were predicted to be zero, while one-tailed tests were carried out on the means which were predicted to be either positive or negative. Each mean was tested against its own standard error, rather than against a pooled estimate, in order to preserve the independence of the tests. The results of the tests, given in Table 2, may be summarized as follows: all means predicted to be zero were not significantly different from zero, all mean errors predicted to be either positive or negative were in the predicted direction, and of the 14 means not predicted to be zero, 8 were significantly different from zero, with $\alpha = 0.05$.

Table 1
Table Showing Direction of Nearest Major Frame Axis Relative to True Vertical (DNA) and Predicted Direction of Error (PDE) in Rod Settings for Clockwise Frame Tilt

Frame Tilt (Deg)	Rectangle DNA	Rectangle PDE	Triangle DNA	Triangle PDE	Hexagon DNA	Hexagon PDE	Frame Tilt (Deg)	Hexagon DNA	Hexagon PDE
0	V	0	V	0	V	0	0	V	0
15	CW	+	CW	+	=	0	5	CW	+
30	CCW	—	=	0	V	0	10	CW	+
45	CW	+	CCW	—	=	0	15	=	0
60	CW	+	V	0	V	0	20	CCW	—
75	CCW	—	CW	+	=	0	25	CCW	—
90	V	0	=	0	V	0	30	V	0
							35	CW	+
							40	CW	+
							45	=	0

V—major frame axis corresponds to true vertical; =—two nearest major axes equidistant from true vertical.

DISCUSSION

The present experiment provides further support for the nearest-axis account of the angular function of the rod-and-frame illusion. While the results reported in this paper emphasize the influence of frame axes on settings to the visual vertical, this is not to deny that there may be other determinants of such settings. For example, in rod settings to the vertical with a triangular frame, judgments may be partially biased by the direction of tilt of the side of the triangle closest to true vertical. This possible source of bias may explain, for example, the nonsignificant effect of 75-deg frame tilt. At this angle of tilt, the frame axis closest to true vertical is tilted in a clockwise direction, but the side of the triangle closest to true vertical is tilted in an anticlockwise direction. It could be the case that while the influence of the axis of symmetry is dominant, influence of the side of the triangle is partly counterbalancing the axis effect.

Other factors which might cause some variation from the function predicted by the axis hypothesis are the relative height of the corners of the frame in the visual field and the size of the rod relative to the size of the frame. This latter factor could possibly explain why the magnitude of the effects with a triangular frame are smaller than for a square, rectangular, or hexagonal frame. The further the contours of the frame are from the

Table 2
PDEs, Obtained Mean Settings, Variance Estimates, and t Test Results for Each Frame Shape at Each Angle of Tilt (R = Reject H_0, A = Accept H_0)

	Frame Tilt (Deg)									
Rectangle (N = 20)	0	15	30	45	60	75	90			
PDE	0	+	—	+	+	—	0			
Mean Setting (Deg)	−0.01	+1.44	−0.63	+0.27	+0.11	−1.56	+0.04			
Variance Estimates	0.22	2.92	1.92	1.59	1.16	3.00	0.39			
$t_{.95}$	−0.09	+3.77	−2.03	+0.96	+0.46	−4.00	+0.29			
Decision	A	R	R	A	A	R	A			
Triangle (N = 12)	0	15	30	45	60	75	90			
PDE	0	+	0	—	0	+	0			
Mean Setting (Deg)	0.00	+0.48	−0.01	−0.62	−0.09	+0.16	+0.03			
Variance Estimates	0.43	0.66	0.56	0.72	0.52	0.40	0.52			
$t_{.95}$	0.00	+2.04	−0.05	−2.53	−0.43	+0.87	+0.15			
Decision	A	R	A	R	A	A	A			
Hexagon (N = 10)	0	5	10	15	20	25	30	35	40	45
PDE	0	+	+	0	—	—	0	+	+	0
Mean Setting (Deg)	+0.10	+1.29	+0.59	+0.13	−0.45	−0.60	+0.10	+0.88	+0.60	+0.01
Variance Estimates	0.13	1.24	2.88	2.19	1.43	1.04	0.92	1.51	2.35	0.98
$t_{.95}$	+0.88	+3.66	+1.10	+0.28	−1.19	−1.86	+0.33	+2.27	+1.24	+0.03
Decision	A	R	A	A	A	R	A	R	A	A

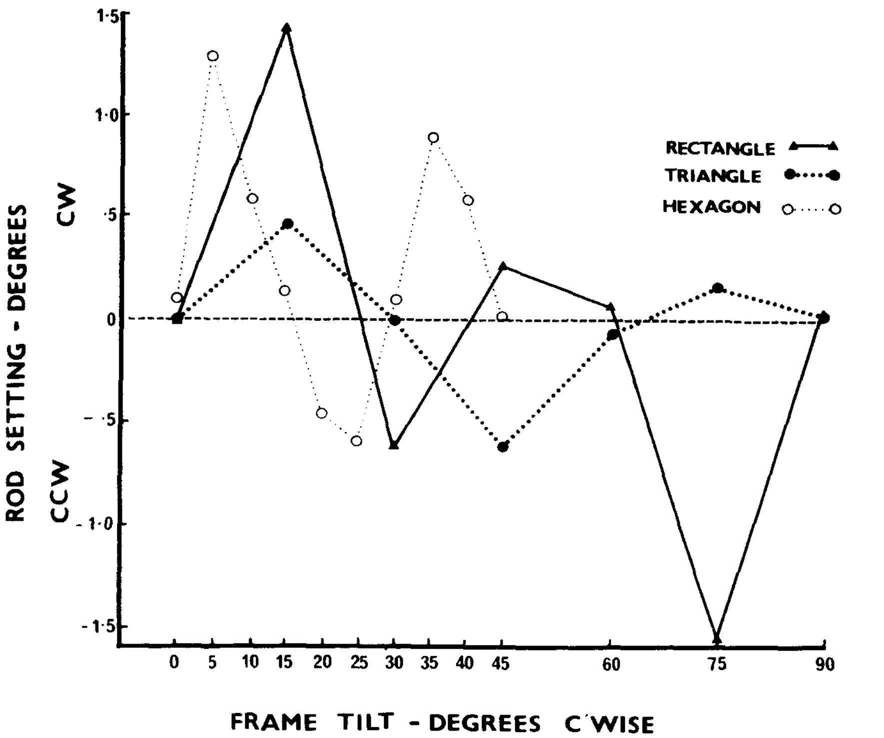

Fig. 4. Mean error in setting rod to vertical for each frame shape as a function of clockwise tilt.

rod, the easier it may be for the S to ignore the frame and its properties, thus reducing the magnitude of rod-and-frame illusion.

There are, in fact, a number of possible explanations of the differences in magnitude of the obtained effects, both within and between frame shapes. It is likely that the *obtained* maxima and minima of all functions are not the *true* extremes, since the treatment values chosen are arbitrary and, in most cases, widely spaced (15 deg). Until the functions have been measured under conditions of finer steps of frame tilt, comparison of the size effects both within and between frames is unwarranted.

Since the aim of the present study has been to test predictions concerning the *direction* of rod settings as a function of frame shape and tilt, no attempt has been made to isolate the determinants of the magnitude of error. Further research is necessary to clarify the nature of such variables and their relative contributions to magnitude effects.

REFERENCE

BEH, H. C., WENDEROTH, P. M., & PURCELL, A. T. The angular function of a rod-and-frame illusion. Perception & Psychophysics, 1971, 9, 353-355.

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