The angular function of a rod-and-frame illusion

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It was predicted that vertical settings of a rod surrounded by a square frame would be in error in the direction of the frame axis closest to true vertical as the frame varied in tilt. Results were in accord with this hypothesis. The implications of the results are discussed.

Settings of a rod to the judged vertical have been shown to vary with the optical tilt of the rod's visual environment. Three broad classes of tilted environment have been used in experiments of this nature: tilted fields, tilted frames, and tilted fields with tilted frames.

Visual field tilt occurs when the borders of the inducing field remain constant as field tilt varies. For example, Gibson (1937) studied the effect of a field of tilted parallel lines on vertical settings, but the edges of the field were occluded by a circular tube so that the frame of the field remained invariant.

Visual frame tilt occurs when the visual background consists solely of a tilted outline frame whose borders vary in orientation as the frame tilts around a central pivot. Thus, Witkin and Asch (1948a, b) studied the effect of a tilted luminous square frame on vertical settings of an enclosed rod.

Finally, a tilted field with a tilted frame occurs when a tilted frame is not simply an empty contour but contains an array of contours. For example, Asch and Witkin (1948) had Ss judge the tilt of a rod viewed against a tilted model room, when both the edges of the room and its contents were visible.

The purpose of this experiment was to measure the angular function of the tilted frame illusion. Vertical settings of a rod were measured as a square outline frame surrounding the rod varied in tilt from vertical (0 deg) to horizontal (90 deg).

Gibson (1937) and Logan (1962) measured the angular function of the tilted field illusion. Both found that vertical settings of a rod were in the direction of field tilt for field tilts from 0 to 45 deg, with the maximum effect between 10 deg (Gibson) and 30 deg (Logan). Logan measured the angular function between 45 and 90 deg and found that the illusion was consistently in the reverse direction to that obtained between 0 and 45 deg, with a maximum effect at 75 deg.

The prediction of this experiment was that the tilted frame illusion would have a more complex angular function than that obtained with the tilted field. The basis for the predicted function is shown in Fig. 1.

A square frame (Fig. 1A) has four major axes: the vertical and horizontal axes (1 and 2, respectively) and two diagonal axes (3 and 4). It was predicted that an illusion would occur as a result of a judgmental bias toward the axis nearest to gravitational vertical. Fig. 1, A to F, shows the changes in axis orientation as the frame tilts clockwise from 0-deg tilt to 75-deg tilt. At 15-deg tilt (Fig. 1B), the vertical axis (1) is closer to the gravitational vertical than the diagonal axis (3). Hence, settings will be in the direction of Axis 1 (clockwise). At 30-deg tilt (Fig. 1C), the diagonal axis (3) is closer to the vertical than is Axis 1; settings will therefore be in the anticlockwise direction. At 45 deg (Fig. 1D), the figure is symmetrical: the diagonal (3) is at the gravitational vertical, and Axes 1 and 2 are equidistant from it. Thus, no illusion should occur at 45-deg tilt. Beyond 45-deg frame tilt, similar predictions apply. The illusion will initially be in the clockwise direction as Diagonal 3 is displaced clockwise from the true vertical at 60 deg (Fig. 1E), but settings will then reverse direction once again when Axis 2 is closer to the true vertical than the diagonal (3) at 75-deg frame tilt (Fig. 1F).

METHOD

Subjects

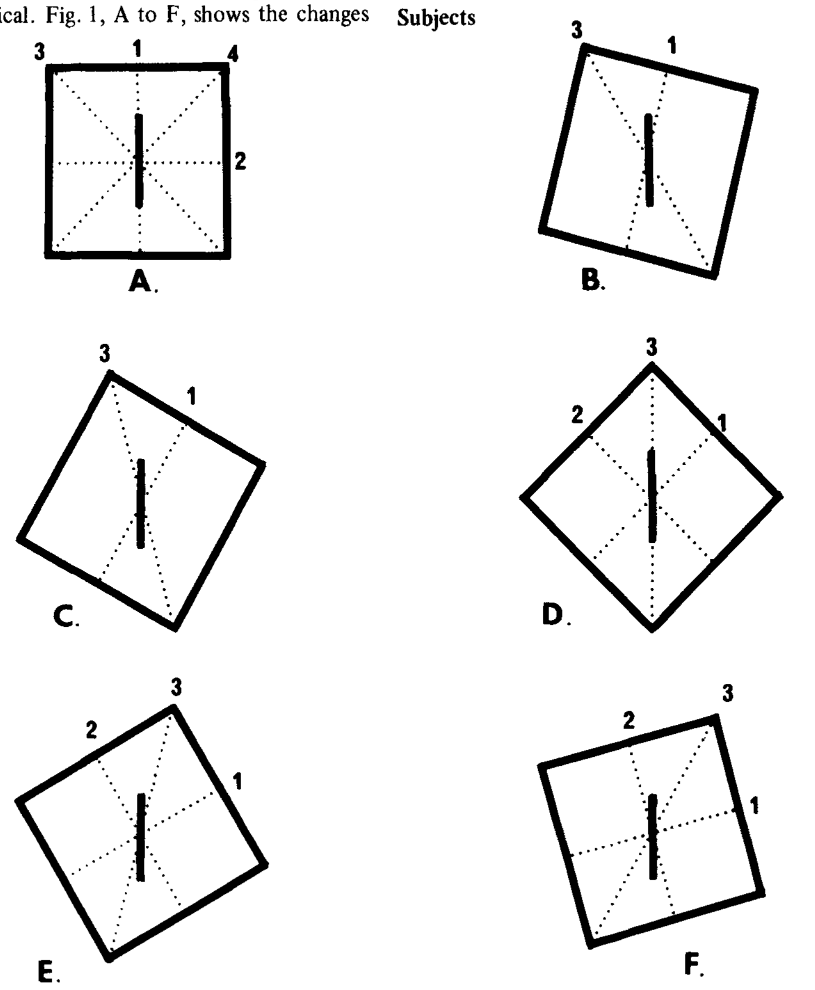

Fig. 1. Orientations of frame axes relative to vertical as frame tilt varies. Frame orientations are: 0 deg (A), 15 deg (B), 30 deg (C), 45 deg (D), 60 deg (E), and 75 deg (F). Frame axes are: vertical (1), horizontal (2), and diagonal (3 and 4).

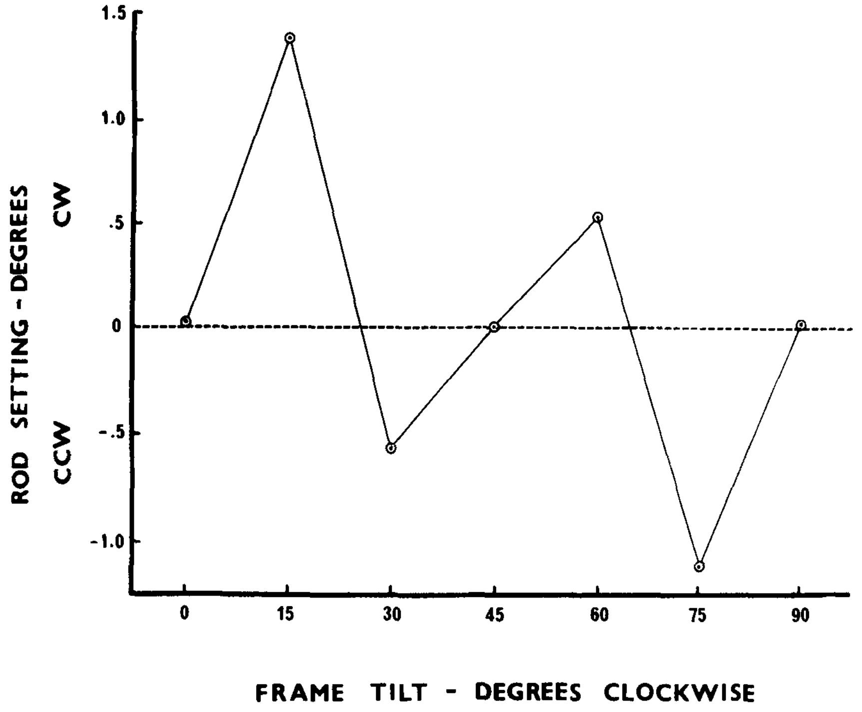

Fig. 2. Vertical settings as a function of clockwise (+) frame tilt.

Twenty students from an introductory course in psychology acted as Ss (4 males and 16 females). Any S who normally wore corretive lenses was asked to wear them during the experiment.

Experimental Design

Each S made four judgments of the vertical under each of seven conditions of clockwise (+) frame tilt: 0, 15, 30, 45, 60, 75 and 90 deg. The four judgments at each angle of frame tilt were from different starting positions (SPs): ±10 deg and ±20 deg. Each S made the 28 judgments in a different random order.

Apparatus

A movable black rod, 6¼ in. long, ¼ in. wide, and 1/16 in. thick, was centrally and coaxially pivoted with a movable black frame. The frame, made of black insulating tape 5/8 in. wide, measured 8 in. on a side between its outside edges and was mounted on a 33-in.-diam white aluminum disk. The rod and frame could be independently rotated through 360 deg in the frontal plane, and the tilt of each could be read to the nearest 0.5 deg from protractors mounted at the rear of the apparatus. The rod was driven by a synchronous motor at 2 deg per second and could be moved in a clockwise or anticlockwise direction by the E by means of one of two buttons at the rear of the apparatus. Frame tilt was changed manually by E.

A circular monocular viewing tube (inside diameter: 1-3/8 in.) was set in a Masonite occluding screen at a distance of 5 ft from the rod-and-frame apparatus. The angle subtended at S's eye by the visible area of the rod-and-frame apparatus was 18 deg, considerably less than the angle subtended by the white disk on which the frame was mounted.

Overhead fluorescent lighting illuminated the apparatus throughout the experiment.

Procedure

The adjustment method without bracketing was used, and S was permitted free inspection of the rod while making a judgment. Instructions to S were as follows: "On each trial you will see a black rod surrounded by a black frame. The rod and the frame can be tilted independently. On each trial when you first look at the rod it will be tilted from the vertical and I will move it slowly toward the vertical from this position. I want you to call 'stop' when the rod is *truly* vertical. You'll have to keep your attention on the task each time you are asked to make a judgment because I am not able to bring the rod back if you let it go past the point where it is vertical."

Rest periods of 30 sec were given between judgments within a block of seven trials. Additional rest periods of 2 min were given at the end of each block. S was not permitted to view the apparatus except when a judgment was being made.

RESULTS

The obtained function relating direction of departures of rod settings from the true vertical to frame tilt was consistent with the predictions of the hypothesis outlined in the introduction (Fig. 2). Two-tailed t tests were performed on the means whose predicted values were zero (those at 0-, 45-, and 90-deg frame tilt), while one-tailed tests were carried out on the remaining means which were predicted to be either positive (those at 15 and 60 deg) or negative (those at 30 and 75 deg).

Since the variance estimates (Table 1) were clearly correlated with the means, each mean was tested using the variance associated with it rather than with a pooled variance estimate. The results of the tests (Table 1) confirmed all predictions, with the exception of that on the mean setting at 60-deg frame tilt, which was not significantly greater than zero. The failure to detect this difference was not surprising, however, since with Type I and Type II error rates of .05, an n of approximately 100 would be required to detect a true difference of 0.5 deg with a variance of the order of that obtained.

Lester (1968) has outlined some of the problems arising from the use of the adjustment method in the measurement of rod-and-frame effects, in particular the problem of SP effects. Such difficulties arise when the adjustment method is used to measure any illusory effect and have been independently discussed elsewhere (Wenderoth, Rodger, & Curthoys, 1968). Table 2 shows the mean settings from each

Table 1

Means and Variance Estimates of Vertical Settings as a Function of Frame Tilt and t-Test Results (R = Reject H_0, A = Accept H_0)

Frame Tilt (Degrees)	0	15	30	45	60	75	90
Mean Setting (Degrees)	+0.038	+1.375	−0.556	+0.006	+0.531	−1.144	+0.014
Variance Estimates	0.648	3.334	1.971	0.761	1.998	3.432	0.720
H_0	$\mu_0 = 0$	$\mu_{15} \leqslant 0$	$\mu_{30} \geqslant 0$	$\mu_{45} = 0$	$\mu_{60} \leqslant 0$	$\mu_{75} \geqslant 0$	$\mu_{90} = 0$
$t_{.95(19)}$	2.093	1.729	−1.729	2.093	1.729	−1.729	2.093
$t_{obtained}$	0.211	3.362	−1.771	0.031	1.680	−2.763	0.132
Decision	A	R	R	A	A	R	A

Table 2
Mean Vertical Settings at Each Angle of Frame Tilt as a Function of Starting Position

SP	Frame Tilt (Deg)						
(Deg)	0	15	30	45	60	75	90
+20	+0.925	+3.500	+1.275	+1.375	+1.950	+0.500	+0.425
+10	+0.400	+1.900	+0.775	+1.225	+1.100	−0.475	+0.425
−10	−0.275	+0.450	−1.750	−1.000	−0.425	−1.950	0.000
−20	−0.900	−0.350	−2.525	−1.575	−0.500	−2.650	−0.800

of the four SPs obtained in this experiment. Although each mean is based on one setting only by each S, a similar trend is exemplified for each SP as a function of frame tilt.

DISCUSSION OF RESULTS

The results of this experiment confirm the hypothesis that the direction of errors in rod settings to the vertical in a simple rod-and-frame apparatus are determined by the direction of tilt of the frame axis nearest to gravitational vertical. Further experiments are being conducted to determine whether the hypothesis requires elaboration. For example, this experiment has shown that the error in vertical settings is clockwise when the frame is tilted 15 deg clockwise, but anticlockwise when the frame is tilted 30 deg clockwise. One implication of our hypothesis is that the crossover point (i.e., zero effect) will occur where both the diagonal and vertical axes are equidistant from true vertical, viz, at a frame tilt of 22.5 deg. One reason that the effect might not be zero at this point is that the frame itself will be asymmetrical about true vertical, in the sense that one corner will be higher in the visual field than the other.

A further experiment currently being conducted is examining the effect of varying frame shape. If our hypothesis is correct, use of a rectangular frame, for example, should change the function in a predictable fashion.

The results of the present study suggest that some previous studies on the rod-and-frame effect have used less than optimal conditions for measurement of the effect. If, as the present experiment demonstrates, the effect reverses direction between +15 deg and +30 deg, then the single angle of frame tilt most often used in studies of the effect—usually about 28 deg—would be expected to yield a minimal or negative effect. It is not clear, at this stage, why errors in the *same* direction as frame tilt are usually reported for such magnitudes of frame tilt (e.g., Witkin & Asch, 1948a, b; Morant & Aranoff, 1966; Lester, 1969), but the difference could be a function of the size of the frame relative to the size of the rod or the absolute size of the frame, possibilities which we intend to investigate.

Finally, it should be stressed that the function obtained in this experiment is pertinent only to the seven angles of frame tilt studied. In further experiments it is intended to study the angular function in more detail, using more frame tilts to determine the angles at which maximum and zero effects occur.

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