Shape-slant relations under reduction conditions¹

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Two experiments are reported which attempted to test implications of the shape-slant invariance hypothesis. Both experiments employed an apparatus in which variations in the slant and in the width settings of a rectangle were highly ambiguous and subject to instructional sets. In the first experiment, the stimulus was varied in both its width and its slant to achieve matches to four standard angles; the resultant width settings were found to be close to the projected widths of the obtained angles of slant. In the second experiment, width and slant were varied to match four standard widths; the projected widths of the obtained angles of slant did not differ from the obtained width settings.

This study is an attempt to develop for shape constancy a parallel to experiments in which apparent size has been studied as a stimulus for perceived distance (e.g., Baird, 1963; Epstein & Baratz, 1964). In these experimental reports, under reduction conditions retinal size served as sole basis for reports about relative distance. Baird (1963), for example, reported that, "...data from the present study indicate that retinal size can be effectively used for the estimation of both size and distance (p. 161)."

It is the interest of the present study to determine whether retinal shape can be as effectively employed for the estimation of both shape and slant. Put in other words, the question is raised: whether under reduction conditions, if slant changes, S might report the change in shape to be predicted from resultant alterations in retinal image; and whether S might report, as shape changes, changes in perceived slant in accord with projected transformations of the retinal shape. This search for the relationship between apparent shape and apparent slant constitutes an exploration of the invariance hypothesis, as stated by Beck and Gibson (1955): "A retinal projection of a given form determines a unique relation of apparent shape to apparent slant (p. 126)." This statement may be rephrased in the context of the present experiment: Variations in projected shape (whether caused by objective changes in shape or in orientation) will be predictably associated with corresponding changes in perceived shape (if the object is seen in the frontal-parallel plane) or with corresponding changes in perceived slant (if object shape is perceived as unchanging). To test this prediction, an apparatus has been designed and will be described that, under reduction conditions, makes possible ambiguous stimulus manipulations; i.e., stimulus changes that may be interpreted by S as variations in either shape or slant, in accordance with the "set" provided by instructions.

With the reduction apparatus to be described, Ss were asked in Experiment I to make judgments about the apparent slant of a stimulus whose width was in fact being changed. These measures for the angles studied (20° , 40° , 60° , and 80°) comprise the apparent slant-objective width scale. To determine the extent to which the settings obtained under these conditions coincided with judgments when slant was actually varied, a second scale was also measured; that is, the apparent slant-objective slant scale obtained under the same reduction conditions. In the second experiment, Ss made judgments of the apparent width of a stimulus whose slant was actually varied, yielding the apparent width-objective slant scale. To provide a comparison, the apparent width-objective width scale was also determined.

Method

A special problem involved in the study of shape-slant relations is the measurement of the deformations involved as familiar shapes are viewed at changing angles of slant. Some studies of shape constancy (e.g., Haan & Bartley, 1954; Nellis, 1958; Nelson & Bartley, 1956) have shown circles at different angles of slant; the degree of constancy is then estimated from S's match to a series of ellipses of varying widths or from quantifications based on S's drawings of the perceived shapes. Stavrianos (1945) matched the shape of a rectangle at different slants with trapezoids of fixed base whose dimensions differed from the standard. Other experiments, preferring to use the continuous variation used in the method of average error, have used rectangular forms and matched width (as slants are varied) to the width of a variable rectangle (e.g., Borreson & Lichte, 1962; Lichte, 1952; Winnick & Rogoff, 1965). The present study has chosen to employ the last of these arrangements.

Experimental design. Two scales obtained in Experiment I, the apparent slant-objective width and the apparent slant-objective slant scales, were obtained at the same angles (20° , 40° , 60° , and 80°) from the same Ss. In Group I, apparent slant-objective width was determined first, while apparent slant-objective slant was measured second; Group II used the reverse order. The experimental design thus proves to be a mixed design, with type of scale and angles "within-Ss" effects and order the sole "between-Ss" effect.

Experiment II followed a parallel design for the two scales measured at four widths (1.00 in., 2.00 in., 3.00 in., and 4.00 in.). In Group I, apparent width-objective slant determinations were followed by apparent width-objective width; Group II again used the reverse order.

Subjects. There were 64 Ss in all; 32 served in each experiment, half with slant judgments first and half with width judgments first.

Apparatus. Ss were required to make judgments, in Experiment I, about the apparent slant of a figure that could be varied in either its slant or its width; in Experiment II, the same stimulus manipulations were the basis for Ss' judgments of apparent width. The figure, a rectangle 10 in. in height and 5 in. in width, was set at the rear of a reduction tunnel 7 ft. in length at the front of which was set a reduction screen 2 ft. square. S sat immediately in front of this screen and viewed the stimuli binocularly through an opening 1 in. in height and 5 in. in width.

In this arrangement, the only visible object was the rectangle, which was painted with fluorescent paint and illuminated for experimental determinations by an electroluminescent night light; the resultant luminance of the rectangle was .0159 ft-L. This luminous rectangle was viewed against a black background set in the frontal-parallel plane. The background was arranged to block from S's view the upper and lower portions of the rectangle.

The slant of the figure was varied by moving its right-hand side away from S, with the figure pivoted on its left side. With the rectangle in the frontal parallel position (slant of 0°), its width was varied by moving a black Masonite piece set in a track in front of the rectangle; thus, the width of the rectangle could be varied from a maximum of 5.00 in. to 0 in. Protocols of individual Ss indicated that, with the instructions used, they had no difficulty in adopting the set suggested.

Procedure. To obtain the four scaling measures, the method of average error was modified somewhat so that judgments were made about a single stimulus to correspond to either a standard slant or a standard width. For the determination of the apparent slant-objective width scale in Experiment I, the task of S was to indicate on each trial when, as E varied the width of the stimulus, it appeared to be inclined at the angle called for (20° , 40° , 60° , and 80°). For the apparent width-objective width scale of Experiment II, the same stimulus manipulation was employed; S's task was to judge when the stimulus appeared to be of the width called for (1.0, 2.0, 3.0, and 4.0 in.). For the apparent slant-objective slant scale in Experiment I, S was to indicate when, as E varied the slant of the figure by rotating it to S's right, it appeared to be inclined at the angle called for. For the apparent width-objective slant scale of Experiment II, the same stimulus manipulation was accompanied by S's judgment about apparent widths.

For both the apparent slant-objective width and the apparent slant-objective slant scales, the instructions, given to S after an explanation of the apparatus, were: "Look at this rectangle and notice that I can turn it away from you at an angle and then back toward you to its original position. I am going to ask you to tell me

Table 1. Mean slant settings (objective angle) in degrees (with projected widths) and mean width settings (objective width) in inches for each of the angles called for (apparent angle)

Apparent Angle	Group I		Group II	
	Objective Angle (projected width)	Width	Objective Angle	Objective Width
20°	22.4° (4.61 in.)	4.45 in.	26.6° (4.47 in.)	4.18 in.
40°	40.5° (3.27 in.)	3.29 in.	42.8° (3.67 in.)	3.78 in.
60°	56.8° (2.74 in.)	2.71 in.	55.5° (2.84 in.)	2.76 in.
80°	73.0° (1.46 in.)	1.33 in.	71.0° (1.63 in.)	1.58 in.

when it seems to be turned at different angles. Now, tell me when it seems to be inclined at an angle of ___ degrees." For both the apparent width-objective slant and the apparent width-objective width scales, the instructions were: "Look at this rectangle and notice that I can make it appear to be wider or narrower by moving this piece here. I am going to ask you to tell me when it seems to be of different widths. Now, tell me when it looks as if it is ___ inches wide."

The experimental sessions began with an explanation of the task and the apparatus and two trials to test S's understanding of the instructions. For each group, the variable was matched to each of the four angles in Experiment I and to each of the four widths in Experiment II for eight trials in both ascending and descending determinations. All slant manipulations were begun randomly either from the frontal-parallel plane (ascending) or at right angles (descending). Similarly, width variations began either from minimal (ascending) or maximal (descending) width.

Results and Discussion

The slant and width judgments from the two groups in Experiment I are shown in Table 1. These are the mean settings as the variable changed in its slant or in its width to match the four angles called for. To compare objective slant settings and objective width settings for the same apparent angles, the objective angles were converted into projected widths by substitution in the formula: $W_{\text{pro}} = \cosine \cdot x \cdot C$ (where C is the 5.00 in. width of the rectangle).

Comparing the projected widths for the objective angle settings and the actual width settings made to match these angles of slant, the data show remarkable agreement between the two sets of figures. This may be taken to indicate the effectiveness of the instructions and the convincing aspect of this ambiguous stimulus situation. In addition, the data obtained from the two groups are highly similar, indicating little or no ordering effect. Analysis of variance showed neither differences between groups, nor differences between width settings and projected widths of obtained angles to be significant.

The relationship between the slant settings obtained (objective angle) and the angles called for (apparent angle) is shown by the upper graph of Fig. 1, with

Fig. 1. Mean slant settings (above) and mean width settings (below) for the four standard (apparent) angles, in the two groups, compared with veridical (ver.) settings.

veridical settings shown to provide an evaluation of accuracy. This graph will be considered to be the apparent slant-objective slant scale for the reduction conditions of the present experiment. As such, it may be compared with the scales obtained by Winnick and Rogoff (1965) for a variety of geometric forms exposed in room illumination. In agreement with data from that study, both groups in the present experiment approached veridicality at close to 40° . In partial agreement also was the finding of a significant deviation from veridicality at 20° for Group I ($t=2.4$, $df=15$, $p<.05$) and at 80° for both groups ($t=1.7$ for Group I and 2.2 for Group II, $df=15$, $p<.05$ for both). Winnick and Rogoff (1965) had found apparent slant to be significantly less than objective slant at 20° and to be significantly greater at both 60° and 80° .

The lower graph of Fig. 1 represents the relationship between the width settings obtained (objective width) and the angles called for (apparent angle); projected widths for each of the apparent angles are plotted as veridical points. The data points shown comprise the scale relating objective width and apparent slant. In this scale the obtained width settings are less than projected widths below 40° , approach veridicality just over 40° ,

Fig. 2. Mean width settings (above) and mean slant settings (below) for the four standard (apparent) widths, in the two groups, compared with veridical (ver.) settings.

and overestimate the widths required for veridicality at 60° and 80° .

Comparing the two scales shown in Fig. 1, there is very close agreement. Underestimation of angle (as at 80°) in the upper scale is paralleled by overestimation of width in the lower scale. Similarly, the overestimation of the 20° angle shown in the upper scale is matched by underestimation of the width setting to match that angle, in the lower scale. This close relationship between the two scales, one based on slant settings, the other on width settings, is evidence substantiating the shape-slant invariance view, for the limited conditions of this experiment, at any rate.

Table 2. Mean width settings (objective width) in inches and mean slant settings (with projected widths) for each of the widths called for (apparent width)

Apparent Width	Group I		Group II	
	Objective Width	Objective Angle (projected width)	Objective Width	Objective Angle (projected width)
1.0 inch	1.49 in.	72° (1.51 in.)	1.45 in.	77° (1.13 in.)
2.0 inch	2.33 in.	61° (2.44 in.)	2.35 in.	65° (2.08 in.)
3.0 inch	3.00 in.	46° (3.46 in.)	3.15 in.	50° (3.17 in.)
4.0 inch	3.82 in.	33° (4.16 in.)	3.85 in.	38° (3.93 in.)

The data from Experiment II corroborate and strengthen the results of Experiment I. Shown in Table 2 are the width settings and the slant settings made to match the four standard widths. Again, as in Experiment I, the slant settings are transformed into projected widths to make comparison possible. As in Experiment I, both sets of data are very similar, as are the data for Groups I and II. Neither the width-slant comparison nor the comparison between groups showed significant differences in the analysis of variance of the results.

The two scales obtained in Experiment II are shown in Fig. 2; the upper graph comprises the apparent width-objective width scale, while the apparent width-objective slant scale is shown by the lower graph. Again, the two scales show the similarity found in the scales of Experiment I. The overestimations of width, found at 1.00, 2.00, and 3.00 in., are accompanied by underestimations of slant. However, the underestimation of width obtained at 4.00 in. was paralleled by a small overestimation of slant in Group 2, but not in Group 1.

Close agreement between slant settings and width settings has been shown in two experiments; in one, these settings were made to match four standard angles of slant; in the second, these settings were made to match four standard widths. The two sets of scales of obtained—apparent slant-objective slant and apparent slant-objective width in Experiment I and apparent width-objective width and apparent width-objective slant in Experiment II—showed highly similar trends. The close agreement found may be considered as providing limited support to the shape-slant invariance hypothe-

sis, with the limitation being imposed by the narrow range of width and slant judgments involved.

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Note

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