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THE INDUCTION OF NONVERIDICAL SLANT AND THE PERCEPTION OF SHAPE [1]

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Koffka's (1935, pp. 224–235) explanation of shape-constancy is based on the assumption of an invariant linkage between slant and shape. Koffka's hypothesis has been formulated in the following way by Beck and Gibson (1955): "A retinal projection of a given form determines a unique relation of apparent shape to apparent slant" (p. 126). The invariance hypothesis requires that perceived shape vary as a strict function of variations in perceived slant (Langdon, 1951, 1953; Nelson & Bartley, 1956; Stavrianos, 1945).

In order to test this hypothesis Beck and Gibson (1955) induced errors in the apparent slant of a target whose shape was to be judged. A triangular target cut from untextured, white cardboard was mounted on a regularly textured, vertical background, and was slanted outward from the base at an angle of 45° from the background. The target was viewed monocularly with a motionless head. Under these conditions, in the absence of binocular disparity, motion perspective, and texture gradients, the slant of the target was misperceived. The triangle assumed the slant of the background, i.e., it appeared to be perpendicular to the line of sight instead of slanted 45°. Along with this standard target, two comparison triangles placed flat on the background were exhibited. One represented a frontal parallel projection of the standard, and the other had the same physical dimensions as the standard. All *S*s judged the standard triangle to be equal in shape to the projective comparison. This match agrees perfectly with the requirements of the invariance hypothesis. When the same judgments were made with unrestricted binocular vision, 77% of the *S*s selected the objectively equal comparison triangle. This result also is in the direction required by the invariance hypothesis.[2] Since unrestricted observation eliminates the slant-inducing effect of the background, accurate perception of slant was restored; and, with it, veridical perception of shape was also recovered.

The general purpose of the present study was to extend and clarify Beck and Gibson's (1955) findings. The following were the major extensions and modifications: (*a*) The slant-induction effect was investigated when the background also was slanted from the frontal parallel plane. (*b*) A technique was employed which permitted continuous variation of the comparison stimulus. This made possible a more exact test of the invariance hypothesis. (*c*) A more accurate measure of the apparent slant of the target was obtained. These data are necessary for an analysis of the slant-shape relationship. (*d*) The influence of three different instructional sets on the judgment of shape was investigated. Beck and Gibson (1955) do not inform us concerning this variable, and the evidence from other studies (Gottheil & Bitterman, 1951; Klimpfinger, 1933) is fragmentary.

METHOD

Apparatus

The main apparatus was a rectangular light-tight tunnel 7 ft. in length with walls

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[2] The invariance hypothesis actually requires a 100% shift to the objectively equal comparison.

20 in. wide. The interior of the tunnel was painted flat black. In the front wall of the tunnel there was an aperture which could be adjusted for monocular or binocular vision. A head-clamp chin-rest arrangement placed in front of the aperture kept *S*'s head motionless when this was required. The two clamps restrained all but the most determined head movements, and head movements are considered highly unlikely under the conditions of the experiment. A reduction tube was inserted in the front wall which restricted the monocular field to the target and its immediate background. On the inside of the front wall was a circular fluorescent lamp (32 w., standard cool white color) which provided the only illumination in the tunnel. This lighting arrangement made invisible the shadow cast by the slanted standard. At a distance of 6 ft. from the front wall a false back wall (panel) was inserted. This panel was covered with a black and white checkerboard cloth composed of 1 × 1 in. squares. The panel could be adjusted from outside the tunnel to three degrees of slant: perpendicular to the line of sight (vertical), 20° from the perpendicular tilted away from *S* (20° A), and 20° from the perpendicular tilted toward *S* (20° T).

The standard triangle was mounted in the objective center of the panel and directly in *S*'s line of regard, and had a height of 5 in. and a base of 4 in. The adjustable comparison triangle was mounted flat on the background, 4 in. above the apex of the standard. The height and base of the comparison could be varied continuously by manipulating a set of levers located on the exterior of the roof of the tunnel. The design of this comparison stimulus is similar in essentials to the apparatus described by Gottheil and Bitterman (1951, p. 407). The comparison and standard triangles were cut from the same white cardboard of imperceptible texture.

The comparison stimulus for slant was a circular disc of white cardboard mounted on a horizontal axis. The disc could be rotated on its axis, and its angle of rotation could be read directly off a protractor. The disc was located directly in *S*'s line of sight when he turned 90° into the designated viewing position, and it was presented outside the tunnel in a normally illuminated, unrestricted field.

Procedure

Stimulus conditions.—The standard was judged twice by each *S* (one ascending and one descending trial) for each of three background slants. When the background was vertical or 20° T, the standard triangle was at a 45° slant from the background outward from the base. When the background was slanted 20° A, the standard was slanted 45° outward from the apex.

Conditions of observation.—Each *S* observed the standard either monocularly or binocularly.

Instructional conditions.—Three sets of instructions were used which were intended to induce different attitudes of observation. These attitudes are usually designated: the phenomenal, objective, and analytic. Each *S* served under one instructional condition only. The instructions were as follows:

(Instructions for the phenomenal attitude) When you look into this box you will see a standard triangular target on a checkerboard background. I am interested in learning how you perceive the shape of this target. Right above the standard triangle there is a second triangle. The base and altitude of this second triangle can be varied. Your task will be to instruct me to adjust the shape of the variable triangle so that it appears to be the same shape as the standard below it. I would like you to suspend all mental judgments and give me a match which reflects your immediate perceptual impression. Don't try to figure out a good match. I want a report of your immediate perceptual impression even if you feel that the match you make would not agree with the objective physical dimensions of the target.

(Instructions for the objective attitude) I am interested in learning how well you can reproduce the actual physical shape of this target. . . . This means that in the ideal case when you have completed your judgment I should be able to take the match you have made, lay it over the standard, and find that it corresponds perfectly in all dimensions. Please remember that you are to reproduce the actual physical dimensions of the target even if the match you make doesn't *look* equal in shape to you. To make this clear suppose you were looking at a man far in the distance. He would *look* very small but if you were asked to reproduce the actual size of the man you probably would be fairly accurate. This is what I wish you to do here. Reproduce the actual physical shape of the target.

(Instructions for the analytic attitude) I am interested in learning how well you can reproduce the retinal shape of this target. An illustration may help make this clear. If I put a coin on the table and you look directly down upon the coin, it will project a circular retinal image. However, if you stand back along the edge of the table and look at the coin from this new position, the coin will produce an elliptical retinal image. It is this retinal shape in which I am interested. . . . Your task will be to instruct me to adjust the shape of this variable triangle so that it is identical in shape with the retinal shape of the standard triangle. Remember I am interested in the retinal shape. It is not important to me whether or not the two triangles look identical in shape or are actually equal in shape when you have completed your judgment.

The shape-matching procedure may now be summarized. Each *S* was instructed to make two shape-judgments of the standard for each of three background slants. The *S* made the judgments by instructing *E* to adjust the shape of the comparison triangle until a satisfactory match was attained. Each *S* performed this task under one observational condition, binocular or monocular, and under one instructional set, phenomenal, objective, or analytic.

When the shape-judgments were concluded, the standard was presented again, and *S* judged the slant of the standard once for each slant of the background. All *S*s were given the following instructions:

> Now I would like you to judge the slant of the target triangle. By "slant" I am referring to whether the triangle appears to stand straight up and down in front of you, or whether it appears to lean either toward or away from you. This is how your slant judgments will be made. First, you will look at the triangle and determine if it is slanted and, if so, how much. Outside of the box I will show you a circular disc whose slant may be varied. Your task is to adjust the slant of this disc to the same slant as the target. After you have adjusted the slant of the disc you will be given one more look into the box to check your judgment.

The experiment was concluded with an interview which sought to obtain information about three aspects of the experiment: (*a*) the effectiveness and comprehensibility of the instructions; (*b*) the deliberate utilization of perceived slant during the judgment of shape; and (*c*) the relation between the judgments of slant obtained *after* the shape-judgments were completed and the perceived slant *during* the shape-judgments.[3]

Subjects

The *S*s were 84 undergraduates who served in the experiment as a course requirement. They were assigned in order of their appearance to one of six groups (2 conditions of observation × 3 attitudes of observation). Thus, each of the six experimental groups contained 14 *S*s, about equally divided among men and women. None of the *S*s knew anything about the invariance hypothesis, or the questions under investigation.

RESULTS

The main results of the experiment are presented in Table 1. In all of the tables the shape data are represented as height-base (h/b) ratios.

Slant-induction.—An inspection of the mean slant judgments for monocular observation recorded in Table 1 reveals that the slant-inducing effect of the background reported by Beck and Gibson (1955) was obtained for all three background slants. As an illustration consider the fourth row of figures in Table 1. When the background was 20° A and the standard was objectively slanted 65° A, the standard was judged to be slanted 17.21° A. When the background was vertical and the standard 45° T, the standard was judged to be slanted 0.83° T. In the case of the 20° T background slant, an exaggerated slant-induction effect appears to have occurred. While the standard was objectively slanted 65° T, it was perceived to be at a slant of 6.59° T, i.e., slanted 13.41° less than the background.

The comparable data for binocular vision show the expected diminution of the slant-induction effect when the

[3] The use of successive rather than simultaneous slant-shape judgments can be questioned. We sought to eliminate some of the ambiguity during the interview.

TABLE 1

MEAN h/b RATIOS OF COMPARISON MATCHES AND MEAN SLANT JUDGMENTS OF STANDARD

Observation Attitude	Slant of the Background											
	20° A				Vertical				20° T			
	Comparison		Standard		Comparison		Standard		Comparison		Standard	
	Mean h/b	*SD*	Mean Slant	*SD*	Mean h/b	*SD*	Mean Slant	*SD*	Mean h/b	*SD*	Mean Slant	*SD*
	Monocular Vision											
Phenomenal	.370	.043	10.57° A	11.40°	.573	.053	0.80° T	3.37°	.386	.063	4.06° T	7.58°
Objective	.397	.018	17.30° A	12.00°	.556	.043	0.85° T	3.58°	.386	.044	10.21° T	6.48°
Analytic	.387	.097	23.57° A	13.96°	.530	.090	1.15° A	4.75°	.392	.091	7.64° T	7.54°
All attitudes	.384	.127	17.21° A	13.03°	.553	.180	0.83° T	4.43°	.388	.128	6.59° T	7.49°
	Binocular Vision											
Phenomenal	.547	.177	55.72° A	9.57°	.649	.077	20.57° T	8.89°	.584	.117	25.00° T	10.63°
Objective	.706	.102	52.72° A	14.07°	.710	.095	17.57° T	9.45°	.666	.129	35.28° T	12.53°
Analytic	.612	.153	56.65° A	7.91°	.631	.079	20.35° T	6.74°	.507	.134	29.35° T	11.27°
All attitudes	.625	.202	55.03° A	11.40°	.696	.213	19.49° T	7.28°	.585	.192	29.87° T	12.36°
Objective h/b (St.)	.800				.800				.800			
Proj. h/b (St.)	.353				.585				.324			
Objective slant (St.)[a]	65° A				45° T				65° T			

[a] Measured in terms of the deviation from the vertical away from (A) or toward (T) *S*.

cues for slant were restored. The case of the 20° A background illustrates this diminution. When viewed monocularly, the target appeared to be at a slant of 17.21° A—a deviation of 47.79° from its objective slant, but only 2.79° from the slant of the background. However, when viewed binocularly, the target was judged to be at a slant of 55.03° A—a deviation of only 9.97° from its objective slant, but 35.03° from the slant of the background.

In order to assess the relative magnitude of the slant-induction effect, the slant judgments were expressed as deviations from the slant of the background, and an analysis of variance was performed on these deviation scores. The analysis confirmed the observations recorded above. For any given degree of background slant the deviation was significantly greater for binocular than for monocular vision, i.e., the slant-induction effect was greater for monocular vision. The magnitudes of the deviations were not equal for all background slants within each condition of observation. The 20° T background slant produced the greatest deviation for monocular vision and the smallest deviation for binocular vision. However, if the large deviation for monocular vision may be assumed to be an exaggerated slant-induction effect, then we can conclude that the induction effect was more pronounced when both target and background were tilted forward.

Instructional sets.—An analysis of variance showed a significant interaction of attitude with condition of observation. When the target was viewed monocularly, instructional sets were ineffectual, i.e., they did not influence the shape-judgments. However, when the target was observed

TABLE 2

THE MEAN PROJECTIVE h/b RATIO REQUIRED BY THE APPARENT SLANT OF THE STANDARD COMPARED WITH THE MEAN PROJECTIVE h/b RATIO OF THE COMPARISON SETTING

Observation Attitude	Monocular			Binocular		
	Co. Mean Proj. h/b Ratio	St. Mean Proj. h/b Ratio	Sign and % Deviation	Co. Mean Proj. h/b Ratio	St. Mean Proj. h/b Ratio	Sign and % Deviation
	Background Slant = 20° A					
Phenomenal	.347	.200	+ 73.50	.507	.674	−24.77
Objective	.375	.251	+ 49.40	.656	.674	− 2.67
Analytic	.362	.343	+ 5.84	.541	.683	−20.79
	Background Slant = Vertical					
Phenomenal	.573	.609	− 5.74	.649	.735	−11.56
Objective	.556	.601	− 7.65	.710	.732	− 3.14
Analytic	.529	.608	− 12.17	.631	.733	−13.50
	Background Slant = 20° T					
Phenomenal	.368	.135	+172.59	.562	.409	+37.89
Objective	.367	.223	+ 64.12	.638	.514	+24.12
Analytic	.375	.208	+ 79.80	.483	.460	+ 5.00

binocularly, there were significant differences between the shape-judgments made under the various instructional sets. Here we will mention only that the objective attitude consistently resulted in matches which were significantly nearer to the objective dimensions of the target than the matches for the analytic and phenomenal attitudes. This finding is in agreement with the results reported by earlier investigators (Gottheil & Bitterman, 1951; Klimpfinger, 1933).

TABLE 3

SELECTED SAMPLE OF DATA FROM *S*s WHO DISPLAYED COMPLETE SLANT-INDUCTION WITH VERTICAL BACKGROUND AND MONOCULAR VISION

Observation Attitude	*N*	St. Objective h/b Ratio	Co. Mean Proj. h/b Ratio	St. Proj. h/b Ratio	Sign and % Deviation
Objective	10	.800	.540	.585	−7.68%
Analytic	9	.800	.543	.585	−7.17%
Phenomenal	7	.800	.555	.585	−5.12%
All attitudes	26	.800	.546	.585	−7.85%

Apparent slant-apparent shape invariance.—The following procedure was used to evaluate the invariance hypothesis. An h/b ratio was determined trigonometrically for each *S*'s *apparent* (judged) slant of the standard at each background slant. This ratio represents the projective ratio of the shape-match demanded for that degree of apparent slant by strict adherence to the invariance requirements. Next, the projective h/b ratio was determined for *S*'s setting of the comparison triangle at each background slant. A comparison of these two ratios allowed us to evaluate the degree of slant-shape invariance. Any difference between the two ratios represents a deviation from invariance requirements. The results of our analysis are summarized in Table 2.

To clarify the logic of this analysis a selected sample of data has been presented in Table 3. The mean h/b ratios contained in Table 3 were obtained from *S*s who manifested total slant induction when viewing the standard monocularly against a vertical background. In this special case, when the standard is perceived to be perpendicular to the line of sight, the frontal parallel projection for the apparent slant of the target is in effect the actual projective shape of the target. This is to say that, if the invariance requirements are to be strictly satisfied, the projective h/b ratio of the comparison (which in this special case is identical with the objective h/b ratio of the comparison) must equal the projective h/b ratio of the standard. For the dimensions of our standard this means that a perfect invariance fit would be h/b = 0.585. However, consulting the fourth column in Table 3, we find that this theoretical value was not attained. The deviations between the means were not great, but they were present, nonetheless.

An inspection of Table 2 reveals that in no instance did the mean projective h/b ratio of the comparison setting satisfy the invariance requirements. The deviations obtained for monocular observation ranged from −5.74% to 172.59%. For binocular vision the range of deviations was −2.67% to 37.89%. Relatively small deviations from invariance were obtained when the background was vertical. In addition, there was no significant difference between the grand mean deviations for monocular and binocular vision with the vertical background. The greatest deviations occurred when the background was slanted 20° T, although errors of considerable magnitude were obtained with the background 20° A. With only one exception, the deviations obtained with monocular observation under the 20° A and 20° T background conditions were at least twice as great as the deviations obtained for binocular vision.

A review of the ratio pairings for the individual *S*s (252 pairings, 126 for monocular and the same number for binocular vision) confirms these observations. There was not one case of perfect correspondence between the two h/b ratios. Table 4, which presents the distribution of deviations according to sign, reflects this fact.

Verbal reports.—The information derived from the interview tended to confirm the validity of the experimental operations. All *S*s gave evidence of having understood the task which was posed by the instruc-

TABLE 4

DISTRIBUTION OF DEVIATIONS FROM INVARIANCE REQUIREMENTS FOR MONOCULAR AND BINOCULAR VISION

Observation Attitude	Slant of Background: 20° A Deviations +	20° A Deviations −	Vertical Deviations +	Vertical Deviations −	20° T Deviations +	20° T Deviations −	All Slants Deviations +	All Slants Deviations −
Monocular Vision								
Phenomenal	12	2	3	11	13	1	28	14
Objective	10	4	2	12	12	2	24	18
Analytic	8	6	3	11	13	1	24	18
All attitudes	30	12	8	34	38	4	76	50
Binocular Vision								
Phenomenal	3	11	3	11	11	3	17	25
Objective	6	8	8	6	11	3	25	17
Analytic	3	11	2	12	8	6	13	29
All attitudes	12	30	13	29	30	12	55	71

tions. Very few *S*s said that they had made deliberate efforts to take slant into account while making shape-judgments. All *S*s agreed that the judgments of slant made at the end of the experiment corresponded well with the apparent slant of the target during the earlier judgments of shape. Only a few *S*s expressed any strong lack of confidence in their judgments.

Discussion

The results of this experiment confirmed and extended Beck and Gibson's (1955) findings concerning the slant-induction effect. The effect was observed to obtain not only when the background was vertical, but also when the background was slanted 20° A or 20° T. In fact, there is some reason for concluding that the effect was more pronounced when the background was slanted forward. We have no explanation for this latter finding, nor do we see any way of deriving it from the general stimulus-gradient theory.

The results with regard to the invariance hypothesis agreed with Beck and Gibson's findings in their general aspects, but were sufficiently different to warrant comment. The main point of disagreement was this: For both monocular and binocular observation our results showed much less adherence to the invariance requirements than did the results of Beck and Gibson. For instance, Beck and Gibson report that when the standard was viewed monocularly with a stationary head, all of their 30 *S*s selected a projective match, while with unrestricted binocular vision 23 of 30 *S*s selected an objective match. None of our *S*s made a perfect projective or objective match when these were demanded by the apparent slant.

The main reason for this disagreement resides in the difference between the measurement techniques employed in the two experiments.[4] We used a continuously variable comparison which enabled *S* to make sensitive discriminations. The method which Beck and Gibson used forced *S* to choose between one of two extreme alternatives, i.e., objective or projective. There was no way *S* could indicate any other perceived shape. In this situation *S* would probably select the comparison triangle which was *most like* the one he perceived even when he recognized that the two stimuli were not identical. Thus, all perceived shapes which clustered about the projective comparison were designated by that comparison and, similarly, all apparent shapes which clustered about the objective comparison were designated by that comparison. Lacking an opportunity to differentiate in the response system, *S*s produced results which appeared to reflect agreement in the perceptual system.

The evidence from past studies with regard to the effect of attitudes on the perception of shape is difficult to interpret. Klimpfinger (1933), who is most frequently cited, did not actually compare the influence of different attitudes within the same experimental situation. Instead, his conclusions were based mainly on a comparison of his data with the results of other *E*s. Gottheil and Bitterman (1951) used the same *S*s for each of the three attitudes. There is no way of knowing what effect judgments made under a previous attitude may have had on the later judgments obtained for another attitude. In addition, Gottheil and Bitterman do not tell us whether *S* viewed the target monocularly or binocularly. Our own results suggest an interaction of attitude with condition of observation. In light of the paucity of evidence on this question further research is needed.

[4] Beck and Gibson (1955, p. 131) recognized the limitations of their technique for a precise test of the invariance hypothesis.

Summary

The experiment had three aspects: (*a*) to determine whether the slant-induction effect reported by Beck and Gibson (1955) would obtain when the background was slanted; (*b*) to test more precisely the slant-shape invariance hypothesis; and (*c*) to investigate the influence of three attitudes of

observation on the perception of shape under monocular and binocular vision.

The main results were: (*a*) The slant-inducing effect of the background was observed when the background was slanted 20° from the perpendicular either away from *S* (20° A) or toward *S* (20° T) in addition to the case in which the background was perpendicular to the line of sight. (*b*) Under no condition did the judgments of apparent slant and apparent shape covary exactly as demanded by the invariance hypothesis. The deviations from invariance ranged from −24.77% to 172.59%. (*c*) The influence of attitudes on the perception of shape was restricted to binocular viewing. Attitudes were found to be ineffectual in determining perceived shape when the standard was viewed monocularly.

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