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# Compensating for distortion in viewing pictures obliquely*

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Gombrich (1972) suggested that interpretation of obliquely viewed pictures depends largely on the foreshortened image projected to the eye, the attendant distortion rarely being important. Sixteen university students judged whether 128 drawings viewed at 41 and 26 deg to the page pictured rectangular or nonrectangular boxes. Projective geometry predicted Ss' classifications; for many pictures, predictions for normal and oblique viewing differed. Nevertheless, at 41 deg, Ss classified 77% of the pictures where predictions differed according to the normal prediction. Furthermore, performance on cases where the predictions agreed was no better. Even at 26 deg, normal classifications still dominated. Ss demonstrated substantial capacity to compensate for oblique viewing and small tendency to judge according to the foreshortened image.

Many can tolerate and some even choose the extreme front or side seats at the cinema. We often scan the illustrations of magazines lying flat on the table in front of us. At crowded art exhibitions, one sometimes must–and can–be satisfied with a view from the side. In all, the human visual system gets along rather well looking at pictures obliquely. Such an ability is more than just a convenience in a culture where presentation of pictures to family and larger groups is commonplace.

This capacity has not gone unnoticed. A primary question is whether the eye actively adjusts at all to an oblique viewpoint. Gombrich (1972) argues that although several effects are involved, the principle one is that the eye accepts the obliquely projected image as though it were seen perpendicularly, and makes an accordingly distorted interpretation. The distortion is usually not so apparent because, as Gombrich notes, "If trees appear taller and narrower, and even persons somewhat slimmer, well there are such trees and such persons [1972, p. 144]." Gombrich's proposal becomes even more attractive when one considers that such distortions are likely to be small. The foreshortening attendant on oblique viewing varies as the cosine of the angle with the perpendicular. The cosine departs slowly from unity as the angle increases: even from a 30-deg side view, the horizontal dimensions are foreshortened only some 14% relative to the vertical.

A contrary emphasis is suggested by phenomena discussed in Pirenne (1970, Chap. 9). In a wide-angle photograph, an off-center spherical object will yield an elliptical image. Even when such a picture is viewed from its perspective focus, despite the "good form" of the ellipse's circular projection to the eye and the contextual appropriateness of a spherical interpretation, the photographed sphere will appear elliptical. This is a well-known "failure" of the laws of perspective representation. Paradoxically, it suggests a misplaced success of the eye in compensating for the obliquely viewed picture plane: the visual system, adjusting for that slant, takes the circular projection as in fact representing something elliptical.

Of course, Gombrich is well aware of the phenomenon Pirenne discusses. He suggests that such instances of the righting of an obliquely viewed surface are naturally occurring cases of "regression to the real object," a phrase coined by Thouless (1966). In experiments which called for Ss to match cardboard ellipses to the projected shapes of obliquely viewed circles, Thouless found that Ss' choices were less elliptical than they should have been from a projective standpoint, were "regressed" toward the true circular shape. This phenomenon presumably would work against a purely projective interpretation to make those slim trees and people appear somewhat less slim.

In sum, at one extreme the interpretation of an obliquely viewed picture may be *projective*, according with the image projected to the eye of the observer as though that image were seen perpendicularly; at the other, the interpretation might be *orthogonal*, according with a perpendicular viewing of the picture, no matter what the actual viewpoint. There are clear instances both of projective and orthogonal influences. The question is more which sort of response is generally dominant, or what mix or compromise abides. Gombrich's proposal, that projective interpreting dominates, has the initial advantage of simplicity here. No special capacities need be attributed to the visual system; it simply responds directly to the projection, whether a picture is viewed obliquely or not.

An experiment was designed which might counterbalance Gombrich's proposal by demonstrating substantial capacity to compensate for oblique views under common circumstances. The study focused on pictured rectangular objects which, in the forms of tables, staircases, books, rooms, buildings, and so on, are

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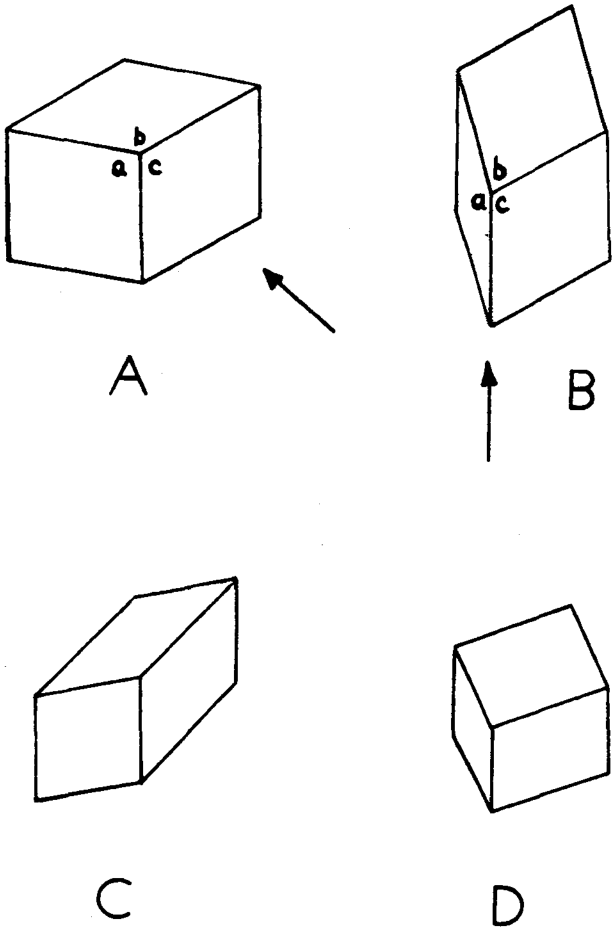


**Fig. 1. Rectangular and nonrectangular appearing boxes (A and B) and their projections under one oblique viewing condition of the experiment.**

frequent elements in pictures, far more frequent than wide-angle off-center images of spheres. The key point is that some pictured corners where the three edges meet in a point can, and some cannot, be projections of rectangular corners in space, where three edges meet at right angles, according to a simple rule described by Perkins (1968) and given later. In perpendicular viewing, the human visual system is quite good at discriminating between these two sorts. Figure 1A meets the rectangularity conditions of this rule, and indeed appears rectangular. Figure 1B does not, and it appears nonrectangular. Employing a deck of 128 box pictures, including some close to the borderline dividing the two categories, Perkins (1972) found that Ss discriminated between the two kinds with an overall mean success of 85%.

Casual observation suggests that this discrimination might be performed from oblique viewpoints. If Fig. 1A is observed from the direction of the arrow at an angle 41 deg to the plane of the page, it still appears rectangular to most viewers. But the projection at that angle is the image of a nonrectangular box–in fact, Fig. 1C. If Fig. 1B is viewed in the same manner, it persists in appearing nonrectangular. But the projection is, in fact, the image of a rectangular box–Fig. 1D.

In the present experiment, Ss were required to judge the rectangularity of the 128 box pictures at two different viewing angles. For certain combinations of picture and viewing angle, called "conflict cases," a projective judging strategy would lead to different classifications, depending on whether the picture was viewed obliquely at that angle or perpendicularly. For the remaining "nonconflict" cases, either projective or compensating judgments would yield the same classification, even at the oblique viewing angle. It was conjectured that, first, Ss would compensate, classifying conflict cases predominantly in accordance with the orthogonal prediction despite the oblique view. Second, Ss' performances under oblique viewing conditions would be somewhat inferior to their performances under conditions of orthogonal viewing. Third, Ss would make fewer judgments contrary to the orthogonal prediction on nonconflict cases where orthogonal and projective predictions agreed than on conflict cases where they competed, revealing a weak trend to occasionally judge projectively.

## METHOD

### Subjects

The Ss were eight male and eight female Harvard College undergraduates. Four of each sex responded to advertisements around the campus; the others were participants in the earlier experiment (Perkins, 1972). These latter Ss, chosen without regard to accuracy of discrimination on the earlier experiment, were contacted expressly for comparing their prior performance with performance on this experiment. Ss were paid \$2/h. Twelve of the Ss also participated in another related experiment concerning judgments of symmetry in figures.

### Stimulus Materials

The stimulus materials were precisely those used in the earlier experiment. These were line drawings of boxes, some of which could have been and some of which could not have been projections of rectangular boxes. The rule for rectangularity is that all three angles, A, B, and C, labeled as in Figs. 1A and 1B, must be greater than 90 deg, or in a special case that two angles be exactly 90 deg (Perkins, 1968). Another special case, with just one angle 90 deg, is referred to throughout this paper as the "borderline" case. Although technically a box picture with one such angle cannot be a projection of a rectangular box, this case falls exactly on the boundary between the range of rectangular and nonrectangular boxes.

There were 128 cards, 4.5 in. tall x 6.0 in. wide, each displaying one box with its central vertex at the center of the card. The cards were constructed by Xeroxing 16 drawings of boxes of different shapes, drawings done with a .5-mm line, in black ink on white paper. The copies were cut into cards so that each box appeared in eight orientations on eight cards–vertically as in Figs. 1A and 1B, rotated 45 deg in the plane of the card, rotated 90 deg, and so on. All 16 boxes shared one constant angle (Angle C in Figs. 1A and 1B) of 120 deg, but Angles A and B varied in each. A taking the values of 70, 80, 85, 90, 95, 100, 110, 120, 130, 140, 145, 150, 155, 160, 165, and 170 deg. The three edges radiating from the central vertex of each box were all of the same length, 3 cm, and the boxes were drawn as parallel rather than polar projections. Thus, opposite edges on each face of a box picture were exactly parallel, displaying no perspective convergence. Given the fixed angle, C, of 120 deg, the rule cited in the previous paragraph implies that all the box pictures with Angle A between 90 and 150 deg could be projections of solid rectangular boxes and that the others could not. Accordingly, seven boxes, 70 through 85 deg and 155 through 170 deg, were within the nonrectangular range, the 90- and 150-deg boxes were borderline, and the seven boxes 95 through 145 deg were within the rectangular range. Close to the borderline cases, Angle A was varied by 5 deg rather than 10 deg to permit sharper scrutiny of Ss' behavior in the neighborhood of these critical points.

The cards were arranged in a random order, and then minimally rearranged so that runs of more than three rectangular or borderline cards, or nonrectangular or borderline cards, did not occur. The cards were presented in this fixed order to each S at one viewing angle. For the other, the first and last halves of the deck were reversed. Thus, whichever viewing angle an S used initially, the rearrangement of the deck before the second angle would tend to nullify any slight memory he might have of his first or last few judgments. In general, the earlier experiment revealed that order of card presentation had no effect: judgments made late in the deck were just as likely to be correct as judgments made earlier.

In addition to the main deck of 128 figures, a smaller deck was constructed by duplicating 32 figures from the main deck, 2 from each variation of Angle C, with rotations distributed systematically through the 16 categories. The intent was to construct a deck of 32 which would be as representative as possible of the original deck. The 32-card deck was used to introduce Ss to the discrimination with perpendicular viewing and to provide a baseline against which Ss' oblique viewing could be measured.

### Viewing Angles

The stimulus cards were viewed at angles of 26 and 41 deg from the picture plane. These choices permitted investigating Ss' discriminative capacities at both moderate and extreme viewing angles. The exact values were chosen as follows. Computer calculations determined precisely which of the 128 figures satisfied the above-mentioned rule when projected at angles ranging from 85 to 5 deg from the plane of the page at intervals of 5 and then from 45 to 20 deg at intervals of 1. the calculations showed that the rectangularity classification (rectangular or nonrectangular) of many figures as projected changed in the neighborhood of 30 deg, while remaining exceptionally stable in the neighborhoods of 41 and 26 deg. The status of each of the 128 figures was exactly the same for the angles of 40, 41, and 42 deg and for 25, 26, and 27 deg. Viewing angles of 26 and 41 deg were then chosen since the apparatus of the experiment could guarantee accuracy in each S's viewing angle only to within three-quarters of 1 deg.

### Procedure

Each S was tested individually. Sample pictures (duplicates of the 70- and 120-deg normally oriented stimulus cards) and three dimensional cardboard boxes introduced Ss to the idea that boxes could be rectangular or not and could appear either way in pictures. Ss were urged to attend to the apparent rectangularity of the individual displays and not to expect patterns in the ordering of the stimuli or the like.

First, Ss judged the rectangularity of the boxes in the 32-card deck. The cards were presented one by one, perpendicular to the line of sight at a distance of 6 ft. S indicated verbally whether each box appeared rectangular. E placed each card face down in one of two piles, depending on S's judgment.

Next, S was asked to make the same judgement of each figure in the 128-card deck. But this time, the pictures would be viewed at an angle. S was seated on a swivel chair with its back against the wall and the height and position adjusted to place S in a relaxed posture with his eyes centered in front of a line marked on the wall. The cards were displayed directly in front of the S, 6 ft from his eyes, on a horizontal rectangular panel whose height depended on the viewing angle. The edges of the panel and cards were oriented parallel to the walls of the room. S viewed the cards through one of two wire frames to maintain the desired viewing angle, each 1.75 in. high x 7 in. wide and both suspended on the same black thread 23.5 in. from the wall. As long as S maintained his position against the wall and observed the cards through the specified frame (E monitored this), the projective rectangularity of each card did not vary.

The viewing conditions were emphatically nonreduced. Stereo vision, the wire frames minimally obscuring the room, the alignment of the panel parallel to the rectangular frame of the room, and the horizontal placement of the stimuli were all arrangements designed to provide S with plentiful information about the true orientation of the stimulus pictures. Only with such information could he be expected to perform the discrimination.

As with the deck of 32, E displayed the cards one at a time, and sorted them into two piles face down in accordance with Ss' verbal judgment. After a S had completed one deck, E took the piles to another room where the results were recorded. The deck was then rearranged as described earlier, and the procedure repeated for the second angle.

The testing of the 16 Ss proceeded according to a three-way factorial design, the factors being sex, whether or not a S had participated in the earlier experiment, and whether 41 or 26 deg was the first viewing angle. The symmetry experiment mentioned earlier, which 6 Ss took just before and 6 just after the present experiment, was originally intended to involve all 16 Ss and complete a four-way factorial design, but was discontinued for reasons not relevant here.

### Method of Analysis

The projective and orthogonal predictions supported one another for some stimulus cards at a given viewing angle, but conflicted on others. The responses of each S were processed into 10 scores, which would summarize his performance and reflect the important distinction between cases of conflict and support. The 16 cards of orthogonal borderline status, the 90- and 180-deg cards, were not considered in the analysis (they were included in the stimulus set to maintain the parallel between the present and initial experiments and facilitate a later close comparison). No cards other than these were of projective borderline status.

The first two scores simply recorded a S's performance on the 32-card deck viewed orthogonally: what percentage of times he judged rectangular boxes rectangular, and nonrectangular boxes nonrectangular. Each viewing angle contributed four more scores to complete the total of 10. For a viewing angle, the stimulus cards were divided into four categories, according to whether both projective and orthogonal predictions were rectangular (a "nonconflict" case), both were nonrectangular (nonconflict), the one was rectangular and the other nonrectangular (conflict), or the one nonrectangular and the other rectangular (conflict). For each category and angle, a S's score was the percentage of times his judgments of the figures in that category agreed with the *orthogonal* prediction.

A preliminary analysis explored the influence on the 10 scores of the four factors, sex, participating in the original experiment or not, which oblique angle was tested first, and whether or not Ss had taken the above-mentioned symmetry experiment prior to the present experiment. Of course, there were insufficient Ss for an analysis of variance. Two-tailed t tests were performed on each score for each factor, with Ss matched according to the

**Table 1**
**Mean Scores Measuring Ss' Success**

| Scores | Orthogonally Rectangular | | Orthogonally Nonrectangular | |
|---|---|---|---|---|
| | Projectively Rectangular | Projectively Nonrectangular | Projectively Rectangular | Projectively Nonrectangular |
| Perpendicular Viewing | | | | |
| Figures/S | 14 | -- | -- | 14 |
| Percent Correct* | 94 | -- | -- | 79 |
| SD | 8 | -- | -- | 12 |
| 41-Deg Viewing | | | | |
| Figures/S | 42 | 14 | 18 | 38 |
| Percent Correct* | 87 | 83 | 72 | 68 |
| SD | 10 | 14 | 16 | 19 |
| 26-Deg Viewing | | | | |
| Figures/S | 20 | 36 | 8 | 48 |
| Percent Correct* | 93 | 73 | 42 | 72 |
| SD | 9 | 14 | 20 | 11 |

**That is, judged in accordance with the orthogonal classification.*

other three factors. In no instance was any difference significant at the .05 level, despite the large number of tests.

## RESULTS

Table 1 summarizes the findings, listing the number of cards contributing to each score for each S, and also the mean percentage of those numbers achieved over the 16 Ss. These percentages measure Ss' conformance with the orthogonal prediction. The conjectures advanced in the introduction were tested by means of several planned comparisons, rather than by an analysis of variance (Hays, 1963, Chap. 14), and the t tests mentioned below are independent as recommended by Hays.

The conjecture that Ss would compensate and judge predominantly in accordance with the orthogonal prediction was supported by the data. With one exception, the mean scores measuring conformity with the orthogonal prediction ranged between 68% and 94%. In each such case, the null hypothesis that Ss' classifications were unrelated to the orthogonal or projective predictions was rejected (chi square, $p < .001$). That the percentages lay significantly above rather than below the chance level of 50% showed that Ss had considerable capacity to accomplish the orthogonally predicted rectangularity discrimination, even at oblique viewing angles and despite projective distortion. The one contrary figure, the 43% of the 26-deg projectively rectangular and orthogonally nonrectangular pictures judged nonrectangular, was not significantly different from chance (chi square, $.05 < p < .10$). The 43% value was likely the result of a conflict between orthogonal and projective factors, rather than a sign that behavior was functionally unrelated to either prediction.

The conjecture that Ss' performances under oblique viewing conditions would be inferior to their performances under perpendicular viewing was confirmed. All eight mean scores from oblique viewing were less than the corresponding scores for perpendicular viewing. The null hypothesis that Ss would do just as well with oblique viewing was rejected by the binomial test ($p < .005$, one-tailed). As Table 1 indicates, the difference was in most cases several percentage points, though in a single case only 1%.

The conjecture that judgments of conflict pictures would agree less often with the orthogonal prediction than would judgments of nonconflict pictures was supported at 26 deg but not at 41 deg. At 41 deg, Ss actually scored higher for conflict pictures in the orthogonally nonrectangular range, and within both orthogonal ranges the difference between conflict and nonconflict scores were not significant (t tests matched by Ss, $p > .05$, two-tailed). At 26 deg, conflict led to substantially and significantly inferior performances (t tests matched by Ss, $p < .001$, two-tailed). In sum, oblique viewing affected Ss' judgments in two ways: first, performance was considerably impaired for conflict and nonconflict cases alike; the task was just generally harder. Second, in the 26-deg cases, there was impairment ascribable to conflict.

It was somewhat surprising to find no signs of projective influence at 41 deg. A more sensitive test was attempted. Six stimulus cards were selected whose projective predictions changed the earliest as the hypothetical angle of viewing in the computer calculations varied from perpendicular to 41 deg. Three were orthogonally rectangular and three were nonrectangular. When viewed at 41 deg, these of all the pictures would offer projections most decisively contrary to their orthogonal appearances. Here, if any place, projective influence should be found. In the original experiment (Perkins, 1972), there was no significant difference due to the different rotations for figures sharing Angle A, so Ss' judgments of the six figures were pooled and compared with their pooled judgments on six other figures matched to the first six by Angle A, but having the same rectangularity status at

41 deg that they did at 90 deg. Accordingly, there were 96 judgments where orthogonal and projective predictions conflicted and 96 where they did not; conformance with the orthogonal prediction was, respectively, 69% and 77%. The difference, although in the direction of projective influence, was not significant (chi square, $p > .30$).

This finding invited appraising Gombrich's suggestion that whatever compensation does occur is perhaps accounted for by phenomenal regression to the real object (Thouless, 1966). The six figures discussed above presented conflicting orthogonal and projective interpretations at a viewing angle of 65 deg to the plane of the page. Since significant projective influence was not found, and much less projective dominance, compensation "righted" the pictorial interpretation at least from 41 to 65 deg. Thouless's data from the ellipse matching experiment (Fig. 3, p. 164) indicated that the judgments of a circle at a 41-deg angle with the line of sight regressed to proportions appropriate to a circle seen at 45 deg. This does not really mean that Ss saw the circles as less tilted than they were. As Wartofsky points out (1972), the Ss' task was the painter's task of eschewing interpretation to capture the scene as projected, not a viewer's task of achieving a veridical spatial reading from a projection. At any rate, the regression effects found did not approach the magnitude needed to account for the present results.

## DISCUSSION

The results demonstrate that the visual system can compensate for projective distortion in obscuring pictures obliquely. Gombrich's notion that viewers judge principally by accepting the projected image and its attendant distortions is brought into question. On the contrary, the present findings suggest that compensation is the dominant trend in dealing with oblique views of depictions of rectangular solids. There was too much compensation to be accounted for by Thouless's regression to the real object. Furthermore, when judgments were inaccurate, they were largely *merely* inaccurate, rather than being governed by the projected image.

Some qualifications are in order, of course. Certainly there are occasions of projective influence. Evidence of such was found under the 26-deg oblique viewing condition. And such effects can be quite striking. Gombrich (1960, p. 252) offers an illustration of an "anamorphic picture," a portrait painted with extreme elongation of the face, but intended to be viewed almost edge on. The profile seems to emerge magically from the picture plane. Furthermore, the present results only demonstrate compensation in judgments of rectangularity. Possibly, a more general mechanism is involved, one which would facilitate compensation for many other sorts of judgments. On the other hand, to recall Gombrich's example, there may be people and trees a bit thinner, but there are not skyscrapers, rooms, staircases, books, tables, and so on, a bit less rectangular. In seeking a plausible reading of a picture, the eye might be more concerned about discriminating rectangularity than proportion under oblique viewing conditions. If so, since the two are mathematically related, how the visual system could get away with a double standard remains to be seen.

Finally, effective compensation necessarily depends on good evidence for the orientation of the picture plane; stereo viewing, a textured picture surface with a square frame, horizontal or vertical picture placement, and like factors would contribute to this. When such information is absent or inadequate, pictorial interpretation certainly tends to be based on the projected image, as Pirenne (1970, pp. 79-93) points out in his discussion of the ceiling painted by Pozzo in the Church of St. Ignazio, Rome.

However, under normal circumstances, there is ample evidence for the orientation of a picture plane. The remarkable compensation that can then take place should not be mistaken simply for a shape constancy phenomenon, for instance an ellipse interpreted as a tilted circle. The ellipse received by the eye is once projected, and the eye works backward from that single projection to achieve its interpretation (an interpretation which under reduced viewing conditions may not be accurate as to tilt—Eriksson, 1967). But in obliquely viewed pictures, the image the eye receives is twice projected, once to the picture plane and once again obliquely to the viewer's eye. Because the second projection is not parallel to the first, the combination of the two cannot even approximately be treated as one.

Accordingly, the eye has more work to do. It is as though the received image were corrected for the tilt of the picture plane—a task of spatial interpretation—and then the modified image were fed back through the visual system for another spatial reading. If such a mechanism were truly general, appropriate experimental conditions should elicit compensation for projective distortion of proportions of people or trees (for instance), whether or not such compensation is routinely practiced in the viewing of pictures. Just on the basis of the present experiment, at least a limited recursive capacity in visual functioning seems a plausible conjecture.

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