play a communicative role. In one species, which is similarly marked with orange in both sexes, a pronounced sexual dimorphism becomes apparent when the same markings are viewed in ultraviolet (Fig. 2, G–H). One is tempted to conclude that the orange is an aposematic display aimed by both sexes at enemy birds, while the ultraviolet disparity provides the basis whereby the insect communicates sexually within its "private" visual domain.

Ultraviolet video-viewing is an exciting teaching aid. Any closed circuit television can be adapted for this technique by merely outfitting it with a proper lens and filter.

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References and Notes

1. K. von Frisch, *The Dance Language and Orientation of Bees* (Harvard Univ. Press, Cambridge, Mass., 1967), and references therein.
2. K. Daumer, *Z. Vergl. Physiol.* **41**, 49 (1958).
3. G. A. Mazokhin-Porshnyakov, *Insect Vision* (Plenum Press, New York, 1969), and references therein.
4. F. E. Lutz, *Ann. N.Y. Acad. Sci.* **24**, 181 (1924).
5. J. Crane, *Zoologica* **39**, 85 (1954).
6. *Reference Data for Radio Engineers* (International Telephone and Telegraph Corporation, New York, ed. 4, 1956), p. 423.
7. R. E. Silberglied, thesis, Cornell Univ. (1969).
8. D. B. E. Magnus, *Proc. Int. Congr. Entomol. 10th* **2**, 405 (1958).
9. D. Ilse, *Z. Vergl. Physiol.* **8**, 658 (1928).
10. C. T. Post and T. H. Goldsmith, *Ann. Entomol. Soc. Amer.*, in press.
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Ponzo Perspective Illusion as a Manifestation of Space Perception

Abstract. *The Ponzo perspective illusion, a special case of space perception, is influenced by contextual factors, texture, stereopsis, and familiarity in addition to perspective cues. The importance of familiarity is demonstrated by cultural differences obtained with photographs of natural settings which emphasize depth cues.*

It has been suggested that the Ponzo perspective illusion (Fig. 1A) represents the operation of cues which normally subserve the perception of depth in three-dimensional space (*1*). Specifically, converging lines in the retinal image are ordinarily associated with distance and signal the organism to correct for the diminishing retinal image size of distant objects, that is, size constancy. When one views the Ponzo figure, this same cue falsely indicates depth and produces a size illusion. The hypothesis that the basis of this illusion is simply a manifestation of a normal mechanism of size perception has an intuitive and logical appeal. Whereas it would be an oversimplification to equate the illusion with space perception and size constancy, it would also seem unreasonable to limit the generality of this interpretation by concentrating solely on the perspective cue. Space perception and size constancy are complex phenomena involving various monocular and binocular cues as well as cognitive factors. If the Ponzo illusion is a special case of size and depth perception, it should be subserved by a number of the same cues which are common to two- and three-dimensional viewing situations. Further, this communality of function implies that space and size perception and the illusion should be sensitive to the same sort of experimental manipulations. We now present empirical evidence in support of this hypothesis.

Figure 1B illustrates a scene rich in depth cues which also contains the geometric elements that make up the Ponzo illusion (Fig. 1A). In these figures, the two horizontal lines are the same length, but presumably, because of the context in which they are viewed, the observer "corrects" for the assumed distance of the upper line resulting in an overestimation. In the first phase of a three-phase study of factors influencing this phenomenon, 24 subjects (students at the Pennsylvania State University) viewed the actual scene illustrated in Fig. 1B from the point at which the photograph was taken (*2*). In the second phase, 72 different subjects from the same population viewed the four two-dimensional stimuli illustrated in Fig. 1. In the third phase, 20 students native to Guam (University of Guam) were tested with the two-dimensional stimuli. Similar instructions were employed in all phases to obtain comparable judgments throughout the study (*3*).

In all cases the upper board or line was constant in length, while the lengths of the lower boards or lines were presented in random order. For all observation conditions, the equality value was determined by interpolation as the midpoint of the region at which the subject's responses changed. The magnitude of the overestimation or illusion is the percentage overestimation of the upper line or board.

For the actual scene, the length of the upper line was consistently overestimated, that is, matched by the lower line whose value was on the average 45.4 percent greater than would be predicted from the dimensions of the visual angle or retinal image (100 percent overestimation corresponds to size constancy). This value is comparable to data obtained in size-constancy experiments in which instructions, similar to those given in this study, were utilized (*4*). It should be noted also that the overestimation is three or four times greater than is reported for the abstract Ponzo figure which typically ranges from 10 to 15 percent for adult observers.

Reduction of cues by elimination of stereopsis was achieved either by observing the actual scene monocularly with the subject's head held steady, or by viewing the two-dimensional photographs of the same scene. In both cases, the extent of the visible field was equated. Similar results were obtained under both conditions. The overestimation for monocular observation of the actual scene was 34.7 percent, while the value for the photograph was 31.4 percent. Similarly, inversion of the real scene or the photograph further reduced the overestimation. Inversion was accomplished by rotating the photograph and by viewing the real scene monocularly through a Dove prism. The value for the actual scene inverted was 17.7 percent, and for the inverted photograph, 12.6 percent. A repeated-measures analysis of variance indicated that there were significant differences between the binocular upright, monocular upright, and monocular inverted conditions in the natural setting situation ($F = 48.4$, d.f. $= 2$ for 36 subjects, $P < .01$). An independent-measures analysis of variance indicated a significant difference between observations of the upright and inverted photograph ($F = 25.6$, d.f. $= 1$ for 46 subjects, $P < .01$). Two t-tests indicated no significant differences between observing the natural setting and observing the upright picture ($T = .61$, $P > .05$) or in the inverted condition ($T = 1.65$, $P > .05$).

Thus, the magnitude of the overestimation effect is closely dependent upon the presence of traditional cues to depth. Furthermore, the data illustrate the comparability of substituting a photograph for the actual scene, with the magnitude of the effect being independent of whether one observes the actual scene monocularly or the full-tone photographic reproduction.

Systematic reduction of contextual cues was accomplished by photographing the board configurations in an open field rich in texture but with a minimum of linear perspective cues (Fig. 1C). Further reduction was obtained by employing the classical Ponzo figure (Fig. 1A). Thus, A, B, and C in Fig. 1 all contain the essential elements of the geometric Ponzo illusion but with decreasing richness of contextual cues. A fourth control condition (Fig. 1D) was introduced because of the tendency to overestimate stimuli which are located higher in the visual field (*5*). The magnitude of overestimation or illusion was determined for these four conditions presented in random order to 72 Pennsylvania students, 24 in each group, who viewed the stimuli in the normal position, rotated 90° (side), and inverted. An additional 20 observers from Guam viewed the stimuli in the normal position. For the Pennsylvania subjects viewing the stimuli in the normal position, the greater the context, the larger the magnitude of the illusory effect (Fig. 2). The upper of two lines when presented alone is slightly overestimated. Addition of converging enclosing lines produces a typical illusion value of about 10 percent, the texture cues in the photograph double this value, and addition of the strong perspective cues provided by the railroad track results in a still further increase but one which is less than the effect obtained with the actual scene. The form of this line has no particular theoretical significance as complexity was not scaled on a quantitative or theoretical basis. Inversion of the stimuli reduces the magnitude of the illusion such that the inverted condition shows little difference between the geometrical figure and either of the photographs. The 90°-rotation produces intermediate values. The influence of rotation is relatively greater for photographs than for the geometric figure. The illusion magnitude is increased by the richer cues available in the full-tone photograph as compared to the geometric abstraction; perspective is a relatively stronger cue than texture; and cues provided by photographs are particularly sensitive to rotation and must be presented in a "normal" viewing position in order to be maximally effective. Analysis of variance revealed that both groups ($F = 10.9$, d.f. $= 3$ for 88 subjects, $P < .01$) and viewing conditions ($F = 61.2$, d.f. $= 3$ for 264 subjects, $P < .01$) are significant.

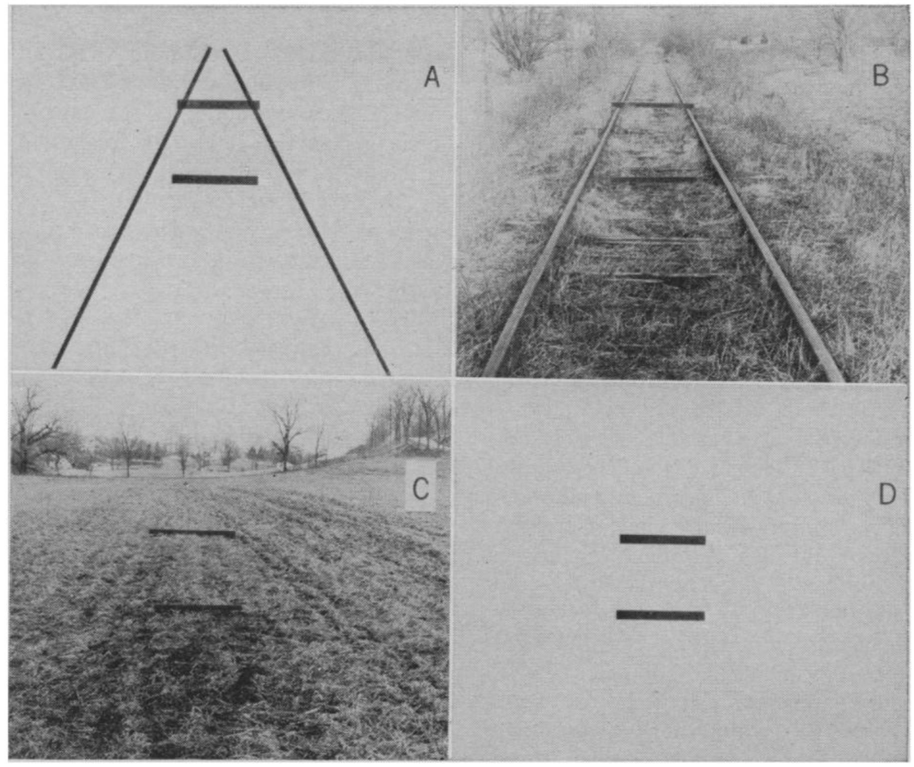

Fig. 1. The stimuli used in this study. The extent of the horizontal lines is the same.

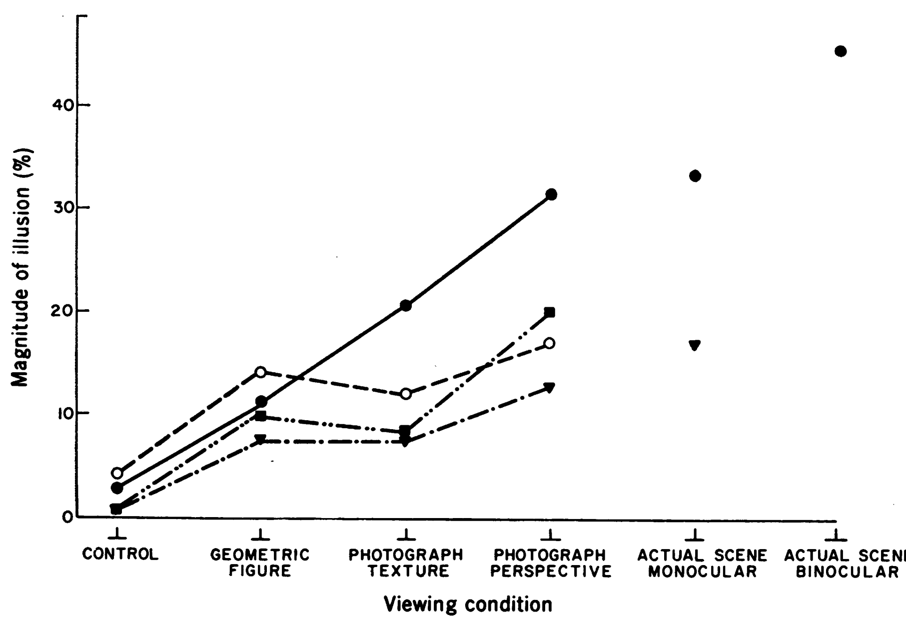

Fig. 2. The magnitude of the Ponzo illusion for the various conditions of the experiment. In each case, the illusion magnitude represents the percentage overestimation of the upper member of the pairs of lines illustrated in Fig. 1. Connecting lines are for descriptive purposes only. (Open circles) Guamanian subjects, upright viewing; (solid circles) Pennsylvania subjects, upright viewing; (squares) Pennsylvania subjects, side viewing; (triangles) Pennsylvania subjects, inverted viewing.

Monocular depth cues which are hypothesized to be operative in the Ponzo illusion and in size constancy are acquired through experience (*6*). If this is so, differential experience with such cues should influence magnitudes of the illusion (*7*). The Guam students were of the same age and educational level as the Pennsylvania subjects, but they had spent their entire lives on the island of Guam where the terrain is markedly different from that of central Pennsylvania. There are no railroads on the island, vistas on land are short due to hilly terrain covered by tropical plant growth, and such individuals do not normally view the kind of environments typified by the photographs used in this study. The Guamanians do not show the effects of context provided by the photographic stimuli that the Pennsylvania students do (Fig. 2). The illusory effect for the geometric figure and the two photographs is essentially the same, the function tending to resemble, at a significantly higher level ($F = 15.6$, d.f. $= 1$ for 42 subjects, $P < .01$), the data from Pennsylvania subjects viewing inverted stimuli. The data from island subjects are also different from that of the Pennsylvania subjects viewing upright stimuli ($F = 4.4$, d.f. $= 1$ for 42 subjects, $P < .05$).

The Ponzo illusion is apparently one manifestation of the general process by which observers compensate for the diminished retinal image size of more distant objects. In actual viewing conditions, size is signaled by a number of cues in addition to stereopsis which may include perspective as well as other monocular cues such as the position of the object in the visual field. Thus, it seems that the more cues available, the larger the magnitude of the overestimation or illusion. With the classic or geometric Ponzo figure, an illusion of 10 percent, which is only a fraction of the real-life effect, is observed in support of the hypothesis that the two-dimensional illusion is a special case representing the operation of only one of the many cues available in three-dimensional space. The influence of familiarity is illustrated by rotation of the figures which essentially eliminates the effectiveness of the additional cues provided by the full-tone photographs, but it has only a slight effect on the abstract geometric figure (*8*). The role of previous experience as a factor in determining the utilization of these cues is emphasized by their reduced influence among a group of subjects reared in a different physical setting. Finally, the study of complex cues and cross-cultural effects as factors in the perspective illusion is facilitated by the use of photographs. Such stimuli are more sensitive to manipulation of those variables of experience upon which the illusion is assumed to be based.

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References and Notes

1. R. Tausch, *Psychol. Forsch.* **24**, 299 (1954); E. V. Holst, *Studium Gen.* **10**, 231 (1957); R. L. Gregory, *Eye and Brain* (World Univ. Library, New York, 1966), p. 145.
2. The photographs were taken with a 90-mm lens on film (5.7 by 7.0 cm) enlarged six times and viewed at a distance of 61 cm. In the real scene, the board was 182.9 by 10.2 cm and located 18.29 m from the subject. The length of the variable boards ranged from 61 to 152.4 cm in increments of 10.2 cm, were 5.1 cm wide, and located 914.1 cm from the subject.
3. The instructions given in the natural setting in effect required the subjects to judge which board subtended the larger visual angle, that is, retinal instructions. The subjects who viewed photographs of the scene (Fig. 1, B and C) and the line figures (Fig. 1, A and D) were asked to indicate verbally which actual line in the photograph or drawing was larger. These instructions were thus equivalent to the visual angle instructions for the natural setting condition.
4. V. R. Carlson, *J. Exp. Psychol.* **63**, 68 (1962).
5. W. James, *The Principles of Psychology* (Dover, New York, 1950), vol. 2, p. 264.
6. H. P. Zeigler and H. Leibowitz, *Amer. J. Psychol.* **70**, 106 (19[illegible] H. Leibowitz and J. Judisch, *ibid.* **80**, 105 (1967).
7. M. H. Segall, D. T. Campbell, M. J. Herskovits, *Science* **139**, 769 (1963); *The Influence of Culture on Visual Perception* (Bobbs-Merrill, Indianapolis, 1966).
8. For the abstract figure (Fig. 1A), the absence of significant differences as a function of orientation and culture suggest that variables of experience are not the only determinants of the illusory effect for this particular stimulus.
9. Supported by NIH grant MH08061 and by the Council for Intersocietal Studies of Northwestern University.

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Rhesus Monkeys: Mating Season Mobility of Adult Males

Abstract. *Groups of rhesus monkeys, heretofore described as closed social units, experience a seasonal exchange of a portion of the adult males. Male shifting corresponds with the season of mating, and results in copulation with females of newly joined groups. This pattern is socially disruptive, but provides opportunity for exchange of genetic material between groups of a region.*

A portion of the adult male rhesus monkeys (*Macaca mulatta*) in northern India change groups during the mating season. Macaque groups have previously been characterized as "closed," highly inbred social units, similar to those described for savannah baboons and certain other primate species (*1*). Although intergroup transfer of males is reported for the colony introduced on Santiago Island in 1938 (*2, 3*) the effects of the spatial limitations, high population density, and intergroup familiarity of Santiago Island on group dynamics are not known.

Male shifts were studied for five groups residing on the grounds of the Forest Research Institute near the city of Dehra Dun. These groups ranged in size from 8 to 40 monkeys when observations began (Table 1). The total area of frequent use for all groups equalled about 2.59 km^2. Most of the nearly 400 hours of observation were evenly distributed between September 1965 and May 1966. Visits to the area in the preceding 5 months were irregular.

Transfers varied in details, but in all instances the shifting male clearly altered his patterns of foraging, resting, and travel to conform to those of the group joined. In some of the transfers, initial contacts consisted of short visits, but once the above pattern was established, it persisted from day to day. The shortest observed transfer lasted for 25 consecutive days. Although the five groups in the study area came into frequent contact, there were no observed contacts by individual animals apart from those of the shifting males. Thus, the simplest criterion for transfer is the sighting of any individual male within the vicinity of a group other than his group of origin.

The recorded transfers were somewhat complex (Table 2), involving shifts of varying duration, and without apparent relationship to group size or age (excluding subadults) or rank of the participating males. Four of the five groups received at least one alien male and all groups experienced departures at some point during the observation period, but no more than a single male from any one group shifted permanently. The largest group in the area (II) had the same contingent of males at the end of the shifting period as when it began. A small group (III) was without a resident male for about