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Intermodal Relationships in Children's Perception

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## Abstract

Since judgment of geographical slant requires the use of both optical and postural information, such judgments were used to determine whether intermodal relationships affect children's perception. First, third, and fifth graders made judgments of geographical slant of surfaces depicted in photographs either with or without postural inclination. The results indicate the existence of a linear mechanism which compensates for the effect of postural inclination.

Compensation was about 50% of that expected from an ideal perceptual system and did not change with age. The present data are similar to those previously reported for adults and suggest that the compensation process develops early in childhood.

### Intermodal Relationships in Children's Perception

One question raised in the study of perceptual development concerns children's ability to integrate information from different sense modalities, and several investigators have discussed how multimodal information may be combined to yield veridical perception (Eriksson, 1973; Gyr, 1972; Rosinski, 1974).

One approach to the study of intermodal relations involves examining the normal integrative workings of the perceptual systems. The ability to veridically perceive the world and to function effectively in that world involves an integration of information from various sense modalities (Gibson, 1966; Gibson, Olum, & Rosenblatt, 1955; Purdy, 1960). For example, these authors have pointed out that optically specified information is sufficient for relative spatial judgments, but that additional nonoptical information (such as observer's height, velocity, or postural inclination) is necessary for veridical absolute spatial judgments. Because optical and nonoptical factors must be combined, examining perceptual judgments when optical and nonoptical information are varied independently provides an ideal method for assessing the development of intermodal relationships. Our task made such an assessment by examining the perception of the slant of a textured surface rotated around a horizontal axis. Purdy (1960) has shown that slant judgments are in correspondence with texture-gradient information; however, a given texture gradient uniquely specifies only optical slant, that is, surface slant relative to the line of regard.

For a surface at a specific geographical slant, changes in either posture or eye position result in changes in optical slant. Phenomenally, however, slant remains constant over such changes, indicating that optical slant is being combined with postural information to yield constant judgment of geographical slant. If optical slant is specified by texture-gradient information, and if the coordinate system is specified vestibularly, proprioceptively, and/or kinesthetically, then the simple difference between the optical slant and the subject's inclination would specify geographical slant. (Alternatively, the coordinate system might be specified visually, e.g., by walls and floors; then the difference between the gradients would specify geographic slant in this coordinate system.)

The purpose of the present experiment was to ascertain the extent to which multimodal integration occurs in children's perception of geographical slant. Subjects were required to judge geographical slant while optical slant and postural orientation were manipulated. Specific quantitative predictions could thus be generated for either a total lack of integration or a perfect integration of optical and vestibular-proprioceptive-kinesthetic (VPK) information.

Consider the two viewing apertures in each of the two apparatuses schematically depicted in Figure 1. If a textured surface composed of equal-width black and white vertical stripes is viewed from aperture B, the optical

texture-gradient information specifies a surface in the frontal plane, and the surface should be judged as vertical (90°). If the same surface is viewed from aperture A, however, the optical texture-gradient information projects an optical slant of 135°, where slants greater than 90° indicate the top edge of the surface is closer to the subject than the bottom edge. If no integration occurs and if subjects' judgments are based solely on optical information, a judgment of 135° should be made. However, if the perceptual system takes into account the postural inclination, a judgment of 90° (correct geographical slant) should be made.

If the same textured surface were viewed from aperture C, the texture gradient yields an optical slant of 90°. The optical prediction would thus be a judgment of 90°, whereas the geographical slant is 45°. Similarly, the same surface viewed from aperture D would project an optical slant of 45°.

For photographs specifying surfaces at slants other than 90°, prediction curves based on optical information alone can be generated for each viewing aperture, as depicted in Figure 2. For viewing apertures A and d, projected optical slant,  $\theta'$ , is given by  $\sin \theta' = \sin \theta [\sin \delta / \sqrt{(1 + \cos \delta \sin 2\theta)}]$ , where  $\delta$  is the inclination of the photo relative to the line of regard. If slant constancy involves the difference between optical and nonoptical information, as suggested by Purdy (1960), curves A and C in Figure 2 should be displaced downward by 45°.

## Method

### *Subjects*

A total of 72 Pittsburgh parochial school students (24 (12 boys, 12 girls) in each of three grade levels (first grade, mean age 6.8 years; third grade, mean age 8.9 years; fifth grade, mean age 10.9 years) was tested. Each child made 52 judgments of slant. All subjects who normally wore corrective lenses did so in the experiment.

### *Apparatus*

*Stimulus displays.*—Photographs of a black and white vertical grating printed on F paper were used as stimulus displays. The slant of the grating around a horizontal axis ranged from 30° to 150° in 10 increments, where 90° is vertical and less than 90° indicates a surface whose top edge is farther from the observer than the bottom edge. For all slants the axis of rotation bisected the photograph. The photographic prints (18.4 X 23.5 cm) were cut into trapezoidal shapes so that outline-perspective information and gradient information specified the same slant, and the photographs were then mounted on flat black matte board.

*Viewing apparatus.*—The photographs were inserted into the apparatus schematically depicted in Figure 1. Two viewing apertures in each of two viewing apparatuses comprised the four conditions used in the present

experiment. In one apparatus, the photographs were held vertically ( $90^\circ$ ); in the other, they were held at an orientation of  $45^\circ$ . Subjects viewed the photographs monocularly through a 1-cm aperture, which was 50 cm from the center of the rotational axis of the photograph. Given these specifications, the arrays projected to the eye at apertures B and C were identical to those of the subject viewing the original surfaces. Because subjects' heads were not fixed, some movement of the eye back from the aperture was possible. The slight minification resulting from such a movement would cause a negligible change in the projected optical slant.

The interiors of both boxes were painted a flat black. In each apparatus, a 40-watt incandescent bulb provided illumination for viewing. Cross-polarized filters eliminated reflections from the surface of the photograph. The luminance of the black stripes in the photographs was  $0.17 \text{ cd/m}^2$ , and the luminance of the white stripes was  $3.42 \text{ cd/m}^2$ . The angular size of each bar at the axis of rotation was  $0.57^\circ$ . Under these conditions none of the apparatuses' surfaces could be seen and no visual reference frame was available. The observer saw a black and white striped pattern in black space. The texture gradient provided the only information for the slant of the surface in the photograph, although the orientation of the photograph itself was potentially specified by accommodation and accommodative convergence.

*Response device.*—A freely rotating Plexiglas palm board, pivoted in the horizontal plane, was used as a response device. Each subject placed his right hand on the surface of the palm board and adjusted its inclination to match the perceived slant of the display, without viewing the palm board. The axis of rotation of the palm board was approximately 9 inches (225 cm) below the level of the viewing aperture. Subjects' judgments were recorded to the nearest degree.

#### *Procedure*

Subjects were tested individually and were randomly assigned to one viewing condition with the constraint that an equal number of boys and girls be in each condition. At the beginning of each experimental session, the subject was instructed in the use of the response device and was given four practice trials with a real surface and full binocular viewing.

Each subject made a total of 52 judgments of slant in four blocks of three 13 stimuli. All 13 stimuli used in the experiment were represented in each block in randomized order, with the constraint that the same stimulus display could not end one block and start the next.

## Results

The mean judged slant in each of the four conditions for the 13 surface slants originally photographed is shown in Figure 3. A 3 (grade) X 4 (condition) X 2 (sex) X 13 (slant) analysis of variance was performed with repeated measures on slant.

The effect of physical slant was significant,  $F(12,576) = 61.71, p < .001$ . As the slant depicted by the visual array increased, so did subjects' judgments. Newman-Keuls comparisons showed that slants near  $90^\circ$  were discriminated more accurately. In general, within the range  $50^\circ - 100^\circ$ , slants differing by  $20^\circ$  were judged significantly different ( $p < .01$ ), while slants outside this range were more difficult to discriminate.

The effect of viewing condition was also significant,  $F(3,48) = 39.37, p < .001$ . Newman-Keuls comparisons indicated that judgments in conditions B and C differed significantly ( $p < .01$ ), indicating a substantial effect of postural inclination on judgments based on identical optical slants. Conditions A and B did not differ, suggesting that compensation for the combined effect of postural and photographic inclination occurred. Conditions B and D differed significantly ( $p < .01$ ), indicating some effect of the optic projection. In conditions C and D, where the photographs were inclined  $45^\circ$  from the vertical, performances did differ,  $p < .01$ .

These condition comparisons can be more fruitfully examined in the context of the significant condition X slant interaction,  $F(36,576) = 2.53, p < .001$ . The optical predictions for conditions B and C are collinear (see fig. 2). If perfect compensation occurred in condition C, we would expect performance to be displaced  $-45^\circ$  at every slant from condition B. Results demonstrated that both conditions are primarily linear ( $p$ 's  $< .01$ ). However, judgments in condition C were displaced only  $-23^\circ$ .

In comparing conditions B and A, the predictions based solely on optical information can be seen in Figure 2. The optical prediction is that the difference in judgments across slants between conditions A and B should be in the quadratic component of the interaction between these two conditions, since B was predicted to be a straight line and A was predicted to be curvilinear. The maximum difference between the conditions should occur in the middle range of slants. In fact, the quadratic component of the interaction was significant,  $F(1,576) = 18.29, p < .001$ . However, as can be seen in Figure 3, the greatest difference between conditions occurred at the extremes, instead of in the middle range. This result demonstrates that postural compensation occurred, with judgments in condition A being displaced approximately  $45^\circ$  in the middle range and between  $10^\circ - 15^\circ$  at the extremes.

Finally, conditions B and D differed only in the orientation of the picture relative to the vertical. Again, the optical prediction was that the difference in judgments across slants between conditions B and D should be in the quadratic component of this interaction, since B was predicted to be linear and d was predicted to be curvilinear, with the maximum differences between conditions occurring in the middle range of slant. The quadratic component of this interaction was significant,  $F(1,576) = 9.62, p < .01$ . Although the results follow the form of the optical prediction, the magnitude of the difference does not approach that specified by the optical predictions. In the middle range of slants, judgments in condition D were displaced 20 from the optical prediction.

A marginally significant effect of grade was also observed,  $F(2,48) = 2.40, .10 < p < .05$ . mean judged slant ranged from 76.9 in grade 1, to 79.8 in grade 3, and 79.7 in grade 5. subsequent analysis indicated that approximately 95% of the sums of squares for grade was due to the difference between grade 1 and the other two grades. This suggests that if there is some developmental change in space perception, it may occur earlier in childhood.

The nonsignificant grade X condition interaction ( $p < .10$ ) indicates no developmental change in the ability to combine optical and nonoptical information in the perception of geographical slant after grade 1.

#### Discussion

One of the primary findings of the present study is that by age 6, children are able to combine optical texture-gradient information for slant with postural inclination to make judgments of the geographical slant of a surface. There are two aspects of the present data which bear on perception of slant and compensation for postural inclination. The first issue which can be addressed concerns the adequacy of monocular texture gradients in the perception of slant. In condition B, with no postural inclination, the mean optical slant is equal to the geographical slant. Therefore, performance in this condition provides a "best estimate" of the children's ability to use gradient information. In this condition, as in the others, the data demonstrate some correspondence between judged and physical slant. However, at all grade levels and in all conditions, slants were judged more nearly vertical across the range used in this experiment. This is probably the result of the conflict between gradient information for the slant of the surface in the photograph and accommodative convergence information for the orientation of the picture plane itself. As can be seen in Figure 3, judgments appear to reflect a compromise between surface and photograph slant. Using adults and the same stimulus range, Rosinski, Mulholland, Degelman, and Farber (Note 1) found virtually a perfect regression of judged and physical slant with real surfaces. With frontal photographs of comparable stimuli,

slopes dropped to .5-.6. Displacement of judgment toward the vertical in the present experiment may be the result of a similar compromise and may reflect the effects of the presence of the picture plane.

A further interesting result is that surface slants with the top edge inclined toward the subject (greater than 90) were more difficult to discriminate than were surfaces slanted less than 90. Similar results have been found by both Rosinski et al. (Note1) and by Neilsen (1976). This latter study used a visual matching estimation procedure and found a similar lack of discriminability of surfaces slanted with the top edge toward the observer. The convergent finding in the present study suggest that Rosinski's and Neilsen's results reflect a general perceptual limitation.

Using condition B as such a "best estimate" of the optical registration of gradients, a comparison of conditions B and C provides a demonstration that intermodal integration occurs in children's perception of slant. These two conditions project identical optical slants to the observer's eye, and differ only in the observer's postural inclination. The difference in performance between these conditions indicates that by first grade, postural information influences judgment of geographical slant. The data, however, indicate that the compensation for postural inclination at all grades is approximately 50% of that to be expected from an ideal perceptual system. Comparable data drawn from Rosinski et al. (Note 10) indicate that in adults the compensation is also incomplete and of comparable magnitude when either picture or real surface slants are used. This pattern of results then suggests that the integration of gradient and postural inclination is incomplete over the range from first grade to college adults. These comparisons made against optimal performance in this situation indicate that the deficit in compensation involves either the registration of postural inclination or the accuracy with which the effects of posture can be "removed" from the optical projection.

The present data are not consistent with the predictions of sensoritonic theory, since the effect of kinesthetic, proprioceptive, and/or vestibular (tonic) inputs does not appear to differ over age. In addition, since compensation based on VPK systems is incomplete, perception in terms of a geographical coordinate system may also be affected by "visual proprioception." Lee and Aronson (1974), for example, found that children use the visual framework in perceiving postural inclination and in maintaining balance. It may well be then that such visual proprioception as well as the VPK systems combine with optical information to determine perceived orientation.

The collinearity of performance in conditions B and C suggests that postural compensation may involve a simple linear combination of optical and postural information, as suggested by Purdy (1960). The simultaneous manipulation of both postural and picture plane information, however, results in significant quadratic interaction

components which indicate a curvilinear correction for the effect of both posture and picture inclination. The nature of the compensation that occurs under changes in postural and picture inclination still remains to be determined.

In summary, it appears that by first grade children are capable of using postural inclination for the judgment of geographical slant. The compensation when posture is specified via vestibular, proprioceptive, and kinesthetic systems is incomplete. Since there was no developmental change of the age range tested in the ability to combine optical and postural information, and since the present data are similar to those reported elsewhere for adult subjects, it is suggested that development of a multimodal compensation process is virtually complete before first grade.

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Reference Note

1. Rosinski, R. R., Mulholland, T., Degelman, D., & Farber, J. (1977). Compensation processes in the monocular perception of surface slant. Unpublished manuscript, University of Pittsburgh.

Author Note

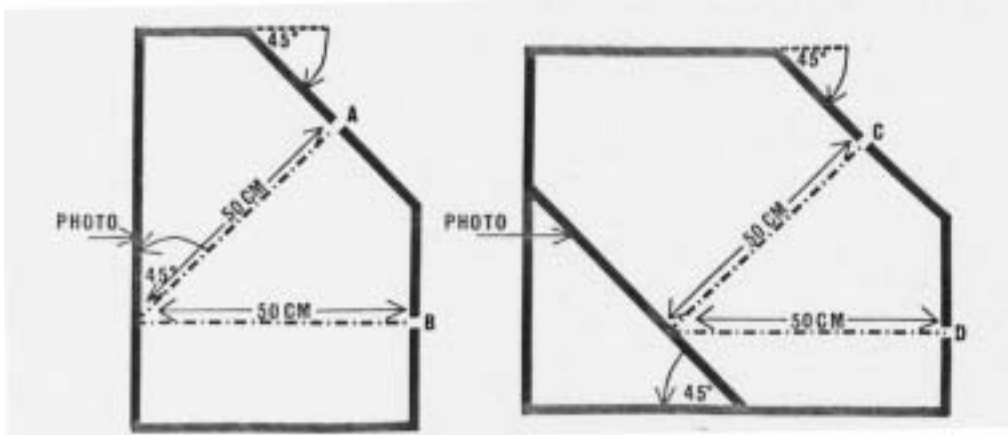
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Figure Captions

*Figure 1:* Schematic diagram of apparatus and viewing conditions

*Figure 2:* Optical predictions for each condition based on a hypothesis of no compensation. Curves derived from Rosinski et al. (Note 1).

*Figure 3:* Mean judged slant in each condition



# OPTICAL PREDICTION

