Influence of the oblique effect on psychometric functions obtained in studies of perceived tilt

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Psychometric functions that are not normal ogives are frequently obtained when the method of constant stimuli is employed to measure perceived tilt. This phenomenon has been reported with the parallel alignment technique (Andrews, 1967); it has also been found with the line-dot method (Matin, 1974). A particularly striking example can be seen in Figure 1, which shows eight psychometric functions obtained by using the line-dot method to measure the perceived tilt of a short luminous slit presented on a dark field for eight exposure durations varying from 10 to 640 msec. The data are plotted in normal deviate form and were fitted with linear functions by the method of least squares (employing Müller-Urban weights). Each of the eight sets of data departs significantly (and quite obviously) from the line expected for a normal ogive [p (chi square) < .01 for seven of the eight functions and p < .05 for one of them].

When the data in Figure 1 were collected, no plausible explanation had occurred to us for these departures from normality. However, inspection of the data and of similar results from a second subject suggested a surprisingly simple interpretation of the phenomenon in terms of meridional differences in sensitivity to orientation (the "oblique effect"; see Appelle, 1972, for a review). This interpretation will be outlined in the following paragraphs with an argument that is, to all intents and purposes, a generalization of Thurstone's analysis of the phi gamma hypothesis in relation to differential thresholds that increase with intensity. We will conclude for orientational sensitivity, as Professor Thurstone did for differential sensitivity functions governed by Weber's law, that the normal ogive is not the theoretically correct function for the psychometric curve (Thurstone, 1928).

To make the discussion concrete, consider the sensitivity function shown in Figure 2 which was obtained in a recent signal detection analysis of the

oblique effect (Matin & Drivas, 1979). For the subject whose data in the present study are shown in Figure 1, Figure 2 shows that sensitivity to orientation (plotted as the slope of the psychometric function in the normal deviate form rather than the more conventional standard deviation of the distribution) is great at a reference orientation of 0° (horizontal), decreases with an increase in reference angle, comes to a minimum at 45°, and then increases again. In the neighborhood of 60°, the reference angle employed in the present experiment, the slope is .195. Assuming a psychometric function that is linear in normal deviate form implies that the slope measured between 58° and 59°, 59° and 60°, 60° and 61°, and so on indefinitely is also .195. Clearly, however, that would only be true if sensitivity were independent of reference orientation—that is, if the slope sensitivity function were linear.

For the curvilinear sensitivity functions found in studies of acuity for orientation, we expect a curvi-

Figure 1. The psychometric functions. Normal deviate of the percentage of correct responses is plotted as a function of orientation of the comparison angle for eight exposure durations varying from 10 to 640 msec.

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Figure 2. The oblique effect. Slope of the psychometric curve as a function of reference orientation. Data taken from previously published signal detection analysis of sensitivity to orientation (Matin & Drivas, 1979).

linear psychometric function with a form that depends on the derivative of the sensitivity function in the neighborhood where the psychometric function is obtained. At 60°, where E.M.'s slope function is increasing, we could expect to find (and did find) negative skewing—functions that bend upward. This can be seen by inspecting Figure 1. To make the effect more obvious, however, we processed the data in another way, designed specifically to obtain a quantitative measure of the skewing. For that purpose, we measured slopes of the lines connecting the two points of successive pairs of data points on the psychometric functions. Thus, slopes were obtained for lines corresponding to seven pairs of comparison angles (55.79° and 58.18°, 58.18° and 60.29°, 60.29° and 62.16°, 62.16° and 63.82°, 63.82° and 65.31°, 65.31° and 66.64°, 66.64° and 67.85°). Eight slopes were calculated for each pair, one for each of the eight exposure durations employed. The data thus yielded a 7 by 8 matrix of two-point slopes. Means of the rows of these matrices (slopes for successive pairs of comparison angles averaged over the duration variable which was not systematically related to comparison angle) are graphed in Figure 3. Averages of the two comparison angles used to obtain the slope are shown on the abscissa.¹ The vertical bars signify $\pm$ one standard error. These graphs would have been horizontal lines for psychometric functions that are linear in normal deviate form. Instead, the slope tends to increase as the comparison angle increases, as would be expected from Figure 2, which shows that sensitivity to orien-

tation is increasing as the comparison angle moves toward the vertical.

If our analysis is correct, positive skewing is predicted for the psychometric function of this subject if measurements were to be made at 30°. In the neighborhood of 45°, where the sensitivity function is at a relative minimum, we would expect a psychometric function that is relatively steep, flattens, and then becomes steeper again. As the horizontal reference orientation, flattening is expected at both ends of the psychometric function relative to its center. A similar situation obtains at the vertical. In both the latter cases, errors on either side of the reference orientation would be expected to be greater than the proportions predicted from the sensitivity function at that orientation. And, indeed, that is the result Andrews obtained when he examined the normality question at a reference orientation of 0° (Andrews, 1967, Experiment II). Quite naturally, he generalized those findings, concluding that "errors of apparent slope are not normally distributed: large errors are relatively more common" (Andrews, 1967, p. 976). From the point of view of the present analysis, the flattened tails in Andrew's experiment are not a general characteristic of psychometric functions in studies of perceived tilt, but rather a special case, peculiar to the reference angle at which he made his measurements.

While the details of our remarks in the preceding paragraphs were focused on acuity for orientation, the essence of the argument only depends on sensitivity functions that are not horizontal. In effect, therefore, our reasoning is applicable to all measurements of differential threshold. As noted previously, Thurstone analyzed the question in detail for the special case of sensitivity that decreases monotonically with stimulus magnitude (for sensitivity expressed as slope of the psychometric function as shown on the left axis in Figure 2 of the present paper²). It was also

Figure 3. Two-point slope functions. Slope for successive pairs of comparison angles averaged over the duration variable is plotted as a function of comparison angle. See text for further description.

considered in Wright's analysis of the pigeon's hue discrimination function, which is not a monotonically decreasing relation (Wright, 1974). Empirically, however, Wright found psychometric functions that were sensibly linear in normal deviate form. And, indeed, despite the logic that would lead us to expect them, departures from normality are not generally noted when the method of constant stimuli or signal detection techniques are employed in measuring sensitivity.

The explanation for this paradox can also be found in Thurstone's analysis, which showed that the expected magnitude of departure from normality in psychometric functions related to monotonically decreasing sensitivity functions (Weber's law) depends on the coarseness of the discrimination. For fine discriminations, the departure is so small that it is practically not detectable. (See Figures 2, 3, and 4 in Thurstone, 1928.) Thurstone's reasoning can be generalized to include sensitivity functions that are not monotonic by simply noting that departures from normality are only practically discernible when the derivative of the sensitivity function is great relative to the absolute sensitivity in the neighborhood where the psychometric function is obtained. If the absolute sensitivity is great and the derivative of the sensitivity function small, the entire uncertainty region can be encompassed by a range of stimuli small enough to make constant sensitivity a good approximation. Because this is not generally the case for orientation sensitivity, departures from normality can frequently be quite readily discerned.

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NOTES

1. Because the percentage of correct responses was sometimes 0 or 100 at the extremes of the distribution, it was not possible to calculate seven two-point slopes at each exposure duration. Accordingly, there were several empty cells in the first and last rows of the 7 by 8 matrix of slopes. Averages of these two rows were therefore less reliable than those of the remaining five rows and were not graphed in Figure 3. It should be noted, however, that inclusion of these points would not have resulted in any change in the argument we have presented.
2. Slope of the psychometric function varies directly with sensitivity. Accordingly, the minimum of the function in Figure 2 occurs at 45°, where the subject's acuity for orientation is poorest. At that point, slope⁻¹, which is directly proportional to the traditional just noticeable difference or standard deviation of the ogive, is maximal. Throughout this note, sensitivity functions refer to slope functions. With that convention, Weber's law describes a monotonically decreasing relation. Thurstone (1928) refers to a monotonically increasing relation because he is writing in terms of just noticeable differences.

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