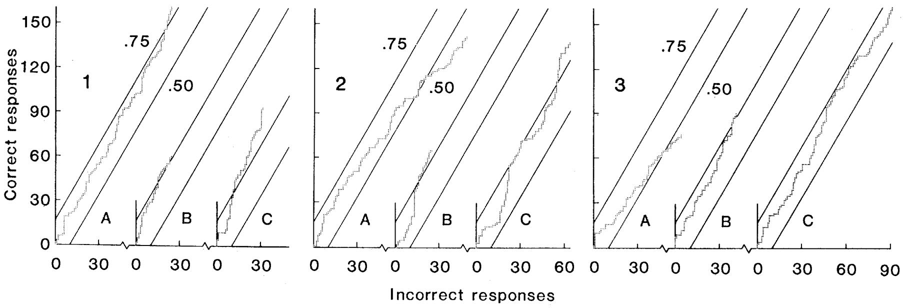

Fig. 2. Results of stingray orientation experiments as evaluated by sequential analysis. Stingrays 1, 2, and 3 were conditioned to orient with respect to uniform electric fields of 5 nV/cm under various magnetic conditions: (A) in a magnetic null field, (B) in the presence of only the vertical component of the earth's magnetic field, and (C) in the normal earth's magnetic field as measured in the southern California area where the rays were collected. The α and β errors associated with acceptance of orientation (.75 or three out of four, upper critical line) and rejection of orientation (.50 or random, lower critical line) were both set at .001.

tional to cosine α, where α is the angle between the electric field vector and the normal to the wall surface. A circular, wide-meshed plastic fence kept the animals from coming too close to the salt-bridge tubes. At a tank diameter of 1.8 m, a water depth of 15 cm, and a resistivity of 22.5 ohm-cm, a total of 0.6 μA sufficed for the threshold field (5 nV/cm). Inside the fence, the field was uniform to within 5 percent (*14*). The magnetic field was controlled by two single-axis Helmholtz coils.

Stingrays were tested two or three at a time, which allowed them to interact competitively. They earned a food reward for entering the correct enclosure, and a gentle prodding for an incorrect choice. Before each trial, the polarity of the field was selected randomly to prevent the use of nonelectrical cues. The experiments began at field strengths common in ocean waters, either 0.16 or 0.08 μV/cm (*10*). After each series, the voltage gradient was lowered by a factor of two until the stingrays failed to orient.

Orientational performances were evaluated by the sequential probability ratio test (*13, 15*). The null hypothesis H_0 was defined by a random or 50 percent correct choice, and the alternative hypothesis H_1 by a three out of four or 75 percent correct choice. The risks of erroneously rejecting or accepting H_0 were both set at $\alpha = \beta = .001$. In conformity with the usual procedure in sequential analysis, it was decided after each trial whether to accept the null hypothesis, to reject it, or to collect more data. The results of the series at 5 nV/cm (Fig. 2) showed that the first stingray oriented electrically, at $P \leq .001$, under all three magnetic conditions (218, 59, and 47 trials, respectively); that the second stingray failed to orient in the null magnetic field (171 trials), but did orient electrically in the presence of the vertical and the normal magnetic fields (62 and 77 trials, respectively); and that the third stingray was random in the null field (113 trials), oriented electrically in the vertical magnetic field (121 trials), and did not reach either critical level in the normal magnetic field (289 trials). At a field strength of 2.5 nV/cm, orientation was random in all three fish.

It should be emphasized that a successful performance would be extremely unlikely, at set criteria, if the fish were actually unable to orient to the field, whereas a lack of orientation need not contradict the animal's capabilities. However, whether elasmobranchs actually apply their electric sense to the detection of ocean currents and territorial cues must still be verified at sea. That the stingrays are able to distinguish the imposed electric fields from the usually much stronger fields that they induce by moving through the earth's magnetic field also suggests a familiarity with the latter and is consistent with the hypothesized electromagnetic compass sense (*12, 13*).

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14. With the distance from the screen to the wall equal to the distance between neighboring electrodes, the field is uniform to ~ 0.5 percent.
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16. I thank S. Dijkgraaf and T. H. Bullock for their encouragement, V. Kalmijn for assistance, and the Eppley Foundation for Research for providing the research vessel. Supported by the Office of Naval Research, contract N00014-79-C-0071.

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Correlations Perceived and Measured

Cleveland, Diaconis, and McGill (*1*) describe three related experiments in which groups of subjects of some to presumably great sophistication about statistical procedures were asked to judge, by the "eyeball method," linear association of synthetic two-dimensional scatterplots. The diagrams were constructed to reflect significant scale (point-cloud size) variation at constant degree of association, for a range of degrees of association (*2*).

The results of all three experiments agreed that an increase in scale, which is manifest in decreased point-cloud size, is usually accompanied by increased judged association; furthermore, the two quantitative studies indicated that perceived degree of association does not appear to be a simple function of the most familiar statistic, the correlation coefficient. Cleveland *et al.* suggest several explanations for the scale effect, including perceived properties of the scatterplot ellipses and point size relative to display area dimensions, but they appear to overlook a simpler explanation which ultimately bears on the second result, that is, the role of the correlation coefficient, as well.

This concerns the perceptual influences of the axes and whether and how they are specified and located implies varying weights for the origin. Can the observer fail to note that the point cloud falls about the line $y = x$ and unconsciously add the origin as a fixed point [with greater effect the further the point distribution appears from the origin (*3*)]? This is tantamount, in the limit of complete reference to the origin, to substitution of the raw relationship

$$R = \left\{ \frac{[\Sigma x_i y_i]^2}{\Sigma x_i^2 \Sigma y_i^2} \right\}^{1/2}$$

for the correct definition of the correlation coefficient

$$r = \left\{ \frac{[\Sigma(x_i - \bar{x})\,(y_i - \bar{y})]^2}{\Sigma(x_i - \bar{x})^2\,\Sigma(y_i - \bar{y})^2} \right\}^{1/2}$$

in quantitative evaluation of linear association. It is well known, however, that R can be made as near unity as desired by translation of the point-cloud distribution with respect to (away from) the origin; r remains invariant to such transformations (*4*). Increasing scale gives the impression of such movement and hence the erroneous conception of improved association (correlation).

This explanation raises several other pertinent questions, some of which may be answerable from data already available from this or related studies. The first is whether significant differences are to be noted between the responses of more sophisticated subjects and those less so, such as beginning statistics students, to whom the role of the mean would be expected to be less obvious. (The existence of this comment suggests not.) Another question is whether complete absence of axes (that is, having point-clouds on otherwise bare panels) or translation of axis origin to the center of gravity of the point clouds or otherwise (without rotation) would change the perceptions and hence the subjects' responses significantly. Such translation without rotation of course maintains the same value of r. Conversely, would different judgments of linear association accompany axis rotation that changes the value of r?

Thus, although the procedures described by Cleveland *et al.* for uncovering perceptual strategies in judging association are clear for the case of centered data, they may not apply when other forms of presentation are used.

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1. W. S. Cleveland, P. Diaconis, R. McGill, *Science* **216**, 1138 (1982).
2. "Degree of association" on a scale of 0 to 100 was the terminology used in the instructions to subjects in two of the three studies. The scatterplot families were in fact separated uniformly by 0.1 from 0.1 to 0.8 in the measure $w(r) = 1 - \sqrt{1 - r^2}$, where r is the correlation coefficient (with $w(r)$ cases of 0.0 and 0.05 thrown in for good measure). In the third experiment, choices of the more highly correlated scatterplot of pairs were requested.
3. Models where the magnitudes of the individual points with respect to the origin are intended do exist. These correspond to regression through the origin by specification or weighting. [G. W. Snedecor and W. G. Cochran, *Statistical Methods* (Iowa State Univ. Press, Ames, ed. 6, 1967), pp. 166–170; M. E. Turner, *Biometrics* **16**, 483 (1960); S. Ehrenson, *J. Org. Chem.* **44**, 1793 (1979)].
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If, as Ehrenson suggests, a subject unconsciously adds the lower left corner of the frame, then it might be that the upper right corner is added as well. We could test all of this with experiments the same as our previous ones, but with the major axis of all point clouds equal to something other than 45°. A competitor to the hypothesis of an unconscious addition of corners is a second hypothesis that the total amount of white space between the frame and the cloud is the important factor. This second hypothesis would predict a similar result in the new experiments as in the old; the first would predict no effect or a lessened effect of a change of point-cloud size.

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Radiation Angle and Heat Transferred to a Bird

In a study of thermoregulatory effects of avian plumage, Lustick *et al.* (*1*) draw two unsubstantiated conclusions: (i) "as the angle of incidence increases, the reflection coefficient goes up no matter what the color" of the feathers, and (ii) "as the bird increases the angle of incidence to direct solar radiation through postural changes . . . color becomes less important," or more specifically that "a dark bird by postural adjustment (increasing the angle of incidence) can effectively become white with regard to solar radiation."

A major difficulty is that analysis omitted the principal variable affected by increased incidence angle: the effective area being irradiated. Absorbed radiant power (R) is governed by $R = A\alpha I$, where A is the silhouette area being irradiated, α the absorption coefficient, and I the irradiance (*2*). Lustick *et al.* (*1*) held I constant and apparently assumed that the inferred change in R was due to altered α, whereas the main effect is actually due to change in A. If a square plane x on a side is normal to the radiation axis, its silhouette area is x^2; but if that square be tilted through an angle θ along any axis parallel to one of its sides, its silhouette has the dimensions x and $x \cos\theta$, for a silhouette area of $x^2 \cos\theta$ (*3*).

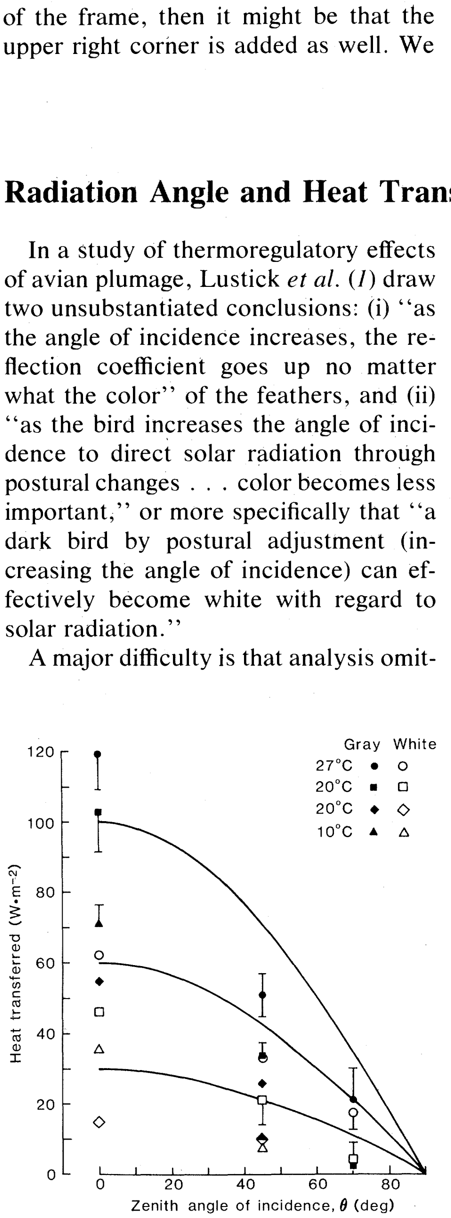

Fig. 1. The expected decrease in heat flow with incidence angle due to decreased area of irradiance is shown by lines calculated with three sample cosine functions having different maximum heat flows at 0° zenith angle. The actual heat flows measured in (*1*) are shown by data points for four experiments with different air temperatures. Error expressions are included where given in (*1*), space on the graph permitting; points not plotted at $\theta = 70°$ are all zero.

There is insufficient information in (*1*) to model heat transfer of the plumage completely (*4*), but one may compare the measured heat flow beneath the feathers with the reduction expected from reduced silhouette areas. Figure 1 shows that the transferred heat does indeed decrease markedly with greater zenith-angle of incidence. However, it does so primarily because of the reduced silhouette area, as indicated by the cosine curves for sample maximum values of 100, 60, and 30 W/m^2. It might also be true that "as the angle of incidence increases, the reflection coefficient goes up" (*1*), but such an effect would be too small to detect in the data-variability at low angles. Furthermore, there is no evidence that by "increasing the angle of incidence" the bird "can effectively become white" (*5*).

Does the experiment apply to real birds in sunlight? By "postural adjustment" Lustick *et al.* apparently refer to bodily orientation, whereas the principal

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