rotation, however, all uneven (3rd, 5th, etc.) moments will change at least their algebraic signs if the rotation is one of 180 degrees, and the value of all moments will change for any other amount of rotation as well as reflection. If Polidora's patterns did not show differences in the values of moments with rotations it means that these measures were either not properly computed or used.

The second reason for the poor showing of measures that were not Polidora's lies in the extremely coarse grain of the matrix used to construct the stimuli. While Polidora's measures work fine with patterns constructed in a 4 by 4, 3 by 3, or even a 2 by 2 matrix, such a coarse grain renders any other measure on these patterns useless. The second moment of area, for example, is a measure of variance. The largest number of lighted cells in Polidora's 4 by 4 matrix was 11, but how meaningful is the variance computed with an N of 11? Just adding or subtracting one element changes the value of a moment drastically, especially the values of the higher moments. The same goes for the P and P^2/A measures. A change in just one element affects these measures to such an extent that they become meaningless. As long as every cell in a matrix is potentially available for use as pattern element, increasing the fineness of grain will not help. As a matter of fact, two patterns constructed in a 20 by 20 matrix, for instance, with one-half of the cells lighted in a random fashion will be indistinguishable even when one is made the negative of the

other, i.e., the UE value is maximized. Moments of area of such matrices would be practically identical and predict no discrimination. Such two patterns, however, may be quite discriminable under certain conditions even if their UE value is only 1, but this type of pattern will of necessity begin to look like a polygon, e.g., two solid squares with just a "hole" in the middle of one, or an indented corner. While the UE measure would not predict discrimination here, some appropriate measure, such as moments of the perimeter, would. What this amounts to, as Polidora points out quite correctly, is that form measures must fit the conditions of their application. This includes not only such considerations as whether single or multiple stimuli are used in a display but also the size of the grain that has been used to construct and measure the stimuli.

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Reply to Zusne¹ by V. J. Polidora

Zusne (1967) has raised three principal points of criticism of my paper (Polidora, 1966), and I shall discuss them in turn.²

(1) Only four of the 15 dimensions were systematically varied, and "Unless these other (11) dimensions are correlated with these four, they will vary randomly, and it will be impossible to determine their respective contributions." The 11 dimensions did indeed vary randomly in terms of how frequently individual discrimination problems represented values of each dimension. I feel, however, that this fact does not detract from the validity of the results of the multiple regression and discriminant function analyses. The former analysis showed that discriminative performance significantly covaried with certain of these 11 dimensions (simple product-moment correlation), but that when the intercorrelations of each dimension were evaluated by partial correlation techniques, only the Unique Elements dimension remained significantly related to performance. The discriminant function analyses corroborated this conclusion. This result was obtained despite the fact that the Unique Elements dimension also varied randomly (as acknowledged on p. 411). Random sampling of different numbers of problems at each level of a

(hypothetical) truly "valid" dimension will not necessarily destroy the predictive power of the "valid" dimension provided the size of the sample is adequate, nor will such an experiment necessarily reveal insignificant relationships simply because of random sampling.

(2) "All measures were pitted against one, Unique Elements, which, by definition, reflected any and all possible differences between two patterns, hence correlated with every one of the measures used." Zusne is in error on two counts: In the first place the statistical analyses pitted every dimension against every other; the results revealed the predominant contribution of the Unique Elements dimension. Secondly, the intercorrelations between Unique Elements and the remaining 14 dimensions were invariably low for all dimensions, correlating poorly with performance (range -0.04 to +0.12) and somewhat higher (+0.05 to +0.28) for dimensions which did correlate significantly with performance (i.e., the six dimensions Zusne referred to). The important point, however, is that the significant partial correlation between Unique Elements and performance proves that the significant simple correlations were due solely to their intercorrelations with Unique Elements.

Furthermore, (see p. 412) Unique Elements computed "as if" one of the two patterns were rotated 90° , 180° or 270° also "...reflected any and all possible differences between two patterns..." but the partial correlations of performance with these "rotated" Unique Elements dimensions were insignificant, and all intercorrelations with other dimensions were not significantly different from zero. The insignificant partial correlations of the three "rotated" Unique Elements dimensions also disproves Zusne's assertion that "As a result and by virtue of the statistical treatment given the data it (Unique Elements) simply had to be the only measure to correlate with the subject's response significantly." The rotated Unique Elements dimensions have all the attributes of the nonrotated Unique Elements dimension except for the latter's being computed on spatially corresponding elements of the two patterns. By Zusne's line of reasoning they too should have been significantly related to S's performance, but they were not.

(3) Zusne's third criticism relates to the very coarse *matrix grain* of 4 by 4 metric patterns. The core of Zusne's criticism on this point seems to relate more to the inappropriate or disproportionate measures which other dimensions make of these simple visual patterns. It must be replied that these inadequacies are inherent in other dimensions and not in the patterns. Simple visual patterns are nevertheless visual patterns, and any candidate dimension should either be tailored to apply to all classes of patterns, or the limitations of the dimension should be explicitly stated. I made no pretext of the universal applicability of a Unique Elements interpretation of visual pattern discrimination, and in fact I expressly raised doubt as to the generality of such an interpretation (p. 413). The main point of my paper was that given such metric patterns—regardless of what dimensions *can* be utilized for discrimination—monkeys *do* discriminate predominantly on the basis of a Unique Elements dimension.

Zusne is correct when he points out that I was in error by stating (p. 412) that only a Unique Elements dimension predicts discriminability of two identical

patterns when one of them is rotated or displaced; certain moments of area also predict discriminability. However, upon reanalysis of the appropriate data (viz., Table 7), performance on these problems was found to be not significantly correlated with either the 2nd, 3rd or 4th moments of area dimensions ($p > .20$ in each case). Therefore, although Zusne has detected an oversight on my part, the moments of area dimensions were found to be not significantly related to performance, whereas Unique Elements was ($r = .81$).

One final point: Zusne says, "As a matter of fact, two patterns constructed in a 20 by 20 matrix, for instance, with one-half of the cells lighted in a random fashion will be indiscriminable even when one is made the negative of the other, i.e., the UE value is maximized." Six such problems, each composed of a pair of eight-element patterns where one is the negative of the other, were by chance included in the experiment subsequent to those reported in the paper under discussion. Performance on these six problems was excellent. Percentage correct responses on trials 2-7 were in the range of 68.1 to 87.5 with a mean of 79.9, a value well in line with that predicted for 16 Unique Elements from the function given in Fig. 5 (additional data to be reported indicate that the shape of this function is exponential).

In summary, then, I believe the bulk of Zusne's criticisms were answered in the original paper.

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Notes

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2. All direct quotes are from Zusne (1967); all page, figure and table citations refer to Polidora (1966).

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