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CLASSIFICATION OF RANDOM FORMS AND DISTORTIONS PRESENTED TO THE LEFT OR RIGHT VISUAL FIELD

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Summary.—Twenty right-handed undergraduate men were taught in free vision to categorize distortions of prototypic random forms and were then tested in a Go/No Go task with lateralized tachistoscopic presentations of previously sorted (old) distortions, new distortions, the prototypes, and unrelated forms. Accuracy of performance on positive items increased in the order New < Old < Prototype. More false alarms occurred to unrelated items in the right than in the left visual field, suggesting that the trace systems generated during training had different characteristics in the two hemispheres.

Although some recent investigators (e.g., Levy, 1974) have contended that the right hemisphere is deficient in the ability to engage in abstract conceptualization, evidence from split-brain studies indicates that the right hemisphere may even be superior to the left in the abstract processing of non-verbal stimuli. Nebes (1971) found that commissurotomized patients were better able to match an arc to the circle of which it was a part with their left than with their right hands; there were no inter-hand differences in arc-arc or circle-circle matching, and Nebes inferred a right hemisphere superiority in generating the concept of the whole from a fragment. Likewise, split-brain patients were better with their left than with their right hands in the tactile identification of a form most representative of, but not identical with, a set of five forms presented visually (Franco & Sperry, 1977). Furthermore, as the number of defining constraints on the geometric stimuli decreased, right-hand performance steadily declined, whereas left-hand performance was maintained at a relatively constant level of proficiency.

Results obtained with commissurotomy patients have not, however, always been replicable in normal subjects, in whom there is opportunity for cross-talk between the hemispheres and for the influence of one hemisphere on the activities of the other. In the present experiment, we asked whether a right-hemisphere superiority in normal subjects could be demonstrated using a procedure based on the prototype-abstraction paradigm of Posner and Keele (1968, 1970).

Posner and Keele found that subjects trained to classify distortions of prototypic random dot patterns were then able to classify the prototypes they had never seen before more accurately than they could new distortions which they had also never seen. They concluded that, in the process of learning the distorted exemplars of a prototype, the subjects had generated the abstract idea or schema of the prototype itself.

It occurred to us that at least two fundamentally different cognitive strategies are available to subjects in the initial training phase. The first, emphasized by Posner and Keele, is to generate a schema or prototype representing the central tendency of the training series. The second is to attend to specific features of the stimuli. We hypothesized that, because the preferred ode of the right hemisphere is said to be configurational and holistic, as opposed to the analytic mode of the left hemisphere (e.g., Bever, 1975), the abstraction of the prototype is likely to be more accurately generated or stored in the right hemisphere than in the left. Attention to specific features, on the other hand, seems more compatible with the preferred processing mode of the left hemisphere.

We trained subjects in free vision to sort distortions of several prototypic random forms and then tested them in classifying laterally presented old and new distortions and the prototypes themselves. We predicted that the superiority of the left visual field (right hemisphere) in this task would be greater for the Prototypes and New items than for Old items. This prediction is based on the assumption that Prototypes and New Items are more accurately classified by matching to an internal prototype than by reference to specific features, whereas an Old item can be recognized not only be reference to a central prototype or feature list, but indeed even by simple comparison with the memory trace of that particular item.

METHOD

Subjects

Twenty male undergraduate students, all self-declared right handers, fulfilled a requirement of an introductory psychology course by serving as subjects.

Stimuli

We selected as prototypes four irregular polygons, modified from 12-angle items of Vanderplas and Garvin (1959). Each prototype was drawn centered on a 30 X 30 grid, and the coordinates of the points formed by the angles were determined. From each prototype a series of 5.3 bits/point distortions was computer-generated by a variant of the technique of Posner, Goldsmith, and Welton (1967), which applies statistical rules to move each prototypic point a variable distance in a random direction. The distortions were computer-plotted in outline by connecting the points in the prototypic sequence.

Each distortion was accompanied by its “complement,” a distortion each of whose angle points deviated from the prototypic point the same distance as in the initial distortion, but in the opposite direction. Thus, if in one distortion a point was shifted three units upward and one leftward form the prototypic point, then in the complementary distortion the point was shifted three units downward and one rightward. The central tendency of such a pair of distortions is the prototype. Distortions that resulted in any lines crossing each other, i.e., those resulting in two or more enclosed areas, were discarded. The mean straight-line distance the points were moved was 2.72 units. Examples are given in Fig. 1.

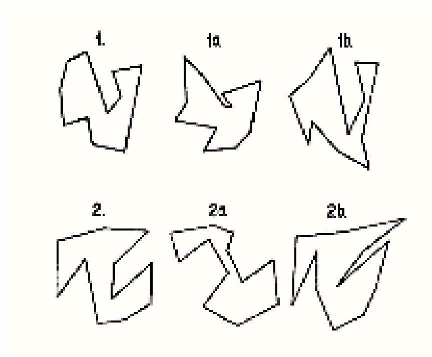

Fig. 1.
1a and 1b are complementary distortions of Prototype 1. 2a and 2b are complementary distortions of Prototype 2.

Sorting decks.—Four decks of 40 3- X 5-in. cards were prepared with a distortion located centrally on each card. Each deck consisted of five complementary pairs of distortions of each of the four prototypic patterns. The sequence of cards was random and varied from deck to deck.

Tachistoscopic slides.—Slides were prepared of Old distortions (from the sorting decks), New distortions of the same four prototypes (which did not appear in the sorting decks), and the Prototypes themselves. For each of the four patterns, a separate 80-trial block of slides was generated. The 42 positive trials in each block consisted of 6 presentations of each of three Old items, 6 presentations of each of three New items, and 6 presentations of the Prototype. Within each of the three categories, half the presentations were to the right visual field (RVF) and half to the left visual field. The sequence and spacing of the 42 positive trials were quasi-random and varied from block to block; the intervening items were buffers, 19 to each field, consisting of random patterns unrelated to any of the prototypes.

Procedure

Phase I: Sorting.—The sorting decks were used to train subjects to classify correctly the 10 distortions of each of the four prototypes. The experimenter sorted the first deck, explaining to the subject that the patterns could be sorted into four bins quickly and without verbalization, on the basis of general similarity in appearance. The subject was then instructed to sort the second and subsequent decks as quickly as possible and without speaking, on the basis of his first impression of the shape. When a card was correctly sorted, the experimenter said “Correct;” if an error was made, the experimenter said “Wrong,” and the subject re-assigned the card until it was correctly placed. Sorting continued until the criterion of no more than one error on a deck was reached.

Phase II: Tachistoscopic Testing.—Slides were presented for 30 msec. by projection tachistoscope, details of which have been presented elsewhere (Axelrod, Haryadi, & Leiber, 1977). Before each trial the subject was instructed to fixate a centrally placed cross. The point on the projected pattern closest to the fixation cross was on average 1˚ from the cross; the most peripheral point averaged 4˚30’ in eccentricity.

The procedure was Go/NoGo. The experimenter covered three of the bins which had been used during sorting, pointed to the remaining one, and instructed the subject to respond to each tachistoscopic stimulus only if the pattern presented “would belong with” the forms he had sorted into the indicated bin. After the 80 trials, another bin was indicated, and so on, until all four blocks were completed. The order in which the blocks were run varied from subject to subject according to Latin squares. Subjects responded with a manual key-press; half the subjects responded with the left hand and half with the right.

RESULTS

Correct key-presses to positive stimuli, i.e., hits, were analyzed in an analysis of variance, stimulus type X visual field X subjects, collapsing across patterns. The left panel of Fig. 2 shows the percentage of hits to Old, New, and Prototype items, separately for the left and right visual fields.

There was a significant main effect of stimulus type: hit rate was highest for the Prototypes, intermediate for the Old items, and lowest for the New items ($F_{2,38}$=12.29, p<.001). Each of the 3 inter-type differences was significant (t_{38}s≥2.40, p<.05). Neither the main effect of field, nor the interaction of type by field was significant (Fs<1.00).

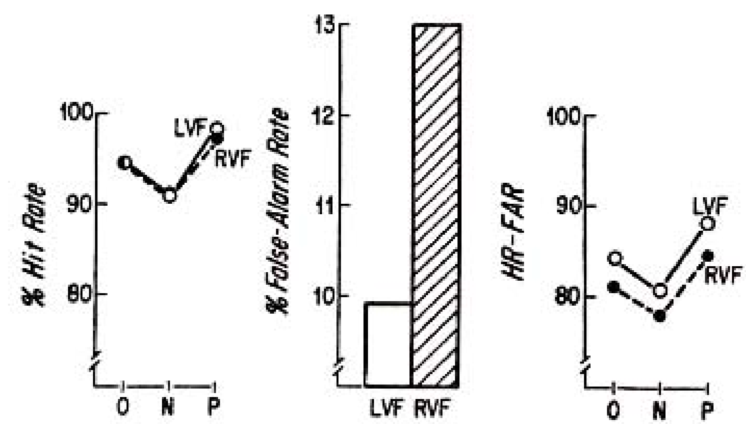

Fig. 2. Left panel: Hit rate as a function of stimulus type, by visual field. Middle panel: False-alarm rate, by visual field. Right Panel: Hit rate minus False-alarm rate as a function of stimulus type, by visual field. LVF = left visual field; RVF = right visual field; 0 = old distortions; N = new distortions; P = prototypes.

The middle panel of Fig. 2 shows positive responses to negative (buffer) items, i.e., false alarms. Here an analysis of variance, visual field X subjects, showed a significant difference between fields; the stimuli in the right visual field elicited more false alarms than those in the left visual field ($F_{1,19}$=8.12, p<.025). To obtain a measure of accuracy corrected for response bias, each subject's false-alarm rate was subtracted from his hit rate for each stimulus type; the values shown in the right panel of Fig. 2 resulted. A type X field X subjects analysis of variance of the accuracy scores showed a superiority of the left visual field ($F_{1,19}$=5.01, p<.05). The Fs for the main effect of type and the interaction of type X field were, of course, identical to those in the analysis of variance on hit rate, the result of the correction being simply to change the relative altitudes of the curves for the left and right visual fields.

DISCUSSION

Over-all, the data are consonant with the notion that schemata were generated during Phase I: performance was significantly better on the Prototypes than on the New items. The Prototypes elicited more accurate performance than even the Old items, i.e., the Prototypes were more obviously members of the appropriate categories than the distortions actually experienced.

Our prediction of a larger superiority of the left visual field for Prototypes and New items than for Old items was not borne out by the accuracy data, which showed a superiority of the left visual field of equal magnitude for all three stimulus types. With hit rates ranging from 91 to 98%, it is possible that the task was simply too easy to allow the predicted differences to emerge. It is also possible that the hemispheric differences in non-verbal abstracting ability found in commissurotomized patients cannot be demonstrated in the normal human brain, in which information may be transferred between the hemispheres.

The absence of the predicted interaction of type X field casts doubt on the hypothesis of feature extraction in the left hemisphere and schema formation in the right. Nevertheless, the finding that the false-alarm rate to buffer items was significantly greater for the right than for the left visual field is consistent with the hypothesized differences between the hemispheres in processing modes. If the left hemisphere stores a list of features of old items, it is likely to be seduced into including in a category those buffer items which happen to have features similar to those in the feature list. If, by contrast, the right hemisphere stores a configurational schema, inclusion of an item in a category would occur only when an over-all match to the schema was achieved, and the right hemisphere would therefore be less likely to be deceived by occasional similarities in individual elements.

This possibility could be tested by presenting two subsets of buffers: (a) a seductive set consisting of patterns each of which has an individual feature, e.g., an angle of particular size, orientation, and position, identical to one of the features of the prototype, the pattern otherwise being unrelated to the prototype; and (b) a control set made up of patterns having no feature in common with the prototype. The prediction is that the inferiority of the right visual field in correct rejections will be greater for the seductive than for the control set.

The visual field difference in false-alarm rates is also consistent with the possibility that during the sorting task the subjects generated two schemata for each pattern, a “loose” schema in the left hemisphere and a “tight” one in the right. Posner (1973, pp. 53-54) proposed that the trace system underlying pattern recognition is characterized by a central tendency and a boundary. Subjects who have learned to sort correctly extreme distortions of a prototype acquire a loose concept with wise or ill-defined boundaries, whereas subjects who have sorted less distorted patterns acquire a tight concept. The central tendencies of the two concepts may however be the same.

Reports of marked superiorities of the left visual field for the perception of stimulus location (Kimura, 1969; Robertshaw and & Sheldon, 1976) and line orientation (Fontenot & Benton, 1972; Atkinson & Egeth, 1973) suggest that the spatial-coordinate system of the left hemisphere is less precise than that of the right, so that the central representation of the same stimulus pattern is intrinsically more variable in the former than in the latter. Thus, when the subject sorts stimuli of any nominal distortion level, e.g., 5.3 bits/point, as here, the left hemisphere is in effect working with more variable patterns than the right and therefore generating schemata having wider or less-well-defined boundaries than those generated by the right; and the wider boundaries make the left hemisphere more prone to false alarms than the right. If errors of localization and slant are random in direction, then the schemata in the two hemispheres will have the same central tendency, which would account for the comparable performances of the two visual fields on the positive items.

Several predictions can be derived from this two-schema model. Wider boundaries mean not only a greater acceptance rate for non-exemplars, i.e., false alarms, but also a greater acceptance rate for category exemplars of a higher level of distortion, i.e., hits. Therefore, lateralized presentation of distortions of higher order than those presented during training should elicit paradoxically better performance by the left hemisphere than by the right ("spatial") hemisphere.

The two-schema model also predicts that it should be possible to produce more nearly identical schemata in the two hemispheres by having the subjects perform the Phase-I sorting on lateralized, tachistoscopically presented stimuli, than those presented to the left visual field. Appropriate choice of the two distortion levels should eliminate the difference in false-alarm rate between fields, leaving intact the equality of the two fields in response to Prototypes. It should even be possible to produce a higher false-alarm rate in the left than in the right visual field with a large enough difference in distortion level.

REFERENCES

ATKINSON, J., & EGETH, H. Right hemisphere superiority in visual orientation matching. *Canadian Journal of Psychology*, 1973, 27, 152-158.

AXELROD, S., HARYADI, T., & LEIBER, L. Oral report of words and word approximations presented to the left or right visual field. *Brain and Language*, 1977, 4, 550-557.

BEVER, T. G. Cerebral asymmetries in humans are due to the differentiation of two incompatible processes: holistic and analytic. *Annals of the New York Academy of Sciences*, 1975, 263, 251-262.

FONTENOT, D. J., & BENTON, A. L. Perception of direction in the right and left visual fields. *Neuropsychologia*, 1972, 10, 447-452.

FRANCO, L., & SPERRY, R. W. Hemisphere lateralization for cognitive processing of geometry. *Neuropsychologia*, 1977, 15, 107-114.

KIMURA, D. Spatial localization in left and right visual fields. *Canadian Journal of Psychology*, 1969, 23, 445-458.

LEVY, J. Cerebral asymmetries as manifested in split-brain man. In M. Kinsbourne & W. L. Smith (Eds.), *Hemispheric Disconnection and Cerebral Function*. Springfield, Ill.: Thomas, 1974. Pp. 165-183.

NEBES, R. D. Superiority of the minor hemisphere in commissurotomized man for the perception of part-whole relations. *Cortex*, 1971, 7, 333-349.

POSNER, M. I. *Cognition: An Introduction*. Glenview, Ill.: Scott, Foresman, 1973.

POSNER, M. I., GOLDSMITH, R., & WELTON, K. E. Perceived distance and the classification of distorted patterns. *Journal of Experimental Psychology*, 1967, 73, 28-38.

POSNER, M. I., & KEELE, S. W. On the genesis of abstract ideas. *Journal of Experimental Psychology*, 1968, 77, 353-363.

POSNER, M. I., & KEELE, S. W. Retention of abstract ideas. *Journal of Experimental Psychology*, 1970, 83, 304-308.

ROBERTSHAW, S., & SHELDON, M. Laterality effects in judgment of the identity and position of letters: a signal detection analysis. *Quarterly Journal of Experimental Psychology*, 1976, 28, 115-121.

VANDERPLAS, J. M., & GARVIN, E. A. The association value of random shapes. *Journal of Experimental Psychology*, 1959, 57, 147-154.

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