Anomalous transfer effects after shape discrimination training in the rat

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Abstract

Krechevsky has observed an anomalous transfer effect in rats which he explained by the Gestalt principle of proximity. The effect has been referred to by others more or less as a curiosity, but has not generated further research until now. The effect was replicated under tighter and more extensive conditions, and was found to apply to both positive and negative training shapes. The importance of these findings for behavioral analysis of shape and contour coding in the mammalian visual system is discussed.

Problem

Krechevsky (1938) demonstrated that there are conditions under which rats will not treat a positive training shape as positive during post-training transfer tests. This may be termed anomalous transfer, if the preference for the new shape is not simply a novelty effect. Krechevsky trained rats to discriminate between rows and columns of squares. The general form of these displays is shown in Fig. 1, which may be called rows, or horizontal squares, since the center-to-center distance between squares is less horizontally than vertically (the columns figure consists of the same display rotated 90°). After training on, say, rows positive, rats showed a significant preference for smooth horizontal stripes over rows. Similarly, rats trained with columns positive subsequently showed significant preference for smooth vertical stripes over columns. Krechevsky showed that the transfer was not simply a brightness preference by introducing appropriate control conditions. However, he did not look at possible preferences before training on rows and columns, nor did he investigate the transfer effect on the negative training shape, or assess the possibility of a novelty effect. Thus Krechevsky's result is not unambiguous evidence of anomalous transfer.

The experiment was replicated under more stringent conditions. It was predicted that the Krechevsky effect would be found in transfer tests, even if no pre-training preference for stripes was observed, and that the effect would be found with the negative shape, i.e., that stripes in the same orientation as the negative training shape would be "more negative" than the latter in transfer tests. Further, it was predicted that both effects would occur even if some preference for a pattern were shown before pre-training, and the expected effects were pitted against this preference. For example, a rat that showed preference for vertical striations over columns would be trained with columns negative so that the predicted anomalous transfer would be for columns over vertical striations. The other possible preference conditions were treated analogously.

The predictions for both positive and negative shapes follow from a shape-coding theory of the writer's (Dodwell, 1957) which was the initial stimulus to the experiment; however, other possibilities are discussed below.

Method

The Ss were male Sprague-Dawley hooded rats, about three months old at the start of training. The apparatus was a modified Lashley jumping stand as described elsewhere (Dodwell, 1957). The training shapes consisted of displays of the sort shown in Fig. 1. Each pattern was 3 1/4 x 3 1/4 in sq, subtending about 30° at the rat's eyes at the jumping distance. Transfer shapes consisted of smooth white stripes, the same distance apart as the larger center-to-center distance in the training shape. One set consisted of 1/4 in stripes ("equally wide") and another of narrower stripes with the same white surface area as the training shapes ("equally bright"). Pairs of shapes were always shown in a Gellerman series.

Ss were habituated to the apparatus and trained to jump on a discrimination between a random white dot pattern and a plain black card (for details, see Dodwell, 1960). Pre-training preferences were then run between rows and horizontal stripes and between columns and vertical stripes. Five preference trials were given for each pair. If some preference was shown (4 or 5 jumps to one of the pair) the rat was assigned to a particular group, as described above. If no preference was shown (2 or 3 jumps to either shape) assignment to groups was random. A few Ss do show some preference, usually for striations over rows or columns, but there was no consistency about preferred orientation between Ss, and none preferred striations in both orientations.

There were two training groups, for one rows were positive, columns negative, and for the second vice versa. Ten training trials were given each day to a criterion of 18 out of 20 correct consecutive responses. After attaining criterion, each S was given a series of transfer tests, consisting of 10 trials to one of the training shapes together with one new shape, as shown in Table 1, interspersed randomly with 10 trials on the original training discrimination. If more than one incorrect choice occurred on these interspersed trials S was retrained to criterion on the original task.

It was intended to run four or six rats in each group, combining transfer preferences over Ss. However, the preferences were so marked and consistent that this was not necessary.

Results

There was no difference in pre-training or discrimination training for the two groups. Transfer data are shown in Table 1. The significance of each preference was assessed for each S by an exact binomial test. On a two-tailed test, choice of one shape nine or ten times is significant. Probability values for Ss on the

Fig. 1.. The type of display used for training. This is the "row" shape. The "column" shape is the same but rotated through 90°.

TABLE I
RESULTS FOR VS AND HS OF BRIGHTNESS EQUAL TO THE
TRAINING SHAPES. R = ROWS, C = COLUMNS,
HS = HORIZONTAL STRIPES, VS = VERTICAL STRIPES.

Group I (N = 4) Training: R positive, C negative			Group I (N = 3) Training: C positive, R negative		
Transfers	Shapes	%	Shapes	%	
1	R, HS	90b	C, VS	87b	
2	C, VS	68a	R, HS	90b*	
3	HS, VS	100c	VS, HS	100c	
4	R, VS	95c	C, HS	100c	

a < .05; b < .01; c < .001 *This test is based on two rats only, since the third rat had the opposite preference (see text).

same transfer were combined by Quenouille's (1950) method, and the resulting χ^2 values were all significant for transfers involving anomalous choice. To date results have been obtained for four Ss in group I and three in group II. The reliability of anomalous transfer is therefore unquestionable and occurs even when an opposite pre-training preference was present.

Additional transfer trials, not shown in Table 1, showed that anomalous transfer occurred as clearly when stripes of equal width rather than equal brightness were used, and that tests on stripes differing in brightness but in the same orientation yielded no preference. Transfer tests 3 and 4 show that stripes in the appropriate orientations are still treated as positive and negative shapes when shown together, and that the positive training shape when shown with stripes in the opposite orientation is still positive. It was also found that rows and columns were appropriately discriminated from diagonal patterns of squares.

The combination of χ^2 values, as shown in Table 1, is only justifiable if the directions of choice are the same for all rats in a group. One S did not satisfy this condition on transfer 2. Two Ss in group II showed preference for the training-negative shape as predicted (choices were 10/10 and 8/10 using "equally bright" stripes), but the third chose the stripes 7/10, and on a re-test 8/10, strongly suggesting avoidance of the training-negative shape and thus no anomalous transfer. This rat also preferred the vertical stripes in the pre-training preference test.

Discussion

A clear pattern emerges from the data. Rats trained on rows and columns learn to discriminate "horizontality—verticality" rather than between more specific aspects of the displays, and this discrimination transfers—often perfectly—to different degrees of horizontality or verticality in the stimuli. One may well ask: why is a set of horizontal stripes "more horizontal" than the rows of squares? Moreover, in what sense are the rows "more horizontal" than the columns, since each pattern contains the same amount of horizontal as vertical contour (each being made up of squares)?

Such questions can only be answered by considering the contour-coding system of the organism that mediates pattern discrimination. A theory couched in terms of additive "positive" and "negative" cues will not do, since the anomalous transfers show that a positive training shape may be less preferred than some other shape, etc. This is not a novelty effect since an analogous argument applies to the negative training shape. The effects are symmetrical with respect to positivity—negativity and horizontality—verticality, and therefore seem to be a form of relational learning. They are compatible with a Spence-type analysis of transposition, given that horizontality—verticality is a dimension of discrimination. However, the interesting question is: why do these shapes constitute such a dimension for the rat, in the order horizontal stripes—rows—columns—vertical stripes?

One possibility is that the rat has a contour-coding system that sums horizontal and vertical contours (Dodwell, 1957) which feeds into a "recognizer" which processes the horizontal and vertical outputs separately (Dodwell, 1964). Such a system would account for the present findings provided the coding was done macroscopically, in which case it could be predicted that rows and columns of circles, triangles, etc., would show the same anomalous transfer effects. Another possibility is that inter-contour distances in one direction are sufficiently small for lateral inhibition between contours to be operative in one direction, but not in the other. Lateral inhibition alone would not explain the effects; some directional anisotropy must still be postulated.

Perhaps the results are best explained in terms of the sort of sensory coding described by Hubel & Wiesel (1962), in which single cortical neurons fire for contours in specific orientations, since they demonstrate summation effects along the direction of the contour. In this case one would still need to postulate a recognizer (or comparator) for summed horizontal—vertical output from such cortical cells to account for the effects.

Finally, it should be established to what extent the anomalous transfer effects are species-specific, to what extent they are apparatus-specific, and also whether they are stable under changes of stimulus parameters. These matters are being investigated, and will be reported on in due course.

References

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