Angularity preferences and stimulus orthogonality in pigeons*

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Seventy-two pigeons were given single-stimulus training for variable-interval reinforcement and were then tested for generalization (preference) with a white line on a dark surround at angles of 90 (vertical), 60, and 30 deg. The training stimuli were (in different groups) a white light, a very dim white light, a green light, and a white dot on a dark surround. Any preexperimental preference for a given line angle should have been reflected in all groups; however, no such consistent preference was found. All training stimuli were logically orthogonal to the line angle dimension, yet training with the white light or the dim light resulted in a preference for vertical, training with the dot resulted in a preference for 30 deg, and training with the green resulted in no preference at all. Thus, orthogonality is an empirical rather than a logical matter, and it must be demonstrated in the context in which the concept is to be employed.

In studying the acquisition of stimulus control by a dimensional stimulus (e.g., a color or a line angle), it is common practice to test for stimulus generalization following different amounts of training with the stimulus in question. A typical result (cf. Hearst & Koresko, 1968) is that generalization slope varies positively with amount of training until an asymptote is reached. It appears to be implicitly assumed in such investigations that, in the absence of any training, the test dimension would exercise no control and equal responding would accrue to all generalization test values. If initial preexperimental preferences occur, however, these might modify the course of acquisition of control by the test dimension.

With a response like keypecking in the pigeon, a preference test in the absence of any training cannot be carried out. A remaining alternative is to train Ss with an orthogonal stimulus which is sufficiently similar to the test stimuli to produce an adequate level of generalized responding during testing to permit a reliable preference test. This was the plan and purpose of the present study.

The test dimension employed was line angle, and three different angles, 30, 60, and 90 deg (vertical) were used. In each case, the test line was white on a black background. Initially, Ss were run with a homogeneous white key as the training stimulus. When a reliable "preference" (for 90 deg) was

found, subsequent groups were trained with other stimuli to determine whether the obtained preference was based on pre- or extraexperimental factors or on some unsuspected relationship between the white training stimulus and the white-line testing stimuli. With regard to the latter possibility, we speculated that the preference might be a consequence of Ss' pecking at a localized portion of the white key. In subsequent generalization testing with a white line, the preferred spot might be illuminated if the line was in the vertical position, but not in the others. If this assumption were correct, training with a darkened key might reveal a trough at 90 deg rather than a peak. A better test of the "peck-locus hypothesis" is provided by a group trained with a white dot on a dark surround, since the birds peck at that spot (cf. Jenkins & Sainsbury, 1969) and, in subsequent testing, all line angles intersect at that point. Such a group should show no preference at all. It was also decided to run a group trained on a green key and tested on white lines to test the common assumption that wavelength and angularity are orthogonal stimulus dimensions (cf. Lyons, 1969; Switalski, Lyons, & Thomas, 1966; Terrace, 1966; Thomas, Freeman, Svinicki, Burr, & Lyons, 1970). In a recent monograph, Hearst, Besley, & Farthing (1970) cited the need for empirical tests of orthogonality in inter- or extradimensional studies. As far as we know, only Lyons (1969) has provided such a test, by training pigeons to peck at a green light and then testing them with a series of white lines to which they had not previously been exposed. Lyons found a flat (zero slope) gradient under this condition. A comparable group was

run in this study in an attempt to replicate that observation.

The four different training stimuli used in this experiment, white, dim, green, and white dot, may differ among themselves in their perceived similarity to a white line on a dark surround, but all are presumably orthogonal to the line-angle dimension, i.e., each is presumed to be psychophysically equidistant from 90, 60, and 30 deg. If a genuine preexperimental preference for a given line angle exists, it should be revealed under all four training conditions.

SUBJECTS

A total of 72 experimentally naive domestic pigeons obtained from a local supplier were used. They were maintained at approximately 75% of their ad lib weights.

APPARATUS

Five standard Grason-Stadler single-key pigeon chambers with associated automatic programming and recording equipment were employed. Stimuli were provided by Industrial Electronics Engineers in-line display cells with GE 1815 bulbs and included a white light (Kodak 0.4 neutral density filter), a dimmed white light, a white line 1/8 in. x 7/8 in. on a black surround in orientations of 30, 60, and 90 deg (vertical), a green light (Kodak Wratten filter No. 99), and a white dot approximately 1/4 in. in diam centered on a black field. The "dim" stimulus was provided by dimming the white light with resistors until E could hardly see it. Continuous masking noise was supplied by a Grason-Stadler white-noise generator, Model 901A. There was no houselight in the experimental chambers; thus, except for the feeder light during reinforcements, the key provided the only source of illumination.

PROCEDURE

Reinforcements consisted of 3 sec of access to a tray of mixed grain. Magazine and keypeck training were followed by 1 day with 30 continuous reinforcements, 1 day with a variable-interval schedule with a mean interreinforcement interval of 10 sec (VI 10 sec), and 1 day of VI 30 sec. All Ss were then given 10 daily 1/2-h sessions of VI 60-sec training. During all of this training, the key was continuously illuminated by the appropriate training stimulus. (The number of Ss assigned to each training condition is indicated in Table 1.) On the next and final day, after a 5-min VI reinforced warm-up with the training stimulus, the Ss were then subjected to a line-angle generalization test in extinction. The three line angles, 30, 60, and 90 deg, were randomized in a series, and 20 different random series were presented to each S. Stimulus presentations were

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Table 1
Frequency of "Preference" for Different Line Angles Obtained Under
the Four Different Training Conditions

Training Stimulus	Test Stimuli			χ^2	
	30 Deg	60 Deg	90 Deg		
White N = 27	3 (1)	8 (2)	16 (9)	9.55	p < .01
Dim N = 15	2.5 (1)	2 (2)	10.5 (6)	9.10	p < .05
Green N = 15	4 (2)	5 (0)	6 (5)	0.40	p > .10
Dot N = 15	10 (4)	4 (1)	1 (0)	8.40	p < .05
				$\chi^2 = 52.72$	p < .01

Note—The χ^2 s in the right-hand column indicate the reliability of the preference pattern for each of the four training groups. The χ^2 under the 90-deg column is based on the proportion of Ss in each group which prefer 90 deg (e.g., 59% of the white-trained group, 70% of the dim-trained group, etc.). Within the parentheses are reported the number of statistically significant individual gradients peaking at each stimulus value (see text for explanation).

for 30 sec each, with no intervening blackouts.

RESULTS AND DISCUSSION

Under none of the training conditions used was our goal of producing an "adequate" level of generalized responding for a preference test realized for all Ss. In fact, under each condition, several Ss emitted very few responses, whereas some gave more than a thousand. Under these circumstances, it would be clearly inappropriate to compute group average gradients. Instead, the data are presented in terms of the frequency of individual Ss which preferred (i.e., responded maximally) to each of the three test values. Table 1 presents these frequencies for each of the four training conditions, along with a chi square, indicating the significance of that preference. As may be seen, training with the white or the dim stimulus led to a reliable preference for 90 deg; however, the group trained on green had no reliable preference and that trained on the dot had a reliable preference for 30 deg.

A statistical test of the relationship between training condition and stimulus preference was achieved by performing a chi-square analysis of the proportion of gradients which peaked at 90 deg under the four training conditions. This chi square, presented in the table under the appropriate (90-deg) column, shows a highly significant group effect.

It may seem questionable to weigh equally in the data analysis the gradients of Ss who responded very little and sporadically and those of Ss who responded consistently throughout the preference test. The above analysis is also incomplete because it does not indicate the degree of stability or reliability of the preference shown by each individual S. It would be of interest to know, for

example, whether some Ss show a consistent preference for a particular stimulus, even when their group as a whole does not. Because each gradient is based on the composite of 20 different test series, it is possible to evaluate the consistency and thus the reliability of each gradient via the analysis of variance technique. In this analysis, the mean square for stimuli is tested against the mean square for interaction between blocks and stimuli; a significant F indicates a reliable gradient. Such an analysis was carried out for every generalization gradient obtained in this study. In each analysis, only those blocks on which some responding occurred were included; zero response blocks were omitted. Table 1 reports (within the parentheses) the number of statistically significant gradients peaking at each stimulus value, and the pattern of preferences based on significant gradients is in substantial agreement with the pattern based on all gradients. It is important to note, however, that an individual S occasionally exhibits a reliable preference for a stimulus which is not preferred by its group as a whole.

Since no consistent pattern of preference was observed across the four experimental groups, i.e., the Ss in different groups tended to prefer different stimuli, we must conclude either that no preexperimental preference exists or that it is too weak to overcome the stronger effects of the training stimuli. Given that there is no evidence for preexperimental preference, the fact of different preferences in different groups requires rejection of the assumption of orthogonality between training and testing stimuli. In other words, stimuli which are logically orthogonal to line angle are functionally nonorthogonal! No apparent reason for this paradox

has occurred to us.

Of the four training stimuli used in this study, only the green light resulted in no consistent line-angle preference. This replicates Lyons's published result and is most reassuring in view of the fact that this combination of training and testing stimuli has been used most often in inter- and extradimensional studies of stimulus control. Where nonorthogonal stimuli have been used in such studies, of what consequence was the violation of the assumption of orthogonality? Presumably the effect of nonorthogonality depends on both the magnitude and the durability of obtained preferences. One measure of preference magnitude is the percentage of total responses emitted to the preferred stimulus. For the 16 Ss in the white-trained group which preferred 90 deg (for example), the mean percentage of total responses emitted to 90 deg was 45.54. For the 10 Ss in the dot-trained group which preferred 30 deg, an even stronger preference was observed, averaging 52.58%. Thus, the preferences observed here were of sufficient magnitude to be of practical as well as of theoretical importance.

The durability of the preference effect has been evaluated in several studies performed in our laboratory. In one of these (Schadler & Thomas 1972), pigeons were given 10 days of VI training with a white key and then were given 0, 5, 10, or 20 min of VI training with either a 90-deg line (initially preferred by the group) or a 30-deg line (initially nonpreferred). The evidence suggested that after 20 min of training, there were no longer any differences in generalization slope attributable to initial preference.

Quite probably, the use of nonorthogonal stimuli would have no demonstrable effect in most experiments where substantial experience with the training stimuli is provided. Occasionally, however, it is necessary or desirable to use minimal training. In one such experiment, Giurintano¹ gave pigeons extended VI training on white, then presented a 49-deg black line for 15, 30, or 60 min and subsequently tested for generalization. Giurintano used an asymmetrical test series with all or most test stimuli at greater angles than 49 deg in order to test for a "central tendency effect" (cf. Thomas & Jones, 1962), i.e., a shift in the peak of the gradient toward the center of the test series. He hypothesized that this effect would occur only under conditions of minimal training, and it did. However, a persistent finding which held up even after an hour of training was the appearance of a secondary peak of the

gradient at the test value closest to 90 deg. This is inconsistent with Schadler and Thomas's finding of no differences in gradient slope after 20 min of training. It may signify that angle preferences with black lines are stronger than they are with white ones, that training with a relatively "neutral" stimulus (49 deg) is inadequate to overcome a strong preference for another one (90 deg), or that Schadler & Thomas's generalization test, with three stimuli spaced 30 deg apart, was simply too insensitive to reveal subtle residual differences after 20 min of training. In any case, the Giurintano study shows that nonorthogonality can contaminate the results of a stimulus control study.

In conclusion, the results of the present investigation indicate that stimuli which are logically orthogonal may be functionally nonorthogonal.

Furthermore, this nonorthogonality can contaminate observations of developing stimulus control. It would, therefore, be appropriate to insist that investigators in this field present empirical evidence of orthogonality rather than relying on face validity, as has been common practice heretofore.

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NOTE

1. Giurintano, L. P. Unpublished research, University of Colorado, 1971.