THE EFFECT OF A FADING PROCEDURE UPON THE ACQUISITION OF CONTROL BY AN OVERSHADOWED AUDITORY FEATURE¹

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Pigeons' key-pecking responses were reinforced in the presence of a compound stimulus that consisted of an auditory feature (a tone) and a visual feature (a light) and non-reinforced in the presence of a compound stimulus that was either a noise and a dark key, or noise and a light. In the condition where reinforcement trials differed from non-reinforcement trials on the basis of both auditory and visual features, the tone exerted very little control over responding on test. In the condition where reinforcement differed from non-reinforcement trials solely on the basis of the auditory features, an abrupt and a gradual introduction of the visual feature of the negative stimulus, a light, were compared for their effect upon control in the compounds. The tone acquired strong control in both cases. Evidence indicated that the tone had acquired control in the gradual condition without the occurrence of responses to the negative stimulus. An incidental finding was that when the negative stimulus consisted of a noise and a light, which was introduced abruptly, responding over the light dimension with tone, on test, was peaked at a point other than that light value used as positive and negative during training.

In conditioning situations where more than one feature is correlated with reinforcement, certain features may more readily acquire control than others. Examples are studies by Newman and Baron (1965) and Miles (1969). In the latter, when a discrimination was formed between a compound stimulus consisting of a lighted key and a tone (S^D), and a compound consisting of a dark key and noise (S^A), there were few responses to S^A because pigeons rarely peck dark keys. A subsequent test in extinction indicated little control by the tone. The light may be said, therefore, to have overshadowed the tone. When the discrimination had to be formed on the basis of the tone-noise feature, the S^D being tone and light and the S^A being noise and light, there was a substantial amount of non-reinforced responding. On test, in extinction, the tone exerted strong control. The present experiment was undertaken to determine whether non-reinforced responding in the absence of the tone is a necessary condition for the acquisition of control by such an overshadowed feature. The method em-

ployed was similar to Terrace's (1963) studies, which demonstrated that control can be transferred from one feature of a compound stimulus to another without the occurrence of errors. The present procedure consisted of beginning with a compound (tone and light) as positive stimulus (S^D), and a dark key and noise as negative (S^A), and then making more difficult a discrimination based on the more prominent light dimension.

METHOD

Subjects

Eight male adult hybrid pigeons without prior training, were maintained at 75% of their free-feeding weight throughout the experiment.

Apparatus

A standard pigeon chamber (Lehigh Valley Electronics) was used. It was constantly illuminated by a diffuse houselight. A response key of translucent plastic, 1 in. (25.4 mm) in diameter, was mounted on one wall of the chamber. Reinforcement was 5-sec access to a tray of mixed grain. The operation of the tray was signalled by illuminating the magazine.

The experiment involved both auditory and visual stimuli. The auditory stimuli were either a tone of 1000 Hz or a broad band white

¹This research was supported by a Science Research Council grant to Professor G. B. Trasler, Southampton University. The authors would like to express their gratitude to Dr. R. A. Boakes for his careful reading of the manuscript. Reprints may be obtained from R. F. Westbrook, Laboratory of Experimental Psychology, University of Sussex, Falmer, Brighton, England.

noise, both of which were maintained at 80-db sound pressure level. These measurements were taken daily against an ambient sound level of 55 to 60 db. The visual stimuli were provided by a miniature light bulb (G.E.C. 1820) located in a housing behind the key. The key could be illuminated at any one of 25 different light levels. These were obtained using a step-down transformer with 1-v ac steps from 0 to 24 volts.

The experiment was controlled by a tape-reader, relay switching circuits, and timers. Total counts of various events were recorded on impulse counters. The experimental chamber and scheduling equipment were located in separate rooms.

Training Procedure

A discrimination trial procedure (Jenkins, 1961) was used. A positive trial was marked by the cessation of noise and the onset of tone and keylight, S^D. The intertrial period consisted of noise and a dark key. S^A trials varied between conditions. In one condition, the S^A trial was simply an extension of the intertrial period, viz., noise and dark key. In two other conditions, the intertrial noise continued throughout the S^A trials, which were marked by the onset of keylight. In the final condition, the S^A trial was marked both by the cessation of noise and the onset of tone and keylight. A trial was terminated when four responses (a response unit) occurred, or by external control if the requirement was not met within 10 sec. On S^D trials, reinforcement followed comple-

tion of a response unit. Trials were presented with an onset-to-onset interval of 25 sec. A response during the intertrial period delayed the onset of the next trial for 40 sec. This delay was not in effect until 1.50 sec after a trial terminated.

Subjects were shaped to peck the key in the presence of the S^D. When 10 stimulus presentations had each been terminated by a reinforced response, the response requirement was gradually raised to four, while, at the same time, brief intertrial intervals were introduced and gradually lengthened. In the session following shaping, 84 S^D trials were presented with the 25-sec onset-to-onset interval in effect. Pre-training consisted of three such sessions. Discrimination training consisted of 12 sessions with 168 trials each. Within each session were seven blocks of 24 trials with an equal number of positive and negative trials in each. These sequences were randomized with the constraints that no more than two negative trials and no more than three positive trials should succeed one another. Two birds were assigned to each of four conditions. In all conditions, the S^D was a tone and a light of 24-v intensity. For all conditions, the intertrial period was a noise and a dark key. The specification and introduction of S^A distinguished the four conditions, as outlined in Table 1.

Condition 1: gradual introduction of the S^A (Birds 291 and 263). The intertrial noise continued through the S^A trials. The S^A was initially a dark key. The voltage to the bulb that transilluminated the key was increased in 1-v

Table 1
Summary of Training Conditions

Conditions	Birds	S ^D	Intertrial Interval	S ^A
1 (Faded)	291	Light (24 v) +	Dark Key +	Light (0 → 24 v) +
	263	Tone	Noise	Noise
2 (Abrupt)	305	Light (24 v) +	Dark Key +	Light (24 v) +
	269	Tone	Noise	Noise
3 (Compound Differential)	279	Light (24 v) +	Dark Key +	Dark Key +
	264	Tone	Noise	Noise
4 (Faded but with Tone irrelevant)	480	Light (24 v) +	Dark Key +	Light (0 → 24 v) +
	472	Tone	Noise	Tone

Table 2

Voltages and their frequency of occurrence in the gradual introduction of the S^A in Conditions 1 and 4.

Voltages	Sessions												Totals
	1	2	3	4	5	6	7	8	9	10	11	12	
0	84	84											
1			10										10
2			10										10
3			11										11
4			11	10									21
5			10	10									20
6			9	11									20
7			10	11									21
8			13	10	10								33
9				9	10								19
10				10	11								21
11				13	11								24
12					10	11							21
13					9	12							21
14					10	12							22
15					13	12	15						40
16						12	15	15					42
17						12	15	15	15				57
18						13	14	15	15	15			72
19							25	14	15	15	15		84
20								25	14	15	15	15	84
21									25	14	15	15	69
22										25	14	15	54
23											25	14	39
24												25	25

Frequency of Presentation

steps throughout each session until by the final session its value equalled the light component on the S^D trials. Table 2 depicts the voltages used and their frequency of occurrence during the fading procedure. The rate of progression through this procedure was based on the results of previous pilot studies.

Condition 2: abrupt introduction of the S^A (Birds 305 and 269). As in Condition 1, the intertrial noise continued through the S^A trials. From the beginning of discrimination training, the S^A was a light that was equal in brightness to the component on S^D trials.

Condition 3: compound differential (Birds 279 and 264). Throughout discrimination training, S^D trials differed from S^A trials on the presence *vs* absence of both auditory and visual features. Thus, the S^D was the tone and the light while the S^A was simply noise and a dark key, *i.e.*, the S^A trial conditions did not differ from those of the intertrial period. This condition, together with Condition 2 above, repeats the procedure used by Miles (1969).

Condition 4: gradual introduction of the S^A but explicit on light (Birds 480 and 472). This

was identical to Condition 1 in the gradual introduction of the light component on the S^A. However, in this condition, the tone was present on S^A trials, *i.e.*, the discrimination could be made only on the basis of differences in light intensities between S^D and S^A trials, differences that progressively decreased until by the final session, S^D and S^A trials were similar in all respects except, of course, in terms of their consequences. This condition provided evidence on the extent to which subjects in Condition 1 could distinguish between S^D and S^A trials solely on the basis of such differences in light intensity.

Test Procedure

At the completion of training, stimulus control was tested in extinction (two sessions). In each session, tone was present in half of the test trials, and noise in the remaining half. Twelve values of light intensity were used during the test procedure: 24, 22, 21, 20, 19, 17, 15, 13, 10, 8, 5, and 0 volts. At each light level, trials were presented with tone and with no-tone, yielding a total of 24 different stimuli.

The 24 stimuli were presented in seven independent random orders, making up 168 trials on each session.

RESULTS

Training

While the probability of completing a response unit during a positive trial remained close to 1.00 throughout training, there was a minimal probability of a response to the blank key for all subjects. Table 3 presents the results in training and in test. The way in which the negative trial (the light) was introduced affected the number of response units during the negative trial: Out of 1008 negative trials, Birds 291 and 263 in the gradual condition (1), terminated three and seven trials respectively; whereas Birds 305 and 269 in the abrupt condition (2) terminated 340 and 299 trials respectively. Responding to the negative trial in this latter condition had almost disappeared by the seventh session (six response units per session thereafter). In the gradual condition, Birds 291 and 263 started to terminate negative trials when their voltage values were 24 and 23 respectively. For the latter subject, these response units occurred to the first four presentations of the negative trial at 23 v and to the first three presentations of the negative trial at 24 v. The former subject similarly terminated the first three presentations at 24 v. This was in contrast to subjects in Condition 4, for which the discrimination had been explicit on the basis of light differences between

trials, in that they started to terminate negative trials when their values were 17 v (480) and 16 v (472). These subjects eventually terminated a total of 162 (480) and 144 (472) negative trials.

Test for Stimulus Control

From the number of responses emitted to each test stimulus in extinction summed over two sessions, an overall index of control by tone was computed. The index was the number of responses in the tone trials divided by the total number of responses. It was designated R. Thus $R = 1.00$ indicates full control by tone and $R = 0.50$ no control by tone. The tone acquired control only in those conditions where it was the sole feature distinguishing S^D from S^A trials (*cf.* Table 3). In Condition 1, where the light component of the S^A had been introduced gradually, the values of R for Birds 291 and 263 were 0.91 and 0.94 respectively. Similarly in Condition 2, where the light component had been introduced abruptly, the values of R for Birds 305 and 269 were 0.96 and 0.91 respectively. There was little control by tone in the other conditions. In Condition 3, where the S^A had simply been an extension of the intertrial period, the value of R for both subjects, Birds 279 and 264, was 0.55. Again, in Condition 4, where the tone was irrelevant, control in terms of the R index was 0.56 and 0.50 for Birds 480 and 472. The total number of responses occurring at each light value with tone and with no-tone summed over both extinction sessions for all conditions is presented

Table 3
Summary of Training and Test Results

Conditions	Birds	Training: Response Units on S^A Trials	Testing: R, Index	Total Responses Emitted in Extinction (2 Sessions)
1 (Faded)	291	3	0.91	70
	263	7	0.94	131
2 (Abrupt)	305	340	0.96	239
	269	299	0.91	173
3 (Compound Differential)	279	0	0.55	65
	264	0	0.55	66
4 (Faded but with Tone irrelevant)	480	162	0.56	117
	472	144	0.50	145

Fig. 1. Total number of responses, summed over both extinction sessions, occurring at each light value with tone and with no-tone for all conditions.

in Fig. 1. To facilitate exposition, Fig. 2 shows the total number of responses occurring during extinction to each value of light intensity, summed over tone and no-tone conditions, and expressed for each subject as a percentage of the total number of responses that occurred for each subject during extinction to light value 24-v. The abrupt condition would seem to have resulted in a gradient that (a) encompasses a relatively greater area and (b) is displaced away from the light value used as positive and negative in training.

DISCUSSION

The small amount of tone control in the compound differential condition, a finding that replicates that of Miles (1969), suggests

that the tone was exerting little or no control before the negative stimuli were introduced in the gradual and abrupt conditions. The fact that Birds 291 and 263 in Condition 1, where the light component of the S^A was introduced gradually, started to terminate S^A trials only when their values were 24 and 23 v respectively, as distinct from Birds 480 and 472 in Condition 4 which started to terminate such trials at light levels as low as 17 and 16 v respectively, suggests that in the former condition the tone had acquired control without such responses occurring. Such systematic differences in the points on the fading procedure at which errors occur in the two conditions must be attributable to behavior in Condition 1 coming under the control of the other relevant cue, *viz.*, the tone. Such an argument

Fig. 2. Total number of responses during extinction to each value of light intensity, summed over tone and no-tone conditions, expressed as a percentage of the total number of responses that occurred for each subject during extinction to light value 24-v.

would seem to be substantiated by the radical differences in the amount of tone control between the two conditions, at least as indicated by the measures used. The errors that occurred in Condition 1 to the full value of the S^A may be related to this stimulus having initially been the feature controlling responding and/or still controlling in conjunction with the tone. A greater degree of success in transferring control to the tone might have been expected had a paradigm been used in which the terminal value of the S^A had never been previously encountered in training in the experimental chamber or, at any rate, had never obtained any excitatory or inhibitory value. For example, one could errorlessly establish a discrimination between red and green in a background of silence, then superimpose the tone-noise feature, and finally fade out the colors to some neutral value.

There would seem to be differences in the areas enclosed by the gradients after the faded and abrupt introductions of the light component of the S^A , Conditions 1 and 2. However, in these conditions where there is substantially the same lack of responding in the absence of tone, it is impossible to assess the relative contributions to the slopes of the gradients by the tone and light features. It is not possible to attribute, for example, the differences in these conditions to the faded introduction resulting in steeper gradients on light or to the abrupt introduction resulting in stronger (but unmeasured) control by tone. In Conditions 3 and 4, where the tone is exerting virtually no control, the slopes of the gradients may be safely attributed to the control exerted by light. To assess the control that the features in the compound exert after the faded and abrupt introductions, a symmetrical testing procedure

should have been employed in which the light values were manipulated with, for example, values on the tonal frequency dimension held constant and *vice versa*.

Unpublished data from our laboratory suggest that the displacement of the generalization gradient observed for both subjects in the abrupt condition (Fig. 1B and 2) is a regular occurrence after such training conditions. Thus, for example, after a 50% partial reinforcement schedule on a compound consisting of the tone and the light of 24 v, there is a similar displacement on test away from the light value that formed part of the compound during training. Explanation of this effect requires further research, especially in view of the gradient shape that one would expect from free-operant studies involving partial reinforcement of responding in a single-stimulus condition (for example, Guttman and Kalish, 1956).

The present results are similar to those reported by Terrace (1963, 1968) with the difference that in the present study, the initial control is built into the situation; in Terrace's studies it was established by prior training. Like the situations reported by Terrace, casual observation of the subjects indicated that there were differences in the "emotional" behavior occasioned by presentations of the S^A in

the faded and abrupt conditions. However, observation of subjects in the faded condition indicated that as the discrimination became more difficult on the basis of the light feature, there was an increasing likelihood for the subjects to make incomplete responses, for example, abortive head movements, to the S^A . The non-reinforcement of such responses may have been instrumental in transferring the basis for responding.

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Received 27 February 1969.