THE STAGES OF ACQUISITION IN STIMULUS FADING¹

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Pigeons were exposed to a stimulus fading procedure in which control of responding was transferred from red and black stimuli to lines of different angular orientation. After superimposing one line on the red stimulus and the other line on the black stimulus, the intensity of the lines was gradually increased and that of the red stimulus was gradually reduced. Probes consisting of red and line stimuli presented separately were used during the course of fading to assess control exerted by each element of the compound. As the lines were faded in, they did not acquire control of responding. As red was faded out, control of responding was acquired first by the lower intensity red stimuli in combination with the line stimulus, and finally by the angular orientation of the lines. Probes also determined the point at which the line stimuli, presented alone, would maintain a high degree of stimulus control. The results demonstrated that new stimuli in fading acquire dimensional control of responding in two sequential stages. Acquisition of stimulus control in fading was explained in terms of attenuation of stimulus blocking.

Key words: stimulus-control transfer, stimulus-control acquisition, discrimination learning, blocking, compound stimuli, probe stimuli, key peck, pigeons

In stimulus fading, a response is brought under the control of new stimuli by first superimposing them upon a set of original stimuli and then gradually eliminating the originals. The new stimuli can acquire control of responding with very few, if any, S- responses (Schlosberg and Solomon, 1943; Sidman and Stoddard, 1967; Terrace, 1963). Ray and Sidman (1970) and Sutherland and Mackintosh (1971) suggested that acquisition of control by the new stimuli must take place in two stages. First, compounds consisting of the new stimuli and the attenuated original stimuli must be exerting control. The original stimuli must continue to control, since no S- responding occurs. Yet, the new stimuli must exert some control or else responses would occur at random when the original stimuli were removed. Second, eventually, the new stimuli alone must control responding.

Although acquisition of control by the new stimuli in the latter stage of fading has been observed directly (Schusterman, 1967; Tou-

chette, 1971), the possibility of prior control by the compound has not yet been observed. The purpose of the present experiment was to observe control by elements and compounds throughout fading.

Subjects

Four naive White Carneaux pigeons, about 2-yr old at the beginning of the experiment, were maintained at 80% of their free-feeding weights.

Apparatus

A Scientific Prototype pigeon chamber (Model No. B-400) was housed in a sound-attenuated enclosure. Visual stimuli were projected through the 25-mm diameter response key from an IEE In-Line display unit (Model No. 10-6777-44L). Stimuli consisted of the unilluminated key (black), the key transilluminated with nominal 630-nm light (red), and a white line 3-mm wide and 25-mm long, with a 0, 45, 90, and 135 degree angular orientation on a black background. Stimulus intensities were varied by changing the value of a resistor (Heath Decade Resistor, Model No. EU-30) wired in series with the display unit projector bulbs (Chicago Miniature No. 44, 6.3 V, 1.6 W). Response-key depression required a force exceeding 0.2 N. Reinforcement consisted of

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3-sec access to mixed grain. During experimental sessions, white noise was present in the experimental chamber, and the chamber was illuminated with a 6-W houselight.

Procedure

Preliminary training. After training the subject to peck a red key with 0-ohms series resistance, where every response produced food, the number of responses required for reinforcement increased by two responses per session up to 30. Then, responses at irregular intervals averaging 15 sec resulted in food presentation for three to six sessions.

Establishing a red-black discrimination. A random series of black key and full-intensity red stimuli were presented. Each red stimulus (S+) lasted for an average of 15 sec and varied from 10 to 30 sec. Reinforcers were available during the last 5 sec of each S+. The S+ periods ended when a response produced the reinforcer, or after the 5-sec availability period if a response did not occur. Black S- periods lasted for 30 sec, during which responses had no consequences. Each S+ and S- period was followed by a 10-sec intertrial interval with the response key black. Responses delayed onset of the next stimulus by 10 sec. All sessions lasted for 70 reinforcer presentations. Subjects had these conditions until responding occurred during all periods with red and none with black.

Introduction and superimposition of new line stimuli. In the next session, red and black stimuli were presented at full intensity. Following every one or two presentations of red, however, one of two white lines were presented at full intensity against a black background for a duration ranging from 10 to 30 sec and averaging 15 sec. For two subjects, horizontal (0°) and vertical (90°) lines were used. For the other two subjects, 135° and 45° lines were used. The two lines were presented in random order. Responses had no scheduled consequences. These line probes continued until neither evoked a response for five successive presentations.

Thereafter, the resistance in series with the bulbs projecting the lines was increased to 40 ohms, and each was superimposed on one of the original stimuli. Thus, for example, red-horizontal was S+ and black-vertical was S-. Following every fourth S+ presentation, the resistance in series with the lines was decreased

by 4 ohms until the compounds contained lines presented at full intensity. Once full intensity was reached, the red and the line element of S+ were presented separately as probes. Each probe was presented once, under extinction conditions. Probe duration averaged 15 sec. Probes were presented after the third and fourth S+s. The session was then ended.

Fading out the red S+ element. In the next session, the red-line compound and the black-line compound were presented. While both lines were always presented at full intensity, the intensity of red was systematically reduced. At the beginning of the session, the red element was at full intensity (0 ohms). After every fourth S+ presentation, however, resistance was increased by 2 ohms. Before each increase, the elements of the prevailing S+ were presented as probes as previously described. For example, if the compound consisted of the horizontal line on a red field having 10-ohms series resistance, the probes were a red light with 10-ohms resistance and the horizontal line presented on a black background. The intensity of red was decreased until no responding occurred during probes with red and response rate in the presence of the line element of the S+ compound equalled or exceeded 95% of the rate in the presence of the S+ compound at two successive fading levels. Thereafter, the red element was eliminated from the compound. Subjects, then, had a line on a black background as S+ and another line on a black background as S-.

Within-subject replication. Beginning with the next session, the entire procedure was repeated. The red-black discrimination procedure was in effect for one session, and the subsequent procedures were repeated with a different set of lines (see Table 1, columns 1 and 2).

RESULTS

Since the effects obtained during the initial fading and the replication series were similar, they will be described together. Before superimposition, neither line orientation occasioned any responding. While the lines were being faded in, responding occurred only in the presence of the S+ compounds. Once the lines were fully faded in, responding evoked by the red probes exceeded that evoked by the compound S+, and no responding was evoked by

Table 1
Rate of responding in the S+, S-, S+ line probe and S+ red probe, in various phases of the fading procedure. All rates are indicated in responses per minute.

(1) Subject	(2) Lines Used (Degrees)	(3) S+	(4) Fading* In Lines	(5) Probes Red Line	(6) Fading Out Red Intensity of Red S+ Element (ohms)												(7) Lines Only after Fading	(8) S+ S- S+ S- S+ S-	(9) Reintroduced Red-Black Discrimination
					0-	2-	6-	10-	14-	18-	22-	26-	30-	34-	38-	42-			
					86	61	88	88	73	92	99	130	140	105	108				
26	0-90	39	116	0	136	135	130	170	195	181	189	180	165	215			90	0	
	45-135	127	170	0													154	9	110 0
53	0-90	56	92	0	82	75	82	107	97	102	84	96	92	78	96		71	0	
	45-135	92	108	0	129	142	123	130	144	127	118	114	116	100	109	107	108	0	96 0
37	45-135	135	168	0	100	60	100	88	81	99	107	115	98	93	97	52	56	6	
	0-90	160	190	0	81	87	65	95	84	135	141	130	96	107			67	0	105 0
60	45-135	77	164	0	162	128	123	136	133	149	145	161	119				139	0	
	0-90	102	160	0	192	163	130	147	173	198	151	116	128	150			147	0	134 0

*Response rates in columns 3 to 5 were obtained at the end of fading-in line stimuli, at 0 ohms.

Fig. 1. Responding emitted in the presence of the line probes and the red probes at each fading level while attenuating the red S+ element. Graphs in the left-hand column present data obtained during the first fade. Graphs in the right-hand column contain data obtained during the replication. Each row contains data for one subject. Fading levels are indicated on the abscissa of each graph, where zero ohms indicates full intensity. Responding is presented as a proportion of the prevailing S+ rate. Subject and angular orientations used as S+ and S- are indicated in the upper center of each figure.

the line (see Table 1, columns 3-5). Since the lines did not evoke any responding before or after being faded in, the lines did not acquire control of responding during that portion of the procedure.

Figure 1 illustrates responding during the probes in the course of fading. During the early stages of fading out red, the rate of responding to red exceeded that to the S+ compounds. As fading continued, responding during red declined and no responding occurred to the line. Yet, responding to the S+ compound continued at a high level (see Table 1, column 6). At this point, responding to the compound could be attributed to control by the red element, the S+ line element, or the conjoint presence of both. Identification of the stimulus configuration(s) that controlled responding is indicated by comparing probe responding to compound S+ responding. Since line alone occasioned no responding, control cannot be attributed to it in isolation. Since S+ responding differed systematically from the responding evoked by red alone, control cannot be attributed to red in isolation either. Responding in the presence of the compound S+, then, appeared to be under the control of the compound red-line when responding to the red probe was declining.

As fading continued, responding to the line increased to approximate the prevailing rate of the S+ compound, while little or no responding occurred to the S- compound, implying that angular orientation acquired control of responding. This was confirmed by the fact that most responding occurred in the presence of the S+ line once the red S+ element was eliminated and subjects were presented with S+ and S- lines alone (see Table 1, columns 7 and 8). Finally, when the red-black discrimination was reintroduced, responding occurred only in the presence of red, indicating that initial controlling stimuli did not lose control even though new stimuli had acquired control during fading (see Table 1, columns 9 and 10).

DISCUSSION

Different stimuli acquired control of responding in serial order. As the new stimuli were being faded in, responding was controlled by the original stimuli. As the original S+ element was faded out, control of responding was acquired first by the combination of the

stimulus being faded out plus the new element, and second by a specific dimension of the new stimuli alone. The results confirm the notion that new stimuli in fading acquired control of responding in two stages, as suggested by Ray and Sidman (1970) and Sutherland and Mackintosh (1971).

An account of how the new stimuli acquired control can be provided by considering the effects of blocking on the acquisition of stimulus control. Blocking means that previous discrimination training with one set of stimulus elements found in compound stimuli reduces the control acquired by the other elements of the compound stimuli (Kamin, 1968; Rescorla and Wagner, 1972). In the present experiment, as in many other fading experiments, responding was first brought under the control of an initial set of discriminative stimuli. When new stimuli were subsequently superimposed, the original stimuli should have blocked the acquisition of control by the new stimuli. Indeed, in the present experiment, the new stimuli did not acquire control of responding when superimposed and faded in on the original stimuli.

Johnson (1970), Kamin (1968), Miles (1970), and vom Saal and Jenkins (1970) demonstrated that control acquired by new stimuli was inversely related to the intensity of the blocking stimuli. In fading experiments, where the intensity of the original (blocking) stimuli systematically decreases, the blocking effects might be expected to decrease as fading progresses, and the new stimuli should acquire control of responding. This, in fact, is what happened, and in an errorless fashion. Stimulus fading, then, can be conceptualized as a procedure by which a thoroughly blocked stimulus dimension acquires control of responding in an errorless fashion due to the gradual elimination of the original blocking stimuli. Such an analysis of fading suggests that the determinants of blocking should influence the acquisition of control by new stimuli in fading. That is, parameters that reduce blocking effects of stimuli, when applied to the original stimuli in fading should enhance rate of acquisition of control by the new stimuli in fading.

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