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ACQUISITION OF STIMULUS CONTROL WHILE INTRODUCING NEW STIMULI IN FADING

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After establishing a discrimination between a red positive stimulus and a green negative stimulus, the lowest intensity colors that restricted all responding to the positive stimulus were determined. Then, two new white lines differing in terms of line orientation were each superimposed on one of the colors and were increased in intensity. Thereafter, the intensity of the colors was decreased and eventually eliminated. Probe stimuli consisting of the lines presented against dark backgrounds were presented before each change of stimulus intensity, and probe responding was used to assess the control acquired by various dimensions of the new stimuli during the course of fading. The lines acquired control of responding while they were being introduced, and control was strengthened as the colors were attenuated. Such a locus of acquisition was attributed to the starting intensity of the original controlling stimuli and was explained in terms of stimulus blocking. Finally, using probes while introducing the new stimuli enhanced the acquisition of control by the new stimuli.

Key words: errorless learning, stimulus blocking, stimulus salience, discrimination training, transfer of stimulus control, measurement of acquisition, probe stimuli, key peck, pigeons

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In studies of stimulus fading, originally responding is under control of very salient high intensity discriminative stimuli. Thereafter, new stimuli are superimposed at low intensity upon the original controlling stimuli and increased gradually to a high level. Finally, the original controlling stimuli are attenuated gradually and eventually eliminated (Corey & Shamow, 1972; Moore & Goldiamond, 1964; Sidman & Stoddard, 1967; Terrace, 1963). Theoretically, the new stimuli could acquire control of responding at any point after being superimposed on the originals but before the originals reach absolute threshold. To make such a determination, however, the process of acquisition must be measured during the course of fading. Procedures for measuring the acquisition have been reported by Sidman and Stoddard (1967), Schusterman (1967), Touchette (1971), Fields, Bruno and Keller (1976), and Fields (1978). In each case, the procedure involved presentation of the new stimuli alone, as probes, throughout the course of the fading procedure, where responding to the probes was used to assess the control acquired by the new stimuli. An experiment conducted by Fields (1978) serves as a representative example. Pigeons were trained to discriminate between red and green stimuli, after which two white lines differing in angular orientation by 90° were superimposed on the colors forming red-horizontal S+s and green vertical S−s. Finally, the intensity of the red and green stimuli were attenuated in small steps. Before each color attenuation, each line was presented as a probe, and responding to the probes was used to measure acquisition of control by angular orientation. No probe responding occurred while introducing the line stimuli; only after the colors were partially attenuated did differential probe responding begin. These results indicated that the new stimuli did not acquire control while being introduced. Rather, they acquired stimulus control only after the original controlling stimuli had been substantially attenuated. Similar results were also obtained by others who have measured stimulus

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control acquisition during fading (Moore and Goldiamond, 1964; Schusterman, 1967; Touchette, 1971).

The observed locus of acquisition, however, may depend on specific procedural parameters, especially when the role of blocking in the transfer of stimulus control is considered. Fields et al. (1976) and Fields (1978) argued that the original controlling stimuli in fading are blocking agents by dint of their prior conditioning history. Further, since the degree of blocking is directly related to the intensity of the blocking stimuli, the point in fading at which the new stimuli acquired control should be function of the intensity of the stimuli being attenuated—the blocking stimuli (Johnson, 1970; Kamin, 1968; Miles, 1970; vom Saal & Jenkins, 1970). Thus, on the one hand, if the original controlling stimuli are introduced at high intensity, the new stimuli should acquire control late in the fading procedure (i.e., after the original controlling stimuli had been substantially attenuated). On the other hand, if fading is started with low intensity original controlling stimuli, the new stimuli should acquire control of responding earlier during fading.

The starting intensities of the original controlling stimuli in the studies cited were relatively high. Thus, replicating one of them with the exception of using a lower starting intensity of the original controlling stimuli should produce acquisition of control by the new stimuli earlier in fading. The experiment to be reported using the same apparatus and procedure described by Fields (1978) and was conducted concurrently with that experiment. The only difference was that the starting intensity of the original controlling stimuli was set at a low level before the fading operations were initiated.

METHOD

Subjects

Eight naive White Carneaux pigeons, about two yr old at the beginning of the experiment, were maintained at approximately 80% of their free feeding weight.

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 (dark), the key transilluminated with nominal 630- (red) or 555- (green) nm light, and 3-mm-long white lines with 0, 45, 90, or 135 degree angular orientation. Stimulus intensities were varied by changing the value of a resistor (Health 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). Thus, intensity was inversely related to resistance value and zero ohms corresponded to the maximum intensity. Response key operation required a force exceeding .2 *N*. Reinforcement consisted of 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. Experimental contingencies were programmed with electromechanical logic modules.

Procedure

Preliminary training. After training the subject to peck a red key presented at 0 ohms series resistance (full intensity) where every response produced food, the number of responses required for reinforcement increased by two responses per session up to 30. For the following 3 through 6 sessions, responses at irregular intervals averaging 15 sec resulted in food presentation.

Establishing a red-green discrimination. A random series of full intensity red and green stimuli were presented. Each red stimulus (S+) lasted for an average of 15 sec and varied from 10 to 30 sec. One reinforcer was 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. Each green stimulus (S−) lasted for 30 sec during which responses had no consequences. Each S+ and S− period was followed by a 10-sec intertrial interval (ITI) during which the response key was dark. Intertrial responses delayed onset of the next stimulus by 10 sec. All sessions lasted for 70 reinforcer presentations. Subjects were exposed to these conditions for 10 to 12 sessions until responding occurred only during periods with red.

Determining the lowest intensity red and green stimuli that maintain stimulus control.

The lowest intensity red and green stimuli that restricted responding to only the S+ was approximated by increasing the resistance in series with the bulbs projecting the red and green stimuli in 4-ohm steps following every third S+ presentation. Once S− responding occurred, the resistance was decreased by 4 ohms and held constant at that level for the remainder of the session. That resistance setting, referred to as the starting intensity, was determined in the session following the criterion red-green discrimination training session.

Introduction and superimposition of new line stimuli. In the next session, red and green stimuli were presented at the starting intensity level. Following every one or two presentations of the colored stimuli, one of two white lines was presented at full intensity against a dark background for a duration ranging from 10 to 30 sec and averaging 15 sec. With four subjects, 0° and 90° lines were used. With the other four subjects, 135° and 45° lines were used. The two lines were presented in random order. Responses emitted in the presence of the lines had no scheduled consequences. Presentation of these lines continued until neither evoked a response for five successive presentations.

Thereafter, the resistance in series with bulbs projecting the lines was increased to 40 ohms, and each line was superimposed on one of the colors, forming compound stimuli. Thus, for example, red-horizontal was S+ and green-vertical was S−. Following every fourth S+ presentation, the resistance in series with the bulbs projecting the lines was decreased by 4 ohms until the compounds contained lines presented at 0 ohms (full intensity). With four subjects (Group II) probes consisting of the full intensity S+ or S− lines were each presented once against a dark background following the third and fourth compound S+ of each fading level. Both probes were presented under extinction conditions for an average of 5 sec and varied from 10 to 30 sec in duration. Thus, probes were presented throughout the line fade in. With the remaining four subjects (Group I), the S+ and S− probes were presented only after the third and fourth compound S+ presented at 0 ohms, that is, only at the end of the line fade in.

Fading out the original controlling stimuli. At the beginning of the next session, red-line compounds were presented as S+s and green-line compounds were presented as S−s. While the intensity of the line elements remained constant at 0-ohms resistance throughout the procedure, the colors were presented initially at the starting intensity and then were attenuated by increasing the resistance in series with the bulbs projecting the red and green stimuli following every fourth S+ presentation. Before each change in resistance, each line element was presented once as a probe at full intensity against a dark background under extinction conditions for a period lasting from 10 to 30 sec and averaging 15 sec. These probes were presented after the third and fourth S+. Colors were attenuated in 4-ohm steps until probe responding began. Thereafter, colors were attenuated in 2-ohm steps.

When response rates evoked by the S+ probe equaled or exceeded 95% of the prevailing S+ rate and no responding was evoked by the S− probe at two consecutive fading levels, the red and green stimulus elements were eliminated and the subjects were presented with S+s and S−s consisting of the lines only presented against black backgrounds. Subjects were exposed to these conditions until responding occurred in the presence of 10 consecutive S+s and did not occur in the presence of 10 consecutive S−s. Subjects 3, 31, 30, and 42 were exposed to 0° and 90° lines while subjects 25, 36, 20, and 35 were exposed to 45° and 135° lines. Assignment of line orientations to subjects was random.

RESULTS

The results for the subjects with whom no probes were used while fading in the lines are presented in Figure 1. Figure 1 illustrates responding to S+ and S− probe stimuli presented throughout fading. For three subjects (Nos. 25, 31, and 36), at the end of the line fade in, more responding occurred in the presence of the S+ than the S− probe. As color attenuation progressed S+ and S− probe rates diverged. For the last subject (No. 3), minimal probe responding occurred at the end of the line fade in, or during the first portion of color attenuation. As color attenuation continued, S+ probe responding began to occur, while no S− probe responding occurred. For all subjects, once the lines were presented alone as S+ and S−, responding occurred predominantly in the presence of the S+ line.

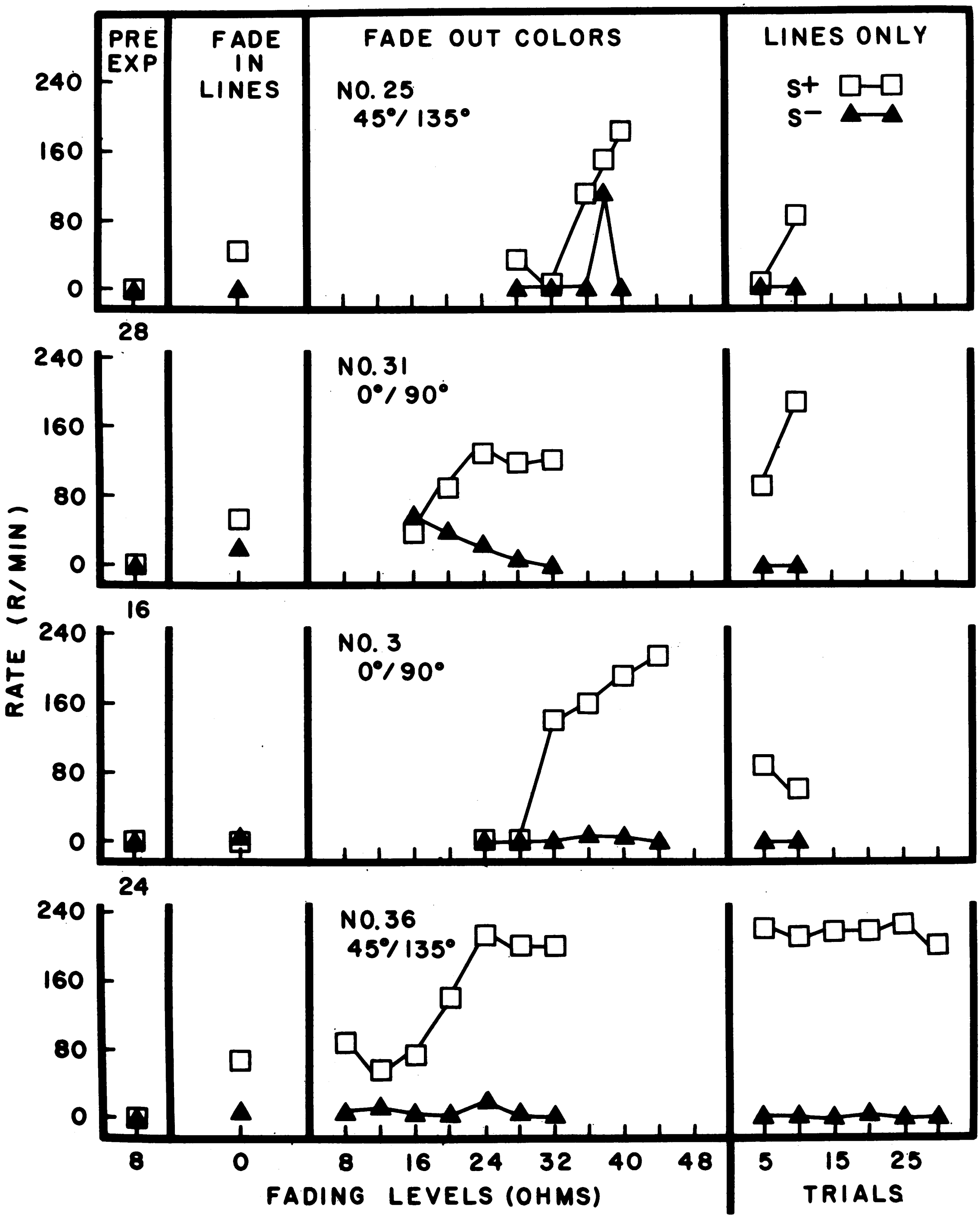

Fig. 1. Responding emitted in the presence of each line probe presented as a function of fading level during each experimental condition for subjects in Group I. Experimental conditions are listed across the top of the figure. Each row contains data for one subject. Subject number and the line tilts used are indicated in the third section of the graph on each row. Responding is presented in responses per min. The intensity of the stimuli being introduced or attenuated is indicated in terms of resistance (ohms) and is inversely related to resistance value where 0 ohms is full intensity. The right-most panel on each row indicates S+ and S− response rates plotted as a function of number of blocks of 5 S+s and 5 S−s once the colored stimulus elements were eliminated.

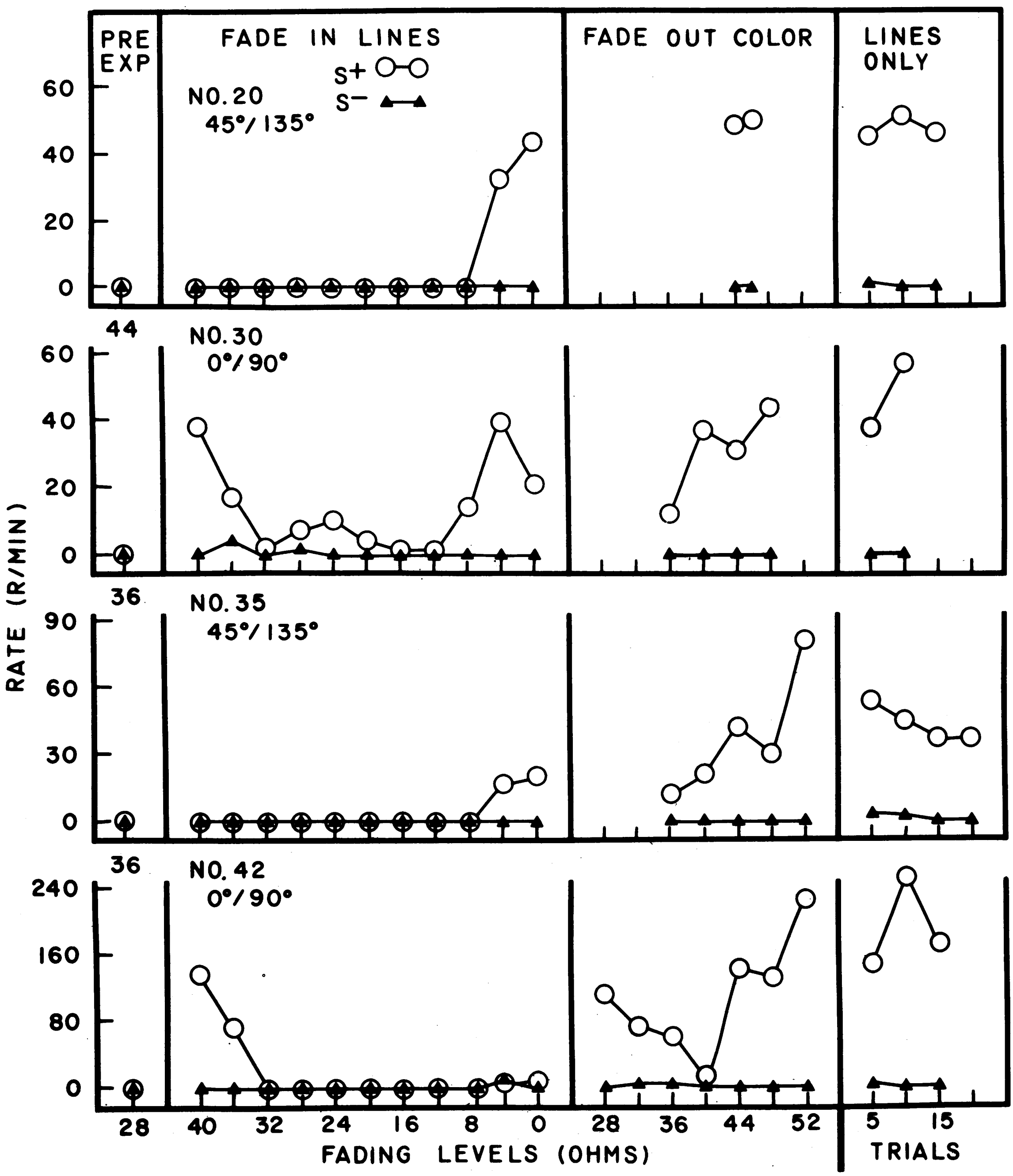

Fig. 2. Responding emitted in the presence of each line probe presented as a function of fading levels during each experimental condition for subjects in Group 2. Experimental conditions are listed across the top of the figure. Each row contains data for one subject. Subject number and the line tilts used are indicated in the second section of the graph on each row. Responding is presented in responses per min. The intensity of the stimuli being introduced or attenuated is indicated in terms of resistance (ohms) and is inversely related to resistance value where 0 ohms is full intensity. The right-most panel on each row indicates S+ and S− response rates plotted as a function of number of blocks of 5 S+s and 5 S−s once the colored stimulus elements were eliminated.

Figure 2 presents the results for subjects with whom S+ and S− probes were presented throughout fading. For all subjects, once the lines were fully faded in, responding occurred in the presence of the S+ probes and did not in the presence of the S− probes. As the colors were attenuated, responding to the S+ probes increased and no S− probe responding occurred. When presented alone, responding occurred predominantly in the presence of the S+ line relative to the S− line.

Probe responding during line fade in was systematically influenced by the orientation of the lines used. When diagonal lines were used, the S+ probes evoked responding as soon as the lines were superimposed on the colors. S+ probe responding then declined as the lines were faded in and eventually increased. During the line fade in, however, the S− probes occasioned little or no responding. When horizontal and vertical lines were used, neither probe occasioned any responding until the last portion of the line fade in. At that point, notably, responding occurred only in the presence of the S+ probe.

Table 1

Probe responding once new line stimuli have been faded in, when probes have and have not been used while introducing the new stimuli.

Condition	Subject	*Line tilt (degrees)* S+	S−	*Probe responding once lines are fully faded in*[a] S+ probe	S− probe
Group I No Probes	3	0	90	0	.03
	31	0	90	.39	.15
	25	45	135	.30	0
	36	45	135	.23	.03
Group II With Probes	35	0	90	.31	0
	42	0	90	.04	0
	20	45	135	1.28	0
	30	45	135	.30	0

[a]Responding presented as a proportion of the prevailing S+ rate.

DISCUSSION

Effect of starting intensity on locus of acquisition in fading. The differential probe responding observed at the end of the line fade in for seven of the eight subjects in the experiment indicated that the lines had acquired control of responding while they were being introduced. These results were obtained when the starting intensity of the original controlling stimuli were set at a low level. In contrast, when the same general procedure was used and the starting intensity of the original controlling stimuli was set at a high level, Fields (1978) found that the new stimuli did not acquire control of responding while being introduced. Rather, the new stimuli acquired control only after the original controlling stimuli had been partially attenuated. Taken together, then, the results of both experiments indicate that the point in fading at which the new stimuli acquired control of responding is directly related to the starting intensity of the original controlling stimuli. Such findings are predicted from a blocking analysis of fading.

Effects of attenuating the original controlling stimuli in fading. When the colors were attenuated, responding to the S+ probes increased while responding to the S− probes decreased or remained at a zero level. These results suggest, then, that the effect of attenuating the original controlling stimuli was to strengthen the control already established during the previous portion of the experiment.

Effects of probes on acquisition of stimulus control. While utilization of probe stimuli in fading permits measuring acquisition of control by new stimuli, their use can also influence the process of acquisition itself (Skinner, 1968). These possibilities were examined by comparing probe data obtained at the end of the line fade in in each experimental group.

When probes were used while fading in the line stimuli, once the lines were fully faded in, probe responding was evoked by only the S+ line probe for all subjects (see Table 1). When probes were not used while fading in the line stimuli, once the lines were fully faded in, more responding was evoked by the S+ probe than by the S− probe for three subjects and minimal probe responding was evoked by both probes for one subject (see Table 1). Thus, presentation of probes while fading in the new stimuli actually somewhat increased the control acquired by angular orientation of the lines. This comparison demonstrates that probe stimuli influenced the process of acquisition in fading, but not to a great extent. The direction of the influence, *however,* is rather surprising, since it might have been predicted that presentation of probe stimuli under extinction conditions would retard acquisition of control by new stimuli in fading, when in fact the use of probes appeared to enhance acquisition.

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