Stimulus control following response reduction with signaled reinforcement*

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Three pigeons were trained on a multiple schedule in which the availability of reinforcement was signaled in one component which was correlated with a vertical line stimulus. Response rates in the presence of this stimulus were rapidly reduced to a very low level in the case of two of the pigeons, while the third showed only a moderate reduction. When given a generalization test following this training, all pigeons showed markedly excitatory gradients on the dimension of line orientation.

Recently, there has been interest in the possibility that behavioral contrast and inhibitory stimulus control may be produced simply by a reduction in response rate in the presence of a discriminative stimulus (Terrace, 1966). The independent studies of Baldock (1970) and Brownstein & Newsom (1970) demonstrated that behavioral contrast could occur when response rate in one component of a multiple schedule was reduced by signaling the availability of reinforcement. Weisman (1969, 1970) found both behavioral contrast and inhibitory stimulus control following reductions in responding produced by instituting either differential reinforcement of low rate (DRL) or differential reinforcement of "other" (DRO) responding in one component of a multiple schedule. A feature of all these studies was that the same reinforcement frequency was maintained in both components of the schedules throughout training, despite changes in scheduling.

A problem with DRL and DRO schedules is that they reinforce unspecified responses other than keypecking. There is also the possibility that these schedules have aversive properties, since keypecks can produce a loss of reinforcements, and such properties could themselves produce contrast and inhibitory control independently of the changes in response rate they produce. The signaled reinforcement procedure has the advantage that the S is not penalized for making responses. A response is still required to produce reinforcement under exactly the same schedule, but it is only necessary for the S to emit a response when reinforcement becomes available and the signal is presented. Thus, responses

in the absence of the signal are redundant. At the same time, since reinforcement is available only in the presence of the signal, absence of the signal is actually correlated with extinction. This could produce inhibitory control by a stimulus correlated with absence of the signal and might account for the instances of behavioral contrast observed by Baldock and by Brownstein and Newsom. The present experiment sought to determine if such a stimulus would develop inhibitory control under a signaled reinforcement procedure.

SUBJECTS AND APPARATUS

Three naive locally obtained homing pigeons, maintained at 80% of their free-feeding weights, were Ss. Water and grit were continuously available in their individual home cages, which were housed in a room illuminated 24 h per day. The experimental chamber consisted of a three-key pigeon chamber housed in a sound-attenuating box. The center key could be illuminated by an in-line digital display unit. This provided the only illumination in the chamber, except during reinforcement, when a light over the magazine was on and the key light was off. Reinforcement consisted of 4-sec access to mixed grain. An exhaust fan provided some masking noise. Programming and recording was carried out automatically by equipment housed in an adjoining room.

PROCEDURE

Following shaping of a keypeck and gradual introduction of variable-interval (VI) reinforcement, the Ss were given 20 sessions of training on a single VI 1-min schedule. At this point, a multiple schedule was introduced which had VI 1-min reinforcement in each component. One component of this schedule was correlated with a blank red key (S1), while the other component was correlated with three vertical white

lines superimposed on the red key (S2). These stimuli were presented alternately, and each occupied half of the 40-min sessions. Each stimulus presentation was 1 min in duration and was separated from a presentation of the other stimulus by a 5-sec timeout. Training was continued with this schedule for either 40 (Pigeon 55) or 50 (Pigeons 61 and 67) sessions, at which point responding appeared to be sufficiently stable to provide a baseline.

In the next phase of training, the schedule was the same, except that the availability of reinforcement under the VI 1-min schedule was signaled in the presence of S2. The signal consisted of a change in the background illumination of the key from red to black. Following presentation of this signal, the first peck on the key delivered reinforcement. Training with this signaled reinforcement procedure was continued for 15 (Pigeons 61 and 67) or 25 (Pigeon 55) sessions. Following this training, a generalization test was administered. In this, each of five different orientations of the three lines, all superimposed on the red background, were presented in extinction. The five orientations employed were 0 (S2), 22.5, 45, 67.5, and 90 deg from vertical. Each of these orientations was presented once, in a randomized sequence, in each of eight blocks of 1-min presentations.

RESULTS

Mean rates of responding during the last 10 sessions on the baseline schedule (Day 0) and in blocks of five sessions on the signaled reinforcement schedule are plotted in Panel A of Fig. 1. It can be seen that signaling the availability of reinforcement had the effect of reducing the rate of responding in the presence of S2. This reduction was large and occurred quite rapidly in the case of Pigeons 55 and 61, while Pigeon 67 showed a smaller reduction. An inverse relation between changes in response rate in S1 and S2 did not hold across Ss. Pigeons 55 and 67 showed an increase in response rate in S1, indicating the occurrence of behavioral contrast. On the other hand, Pigeon 61 showed a small overall reduction in response rate in the presence of S1, despite a large reduction in the presence of S2.

Rates of responding in extinction during the generalization test are plotted in Panel B of Fig. 1. The same scale has been used on the ordinate to facilitate comparison of absolute response rates during training and testing. The response rates at each line orientation were averaged over the eight 1-min presentations given during the generalization test. For each pigeon, the highest rate of responding

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was obtained in the presence of the orientation 0 deg from vertical (S2). Response rates decreased progressively with increasing differences in orientation away from vertical. Thus, for all pigeons, the obtained generalization gradients were clearly excitatory in form. The excitatory nature of these gradients does not appear to depend upon any lack of reduction in response rate in the presence of S2, since Pigeons 55 and 61 showed large reductions resulting in a very low level of responding during training. An interesting feature of these data is that the rate of responding in the presence of S2 (0 deg) occurred at a considerably higher rate during the extinction test than during the last sessions of training with signaled reinforcement. This is rather surprising in view of the fact that this stimulus was identical under both conditions and was actually correlated with extinction under both testing and the preceding training (when it was correlated with absence of the reinforcement signal).

DISCUSSION

Signaling reinforcement availability in one component of the multiple schedule produced a reduction in response rate in that component and some instances of behavioral contrast. Thus, the results obtained with this training procedure were similar to those previously reported by Baldock (1970) and Brownstein & Newsom (1970). They are also consistent with Baldock's finding of a lack of correlation between the magnitude of the reduction in response rate in one component and the occurrence of contrast in the other component. Reynolds (1968) has noted a similar lack of correlation during the development of behavioral contrast produced by varying reinforcement frequency. This suggests that there is not a simple relation between response-rate reduction and the production of behavioral contrast.

Although responding was markedly reduced in the presence of S2 during training with signaled reinforcement, the generalization test showed excitatory, rather than inhibitory, stimulus control on the dimension of line orientation. Although the performance of the three Ss differed in a number of respects during training, their performance on the generalization test was uniform in that they all produced clearly excitatory gradients. It seems likely that the large increases in absolute response rates in the presence of S2 during the generalization test contributed to the excitatory form of the gradients. There is no indication in these data that S2 acquired any inhibitory properties.

Fig. 1. Panel A: Mean response rates in the presence of S1 (open points) and S2 (filled points) during training with signaled reinforcement. Mean response rates over the last 10 sessions of baseline training are plotted at Day 0 on the abscissa. Baseline rates in the presence of S1 are also represented by the horizontal dashed lines. Panel B: Response rates in the generalization test. Orientation of the lines is specified in terms of degrees from vertical. The stimulus having 0-deg line orientation was identical to S2.

Formally, it is possible to reanalyze the component in which reinforcement was signaled as comprising two subcomponents, the first consisting of extinction in the presence of S2 and the second consisting of FR1 in the presence of the reinforcement signal. In terms of this analysis, the presence of the extinction subcomponent might have produced both the instances of behavioral contrast observed and some inhibitory control by S2. In addition, the presence of the vertical line during the signal for reinforcement might

account for the excitatory generalization gradients obtained. However, such an account would appear to attribute both inhibitory and excitatory properties to the S2 compound, since line orientations were always compounded with the red background during the generalization test. In any case, the real question of interest is not how the schedule can be analyzed in formal terms, but how the schedule was analyzed by the pigeons. Their performance does not appear to have been consistent with S2 having acquired the properties of an extinction stimulus. Although the S2 compound was, in fact, correlated with the same schedule, extinction, during both training and testing, performance in the presence of S2 was very different during these two phases of the experiment. If the reduction in responding in the presence of S2 during training was a result of the pigeons' analyzing this as an extinction stimulus, it is difficult to see how responding could have increased to such a high level during a single session on the generalization test. Since there is evidence that inhibitory effects produced by extinction persist for a number of sessions, even when responding is being reinforced (Hearst, Besley, & Farthing, 1970), this increase in responding in the presence of S2 during the test appears more consistent with the absence of any inhibitory control by this stimulus. On the other hand, a sudden increase in response rate accompanying the introduction of extinction is commonly found following intermittent reinforcement of a response. Thus, if this effect contributed to the large increase in S2 responding during the generalization test, it would also be evidence for S2's having excitatory properties during training.

The foregoing, together with the generalization gradients obtained, suggests that the signaled reinforcement procedure led to the development of excitatory control by S2, despite a marked reduction in responding in its presence during training. There appear to be a number of ways in which this could have come about. One possibility is that responding in the presence of S2 was adventitiously reinforced by presentations of the signal, thus maintaining the excitatory properties of the stimulus. The performance of Pigeon 67 during training was quite consistent with the development of a superstitious chain in Component 2. The moderate decrease in responding which occurred was followed by an increase and the eventual maintenance of a rate of nearly 60 responses/minute. However, it seems

unlikely that chaining played an important role in the performance of the other two pigeons, since their responding in S2 decreased quite rapidly to a very low level. Another possibility is that both the excitatory properties of S2 and the reduction in responding in its presence were generated directly by the signal for reinforcement. Indeed, the fact that reinforcement frequency was held constant at the baseline level in Component 2 may, in itself, have been sufficient to maintain the excitatory properties of S2 that were established under baseline training (cf. Catania, 1961). Insofar as introduction of the signal increased the predictability of reinforcement, the favorability of this component was presumably increased. Responding in the presence of S2, which the signal made redundant with respect to obtaining reinforcement, may have been simply omitted or replaced with an alternative behavior without being actively inhibited. In terms of this analysis, the reinforcement signal could be thought of as controlling a low rate of responding by making it redundant. Such control would be consistent with the large increase in responding in the presence of S2 when the signal was removed during the generalization test. In short, the results appear to be most readily handled in terms of excitatory control exercised by the reinforcement properties of Component 2.

The results provide evidence that the signaled reinforcement procedure is one in which a reduction in response rate alone is not sufficient for the production of inhibitory control on a stimulus dimension. Since contrast effects have been found with this procedure, both in previous studies and in the present one, these results also weaken the case for a correlation between the occurrence of behavioral contrast and the development of inhibitory stimulus control. The signaled reinforcement procedure itself appears to have interesting properties which could be valuable in the analysis of the determinants of stimulus control.

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Schedule-induced polydipsia with nutritive and nonnutritive reinforcers

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Eighteen Charles River (cd) male rats were conditioned to drink water polydipsically by the delivery of food pellets on FFI 45 sec, and then, varying percentages of sweetened nonnutritive pellets were substituted for the nutritive pellets. The mean volume of water ingested decreased with decreased nutritive content of the pellets, suggesting a relationship between schedule-induced polydipsia in the rat and the nutritive content of the reinforcer.

Intermittent delivery of a food substance to a food-deprived rat is accepted as a necessary condition for the development and maintenance of schedule-induced polydipsia. Unresolved, however, is the issue of the relationship between the magnitude of the reinforcement and the amount of water ingested. Keehn (1970) suggested that a 21-pellet reinforcer induced longer drinks, while there was only a weak relationship between number of pellets per reinforcement and drink size for 1, 3, 6, and 9 pellets. Falk (1967) had earlier reported that smaller portions per reinforcement produced increased water intake per session. On the other hand, in a partial replication, Hawkins, Everett, Githens, & Schrot (1970) found that increasing the portion size enhanced the level of drinking, reinterpreting Falk's (1967) results to indicate the same thing if one controlled for session length and did not evaluate solely the total volume consumed per session. Rosenblith (1970) also reported a greater amount of water drinking per interpellet interval with 250-mg food pellets than with 45-mg pellets.

A summary (Falk, 1969) of the issues involved in parameter control in such research cited the animal's

motivation, the motivational or reinforcing properties of the food, interpellet time, etc. To these must be added the above control on session length, as well as caloric value, as determiners of the reinforcing properties of food. Although Falk (1967) concluded that "caloric value per reinforcement, when compared across diets [was not] a predictor of drinking" of water, other studies (Freed, Carpenter, & Hymowitz, 1970; Freed & Lester, 1970) have suggested that, if the fluid is ethanol, its caloric value may be a prime factor in both its polydipsic consumption and in its resistance to extinction.

The present study attempted to elucidate further the relationship between polydipsia and its food determinant through the substitution of nonnutritive pellets, equal in size and weight to 45-mg Noyes food pellets but devoid of caloric value. Thus, while the number of reinforcements (or meals) and session length were held constant, the motivational property of the reinforcer was varied. By delivering the pellets on a free fixed-interval (FFI) schedule, barpress behavior, which presumably would reflect qualitative changes in food pellets, was eliminated as a possible confounding factor in Ss' drinking behavior.