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CONTROL BY THE AUDITORY OR THE VISUAL ELEMENT OF A COMPOUND DISCRIMINATIVE STIMULUS: EFFECTS OF FEEDBACK[1]

VINCENT M. LOLORDO AND DAVID R. FURROW

DALHOUSIE UNIVERSITY AND YALE UNIVERSITY

Groups of pigeons were trained to depress a treadle in the presence of a compound stimulus consisting of a tone and a red houselight (a) to avoid electric shock, or (b) to obtain grain. Immediate, exteroceptive feedback was equated for avoidance and appetitive groups within an experiment, but varied across experiments from elevation of a nonilluminated feeder to darkening of the chamber, termination of the tone, and elevation of an illuminated feeder. Responding in the absence of the compound stimulus postponed its next occurrence. After performance had stabilized, the degree to which each element controlled treadle pressing was determined. Generally, in the appetitive tests, the red light controlled much more responding than did the tone, but in the avoidance tests, the tone controlled more responding than did the red light.

Key words: compound discriminative stimulus, stimulus-reinforcer interaction, feedback, attention, positive reinforcement, avoidance training, pigeon

The relative control over responding by the elements of a compound conditioned or discriminative stimulus depends on the reinforcer that follows that compound stimulus (Garcia and Koelling, 1966; Foree and LoLordo, 1973; Weisinger, Parker, and Skorupski, 1974). For example, Foree and LoLordo (1973) trained pigeons to depress a treadle in the presence of a compound stimulus consisting of tone and illuminated red houselights. For some birds, the reinforcer was avoidance of electric shock; for others, it was presentation of grain. When a bird was responding on a high proportion of the compound trials, but responding infrequently between trials, the degree to which the compound and each of its components controlled treadle pressing was determined. In the appetitive test, the compound and the light exerted strong control over treadle pressing, but the tone controlled very little responding. On the other hand, in the avoidance test, the compound and the tone controlled more responding than did the light.

In Foree and LoLordo (1973), feedback contingent on a response during the discriminative stimulus differed between conditions. An avoidance response re-instated the intertrial conditions, white houselight and no tone, but an appetitive response turned off the tone and produced a 5-sec blackout simultaneous with elevation of an illuminated grain magazine. Thus, there was more total feedback, and indeed greater visual feedback, in the appetitive than in the avoidance condition. Perhaps this differential feedback was responsible for the greater visual control in the appetitive condition. The present experiments investigated this possibility. They differed from the procedures described by Foree and LoLordo (1973) only in the stimuli that immediately followed a treadle press in the presence of the discriminative stimulus.

METHOD

Subjects

Thirty-two naive White King pigeons, from Palmetto Pigeon Plant, Sumter, South Carolina, were deprived to and maintained at 80% of their free-feeding weights. Water was freely available. Stainless-steel wire electrodes were implanted around each bird's pubis bones be-

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fore its first experimental session. The electrodes were connected to a double banana plug, which was attached to a leather harness worn at all times (Azrin, 1959; Coughlin, 1970).

Apparatus

In a 42- by 28- by 30-cm chamber, a 9- by 7-cm aluminum treadle, similar to one used by Foree and LoLordo (1973), was attached to a wooden bar that protruded from a hole in the right center of the black front wall. The treadle was tilted down from the wall at a 30° angle to the cardboard-backed, wire grid floor, with the lower edge 3.5 cm from the floor when the treadle was not depressed. Approximately 50 g (0.49 N) downwards force on the treadle was required before a response pulse was recorded. A 5- by 4.5-cm food magazine was located on the front wall 4 cm to the left of the treadle. Two speakers were mounted one above the other in the front of the white left wall. The tone stimulus was 440 Hz emitted by the top speaker. Visual stimuli were mounted above a translucent white Plexiglas ceiling. Four red 120-V, 7-W Christmas tree bulbs made up the red-light stimulus, and two simlar white bulbs served as the white-light stimulus.

Electric shocks, 120 msec of 60 Hz, 110-V alternating current passed through a variable transformer and a 10-KΩ resistor, were transmitted via the cables of a swivel mounted in the ceiling of the box. A double banana plug on the swivel cable was plugged into the double banana plug on the bird's harness before each session. The experimental chamber was contained in a ventilated sound-attenuating box, with the ventilation fan providing masking noise. Further masking noise was provided by white noise in the experimental room.

Procedure

Consecutive daily sessions lasted 1 hr each.

Appetitive training. Birds were trained to eat from the grain magazine in the presence of the compound stimulus consisting of a tone, which increased the sound level from 72 to 88 dB (as measured by the A scale of a General Radio Type 1565-B sound-level meter), and illumination of the 7-W red houselights. After magazine training, which took less than one session, responding was shaped until the birds depressed the treadle on a CRF schedule for 5-sec access to grain. During shaping, the compound stimulus was continuously present until reinforcement occurred. The intertrial stimulus consisted of illumination of the two 7-W white houselights and the absence of tone and followed each reinforcement for 0.5 sec. When treadle pressing was established, the duration of the intertrial stimulus was increased to 15 sec and the duration of the compound stimulus was reduced to 5 sec over a period of two to four days. Each intertrial response reset the intertrial interval and darkened the chamber for 160 msec.

The final training schedule thus consisted of an intertrial period of at least 15 sec with white houselights and no tone. Each response in the intertrial period extended the period for 15 sec and then a 5-sec trial began. During the trial, the red houselights and tone were on, and the first response produced 5-sec access to grain. The experiments differed only in the stimuli present during reinforcement. Experiment I ($N = 6$) markedly reduced the visual feedback for a response, relative to the appetitive condition of Foree and LoLordo (1973). During reinforcement, the tone and red houselights remained on and the grain magazine was not illuminated. In Experiment II ($N = 7$), birds received feedback matched to the avoidance conditions of Foree and LoLordo (1973). During reinforcement, the intertrial stimuli, white houselight and no tone, were present. The grain magazine was not illuminated. In both experiments, failure to respond during a trial re-instated the intertrial conditions. Table 1 illustrates the feedback conditions of Experiments I and II.

Training continued until the birds responded on at least 75% of the trials in a session. They were tested on the day after this criterion was reached.

Avoidance training. The avoidance-training procedure was similar to the signalled avoidance procedure used by Foree and LoLordo (1973). Each response in the presence of the intertrial stimulus (white houselights and no tone, as in the appetitive procedure) reset the intertrial duration to 15 sec. Intertrial responses darkened the chamber for 160 msec. After 15 sec without a response in the intertrial condition, the compound stimulus (again consisting of the red houselights and tone) came on. The experiments differed only in the

stimuli present during the 5 sec immediately following a response in the presence of the compound stimulus. In Experiment I (N = 7), the feedback was matched to the first appetitive experiment. The red houselights and tone remained on, while an unlit and empty grain magazine was elevated for 5 sec. The intertrial conditions were then re-instated. In Experiment II (N = 6), the feedback was matched to the second appetitive experiment. The intertrial stimuli, white houselight and no tone, were re-instated when an avoidance response occurred, and an unlit and empty grain magazine was elevated for 5 sec. Experiment III (N = 7) matched feedback to the feedback of the appetitive study of Foree and LoLordo (1973). An avoidance response produced a 5-sec blackout of the chamber lights, terminated the tone, and elevated an illuminated but empty feeder. This condition thus included greater visual feedback than did the other avoidance conditions. Table 1 illustrates the feedback conditions of Experiments I, II, and III.

Table 1

Stimuli present during the 5 sec following a response in the presence of the compound S^D.

	Exp. I	*Exp. II*	*Exp. III*
Houselight	Red	White	None
Tone	On	Off	Off
Feeder	Unlit	Unlit	Lit

In all three avoidance experiments, failure to respond within 5 sec after onset of the compound stimulus resulted in a brief (120 msec) shock. The compound stimulus remained on and the shock was presented every 5 sec until a response occurred. No hand shaping was employed.

The shock voltage was set at 30 V on the first day of training and was increased 10 V each day to a maximum of 60 V for all pigeons.

Birds were trained until they avoided shock on at least 75% of the trials in a session. The test was given on the following day.

Testing. The test session began with a 10-min warmup period during which the training conditions were in effect. The next 60 trials consisted of 20 presentations each of the compound training stimulus and its elements (red light alone, and tone alone), in a random order that was the same for all birds. Throughout the test, responses during the compound stimulus or either of its elements were reinforced. Further, the feedback conditions of training were in effect. In the avoidance test, failure to respond on a trial resulted in presentation of only one shock, followed by re-instatement of the intertrial conditions.

RESULTS

Generally, relatively little intertrial responding occurred in either the appetitive or avoidance conditions (Foree and LoLordo, 1973). Pigeons in appetitive Experiments I and II reached criterion after a range of 2 to 20 sessions, similar to that observed by Foree and LoLordo (1973). Pigeons in avoidance Experiments I, II, and III reached criterion after a range of 4 to 33 sessions, with the birds in Experiment III reaching criterion sooner than the other two groups.

The dependent measure was the number of responses to the test stimuli during the test session. Panels APP-I and APP-II of Figure 1 illustrate the median total number of responses out of 20 opportunities to respond in the presence of each stimulus for pigeons in appetitive Experiments I and II, respectively. In both appetitive experiments, every pigeon made about the same number of responses during the compound S^D and the red light alone, but made few responses to the tone alone. Thus, the marked reduction in the amount of immediate feedback for a response, from blackout of the chamber lights, cessation of tone, and elevation of an illuminated grain magazine in the appetitive procedure of Foree and LoLordo (1973), to elevation of an unlit grain magazine in appetitive Experiment I, did not reduce the relative amount of visual control.

Panels AV-I, AV-II, and AV-III of Figure I illustrate the median total number of responses out of 20 opportunities to respond in the presence of each stimulus for pigeons in avoidance Experiments I, II, and III, respectively. In avoidance Experiments I and II, pigeons made roughly the same median number of responses to the compound and to the auditory element, but made fewer responses to the red light. The group functions characterized all six pigeons of Experiment I and

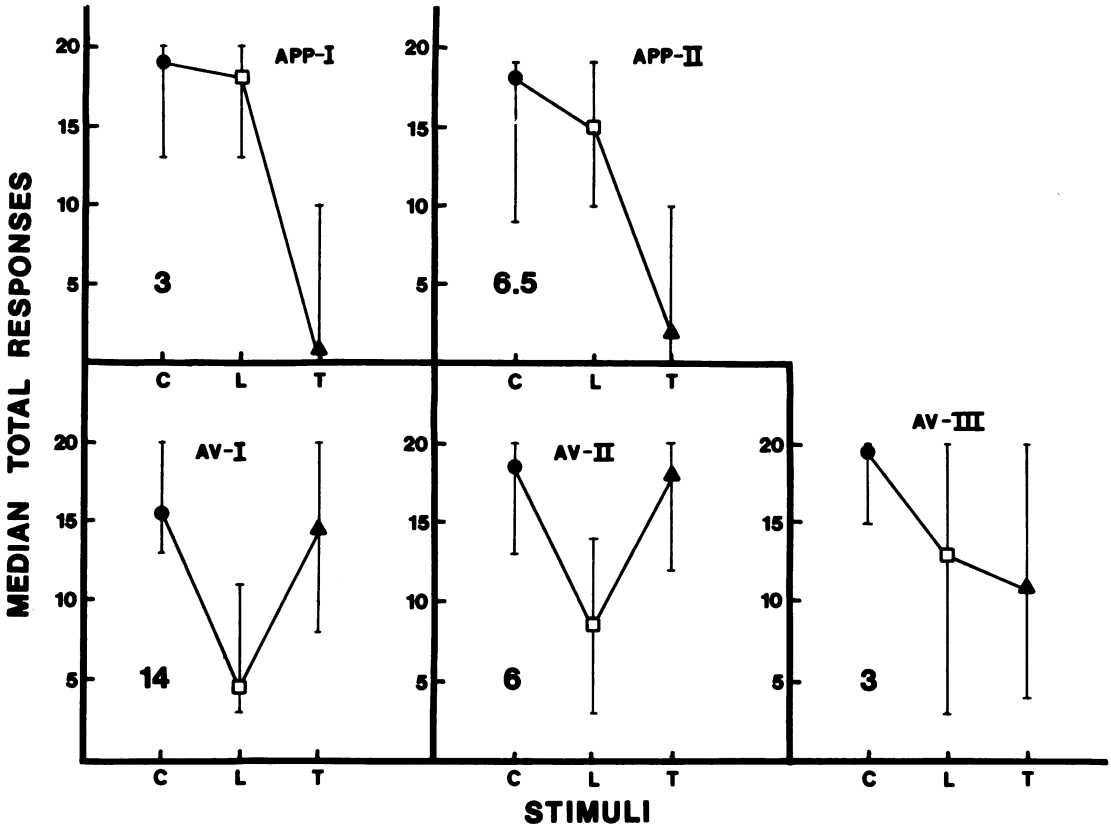

Fig. 1. Median total responses to the compound stimulus (C), the red light (L), and the tone (T) during the test session for pigeons in appetitive Experiments I and II (APP-I, APP-II), and avoidance Experiments I, II, and III (AV-I, AV-II, and AV-III). The vertical lines extending from each data point indicate the range of performance within the group. The large numbers within each panel indicate the median number of sessions to criterion for each group.

five of six pigeons in Experiment II. These results, combined with the data from the appetitive groups, which received equivalent feedback (appetitive Experiments I and II), demonstrate a strong interaction between the stimulus modality and reinforcement conditions, and suggest that the differential feedback conditions of the appetitive and avoidance procedures used by Foree and LoLordo (1973) were not responsible for the stimulus-reinforcer interaction that they observed.

Panel AV-III illustrates that, unlike the other avoidance conditions, control was not primarily auditory when feedback for an avoidance response consisted of 5-sec blackout of the chamber lights, cessation of the tone, and elevation of an illuminated but empty feeder. There was considerable variability within the group, and two birds (Subjects 56 and 78) showed primarily visual control; these birds met the acquisition criterion most rapidly, *i.e.*, on the second day of avoidance training.

The coincidence of rapid acquisition and primarily visual control of avoidance in Birds 56 and 78 suggested a systematic relation between speed of acquisition and the relative control exerted by auditory and visual compound stimuli. The upper panel of Figure 2 illustrates this relation for the avoidance group of Foree and LoLordo (1973), the birds of the avoidance Experiments I, II, and III, and an additional avoidance group (N = 6) that received 5 sec of green houselight, termination of the tone, and elevation of a nonilluminated, empty grain magazine immediately following a response during the compound discriminative stimulus, but was otherwise treated like the other avoidance groups. The figure suggests two main points: (1) there was primarily visual control only when the avoidance criterion was reached in two sessions, which was

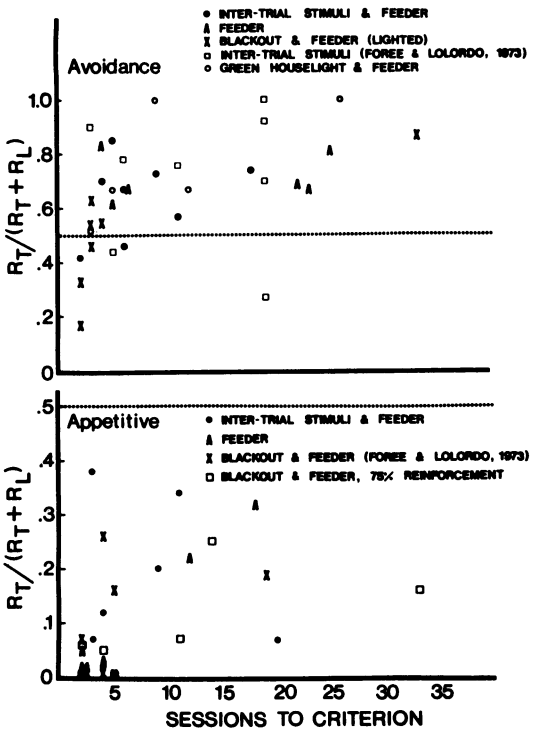

Fig. 2. The ratio of total test responses to tone alone (R_T) divided by the sum of total test responses to tone alone and total test responses to light alone (R_T and R_L) plotted against sessions to criterion for individual pigeons in the various avoidance (upper panel) and appetitive (lower panel) experiments. In the upper panel, open squares represent data from the condition in which feedback consisted of presentation of the intertrial stimuli (Foree and LoLordo, 1973). Inverted "Vs" represent Experiment I, in which feedback consisted of elevation of the feeder. Filled circles represent Experiment II, in which feedback consisted of presentation of the intertrial stimuli and elevation of the feeder. "Xs" represent Experiment III, in which feedback consisted of termination of the tone, blackout of the houselights, and elevation of an illuminated feeder. Open circles represent an experiment in which feedback consisted of termination of the tone, illumination of green houselights, and elevation of the feeder. In the lower panel, inverted "Vs" represent data from Experiment I, in which feedback consisted of elevation of the feeder. Filled circles represent Experiment II, in which feedback consisted of presentation of the intertrial stimuli and elevation of the feeder. "Xs" represent a condition in which feedback consisted of termination of the tone, blackout of the houselights, and elevation of an illuminated feeder (Foree and LoLordo, 1973). Open squares represent a condition in which a response had no effect on 25% of the trials, but produced termination of the tone, blackout of the houselights, and elevation of an illuminated feeder on 75% of the trials.

the case for three pigeons, including two from avoidance Experiment III; (2) as the number of sessions to criterion increased beyond this point, the degree of relative auditory control increased rapidly at first, and then more slowly.

The lower panel of Figure 2 illustrates the comparable relation for the groups that received food reinforcement, as well as an additional group described below. In every case there was more visual than auditory control, although there was a hint of a decrease in visual control as the sessions to criterion increased. To examine this possibility, an attempt was made to increase the number of sessions to criterion in the appetitive procedure by permitting reinforcement on only 75% of the conditioning trials. Seven naive White King pigeons received training and testing procedures like those of appetitive Experiment I, except for the feedback conditions. During the trial, the red houselights and tone were on, and on a randomly selected 75% of the trials the first response produced 5-sec access to grain. During the 5-sec reinforcements, the tone and all houselights were turned off, and the filled grain magazine was illuminated. On a predetermined 25% of the trials responding had no effect; the intertrial conditions were re-instated after 5 sec. The reinforcement and feedback conditions of training continued during the test. These pigeons reached the performance criterion in 2, 2, 4, 5, 11, 14, and 33 sessions. Thus, partial reinforcement had only a small effect on the sessions to criterion. The open squares in Figure 2 illustrate relative control exerted by auditory and visual stimuli as a function of sessions to criterion for individual birds. All seven birds made many more responses to the compound and to the red light alone than to the tone alone, although the three pigeons that required more than 10 sessions to criterion did make a higher proportion of test responses to the tone than did the four pigeons that required five sessions or fewer.

DISCUSSION

When a treadle-press response in the presence of the auditory-visual discriminative stimulus was followed by relatively little immediate feedback, as in the appetitive and avoidance groups of Experiment I, there was a marked interaction between stimuli and re-

inforcers, such that the red light exerted more control over food-reinforced treadle pressing than did the tone, but the tone exerted more control over treadle-pressing avoidance responding than did the red light. The same interaction was observed when the reinforced response produced somewhat more feedback; *e.g.*, when it was followed immediately by reinstatement of the intertrial conditions, as in the paired groups of Experiment II and the avoidance procedure of Foree and LoLordo (1973). However, the stimulus-reinforcer interaction was not clear-cut when there was even greater feedback, consisting of darkening of the chamber, termination of the tone, and elevation of an illuminated grain magazine, as in the appetitive procedure of Foree and LoLordo (1973) and Experiment III. Again, control of treadle pressing was primarily visual in the appetitive procedure. Further, the relative degree of auditory control, as expressed by the ratio: responses to tone/(responses to tone + responses to light) was greater for the avoidance condition than for the appetitive condition. However, several of the birds in the avoidance group, including two that met criterion in two days, showed predominantly visual control. This outcome suggests that avoidance procedures that include considerable feedback and produce very rapid acquisition may lead to strong visual control of the avoidance response. That considerable feedback is not itself sufficient for strong visual control of avoidance responding is suggested by the predominantly auditory control found when avoidance responding changed the illumination in the chamber from red to green (Figure 2).

Although the degree of relative auditory control increased somewhat as the number of sessions to criterion increased in the various appetitive procedures (Figure 2), all 28 birds showed more visual than auditory control. Furthermore, comparing the panels of Figure 2, at any number of sessions to criterion, relative auditory control for birds in the avoidance conditions was greater than for birds in the appetitive conditions.

In summary, the effect observed by Foree and LoLordo (1973) does not depend upon differential feedback for a response in the two conditions, and thus is a stimulus-reinforcer interaction, or example of stimulus relevance (see Revusky and Garcia, 1970; Shettleworth, 1972 for discussions of stimulus relevance).

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