The effect of discrimination training on the response rate and response duration of the rat

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Response rate (responses per minute) and response duration (time in seconds per press) were recorded in rats shifted from multiple variable-interval variable-interval (mult VI VI) to multiple extinction variable-interval (mult EXT VI). This procedure produced positive contrast (i.e., a decrease in response rate in EXT and an increase in VI) in 11 of 12 rats and, in addition, produced an increase in response duration (i.e., bar holding), which, for the most part, was confined to the EXT component of the mult EXT VI condition. One of the 12 rats showed negative induction (i.e., a decrease in response rate in both the EXT and VI components), and also an increase in response duration in both the EXT and VI components of the mult EXT VI condition. The results indicate that generalization of behavior from the EXT to the VI component can produce negative induction, and that such generalization must be prevented if positive contrast is to occur in the rat.

Positive behavioral contrast occurs when the alteration in one component of a two-component multiple schedule (i.e., mult S1 S2) results in a decrease in the response rate in the altered (S1) component and an increase in the unaltered (S2) component. This effect was initially demonstrated by Reynolds (1961) in a three-phase procedure. After baseline training on a multiple variable-interval variable-interval (mult VI VI) schedule, the S1 component was shifted to extinction (EXT) in Phase 2 (i.e., mult EXT VI) and back to variable-interval (VI) in Phase 3 (i.e., mult VI VI). As a result, the response rate decreased in EXT and increased in VI during Phase 2 (i.e., positive contrast), and returned toward the Phase 1 response rate level in both VI components during Phase 3 (i.e., baseline return¹). The mult VI VI condition of Phase 3 served as a control to ensure that the positive contrast effect in Phase 2 was not a function of a spontaneous increase in VI response rate over time.

Although the mult VI VI-mult EXT VI procedure has produced positive contrast more reliably than any other procedure, there are instances in which it has produced negative induction (i.e., a decrease in response rate in both S1 and S2) rather than positive contrast. Both Hemmes (1973) and Westbrook (1973) obtained this effect in pigeons pressing a treadle, and Freeman (1971) and Stern and Eckerman (Note 1)

obtained it in rats pressing a bar. Some investigators view such findings as support for an explanation of positive contrast based on autoshaping (e.g., Hearst & Jenkins, 1974; Schwartz & Gamzu, 1976). For example, Gamzu and Schwartz (1973) have proposed that the shift from mult VI VI to mult EXT VI establishes a contingency between the S2 (VI) cue and the reinforcer, and that this contingency will elicit keypecks if the S2 cue is localized on the key. Consequently, the positive contrast effect is attributed to the algebraic summation (i.e., additivity) of newly conditioned autopecks and the previously conditioned operant pecks. In the case of the studies cited above, the cues were not located on the response manipulanda, and hence, the additivity notion would predict the absence of positive contrast.

There are several problems with this interpretation. First, positive contrast has been obtained in both the pigeon (Farthing, 1975; Hemmes, 1973; Westbrook, 1973) and the rat (Beninger & Kendall, 1975; Gutman, 1977; Gutman & Minor, 1976; Gutman, Sutterer, & Brush, 1975; Mackintosh, Little, & Lord, 1972) with procedures that did not localize the multiple schedule cues on the response manipulandum. Second, in at least one study (Scull & Westbrook, 1973), positive contrast failed to occur even though the VI cue of the mult EXT VI condition was localized on the response key. Finally, negative induction is an effect in its own right, and hence should not be explained by assuming that the conditions necessary for positive contrast are lacking.

The autoshaping hypothesis can explain the occurrence of negative induction in the studies cited above. For example, Hearst and Jenkins (1974) have posited that rats and pigeons alike orient to (i.e., sign track) stimuli signaling positive events. Thus off-key (or

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off-lever) cues could direct the subject away from the response manipulandum, and, in so doing, reduce the response rate. However, this account cannot explain why some of the procedures that locate cues away from the response manipulandum do indeed produce positive contrast. A more plausible explanation of negative induction is that behavior conditioned in the EXT component generalizes to and interferes with the behavior conditioned in the VI component (cf. Gutman, 1977; Sherman & Spitzner, 1975). For example, Stern and Eckerman (1974) and Westbrook (1973) recorded both response rate (i.e., responses per minute) and response duration (i.e., time in seconds per response). In conjunction with the negative induction effect on the response rate measure, they obtained an increase in response duration in *both* the EXT and VI components. There is no reason to expect the change in response duration with continued mult VI VI training. Consequently, it is likely that the bar (or treadle) holding was generated by the EXT schedule, and that its generalization to the VI component may have interfered with and lowered the VI response rate.

One way of testing this notion is to record response rate and response duration in a procedure that produces positive contrast. In the Freeman (1971) and Stern and Eckerman (1974) studies, the discrimination in the mult EXT VI condition was between the presence and absence of a single auditory stimulus (i.e., tone-no tone; clicks-no clicks). Positive contrast has been obtained reliably in the rat with a discrimination between stimuli from different modalities (i.e., light-white noise, e.g., Gutman, 1977; Gutman & Minor, 1976; Gutman et al., 1975). Thus, the present study was designed to compare the response rate and response duration patterns from a procedure that normally produces positive contrast to those of the prior procedures (in the rat) that have produced negative induction.

METHOD

Subjects

Twelve experimentally naive female hooded rats (90-100 days of age) from the colony of the Experimental Psychology Laboratory, Syracuse University, were reduced to and maintained at approximately 80%-85% of their free-feeding weights.

Apparatus

Four Grason-Stadler operant chambers (29.5 × 24.0 × 19.5 cm) were mounted in sound-attenuating enclosures containing exhaust fans that served to ventilate the chambers and mask extraneous sounds. A single response lever requiring .16-.18 N of force to operate was located in the middle of the front panel, 9.5 cm above the grid floor. Standard 45-mg Noyes pellets were delivered into a magazine located 3.0 cm directly below the lever. Three additional exteroceptive stimuli were used. A 10-W lamp (GE 10C7/DC) was encased in a red plastic dome, 1.0 cm above and 7.0 cm to the left of the lever; a second 10-W lamp was attached to the outside of the Plexiglas chamber door, 8.0 cm above and 10.0 cm to the right of the lever; and white noise

(75 dB SPL) was delivered through a speaker located on the left side of the front panel, below the level of the grid floor.

For the response duration measure, pulses (10 sec) were fed through the common of a relay that was operated and remained operated as long as the microswitch from the lever remained closed. These pulses were, in turn, fed into a counter to form a running time meter.

Procedure

After three sessions of leverpress training on a continuous reinforcement schedule, the subjects were placed on a mult VI 30-sec schedule (i.e., Phase 1, Session 1). The multiple schedule consisted of 10 3-min presentations of S1 (the doorlight) and 10 3-min presentations of S2 (the white noise) occurring in strict alternation, beginning with S1. The red domelight served as a houselight and was on in both S1 and S2, and a 4-sec blackout interval (darkness and silence) occurred after each 3-min component. After baseline training on the mult VI VI condition, mult EXT VI 30-sec and mult VI 30-sec VI 30-sec schedules were administered in Phases 2 and 3, respectively, and readministered in Phases 4 and 5. One of the subjects received an additional mult EXT VI 30-sec mult VI 30-sec VI 30-sec cycle in Phases 6 and 7. In each of the mult EXT VI 30-sec conditions, the doorlight signaled EXT and the white noise, VI 30 sec. Six of the subjects were given 8 sessions of baseline training, and the other six were given 20-25 sessions. The number of sessions given in subsequent phases is summarized in the legends of Figures 1 and 2.

RESULTS

The data for each of the subjects are plotted in Figures 1 and 2. Each subject is represented by two graphs. The top set of panels of each pair of graphs depict the response rate (responses per minute), and the bottom set of panels, the response duration (time in seconds per response). The individual data points represent each session of each phase of training for both the altered (dotted functions) and unaltered (solid functions) components. Inspection of Figures 1 and 2 reveals that subjects given 20-25 sessions of baseline training (Figure 1) showed more uniformity on both response measures than did those given only 8 sessions (Figure 2).

20-25-Session Baseline

Positive contrast in the mult EXT VI condition is characterized by a decrease in response rate in EXT and an increase in VI; and baseline return is characterized by a return of the mult VI VI response rate toward the level of the mult VI VI condition that preceded the administration of the mult EXT VI condition. Inspection of the top panels of each pair of graphs in Figure 1 reveals that, in general, subjects given 20-25 sessions of baseline training showed positive contrast and baseline return in the mult EXT VI and mult VI VI conditions of Phases 2 and 3, respectively, and reproduced these effects in the mult EXT VI and mult VI VI conditions of Phases 4 and 5.

Concerning the positive contrast effects, four of the subjects (R11, R14, R15, and R16) showed and maintained a relatively large (i.e., at least 20 re-

Figure 1. Rate (response per minute) and time (time in seconds per response) data for individual rats (Rs) receiving 20-25 sessions of baseline training in Phase 1. The data points represent each session of each phase for both the altered (dotted functions) and unaltered (solid functions) components, and the phases are numbered in the lower right-hand corners of the time panels. The odd-numbered phases contained the mult VI VI condition, and the even-numbered phases, the mult EXT VI condition. All six rats received 10 sessions of training in Phases 2, 3, and 4, and 5-8 sessions in Phase 5.

sponses/min) increase in VI response rate in Phase 2. On the other hand, the increase in VI response rate for R12 was relatively small (i.e., less than 10 responses/min), and the increase shown by R13 was short lived (i.e., was not maintained across the entire phase). However, in Phase 4, all six subjects showed and maintained a relatively large increase in VI response rate relative to the mult VI VI response rate level of Phase 3. Concerning the baseline return effects, four of the subjects (R11, R12, R13, and R15) recovered the Phase 1 response rate level in Phase 3; one subject (R16) nearly did so; and one subject (R14) responded at a level half-way between

the response rates of Phases 1 and 2. In Phase 5, all six subjects responded at or very near the response rate level of Phase 3.

Inspection of the solid (VI) functions in the bottom panels of each pair of graphs in Figure 1 reveals a relatively uniform VI response duration pattern across the phases. Specifically, the VI duration tended to decrease across the first 10-15 sessions of Phase 1, after which it stabilized and remained relatively stable. In other words, with the exception of R14, the relatively large and stable baseline return effects in Phases 3 and 5 were correlated with relatively stable VI durations in Phases 1 and 3.

Figure 2. Rate (responses per minute) and time (time in seconds per response) data for individual rats (Rs) receiving 8 sessions of baseline training in Phase 1. The data points represent each session of each phase for both the altered (dotted functions) and unaltered (solid functions) components, and the phases are numbered in the lower right-hand corners of the time panels. The odd-numbered phases contained the mult VI VI condition, and the even-numbered phases the mult EXT VI condition. Four of the rats (R3, R4, R5, and R6) received 10 sessions of training in Phases 2, 3, and 4, and 8-10 sessions in Phase 5. R3 received 5 additional sessions in Phases 6 and 7, and R1 and R2 received 30 sessions in Phase 2, 10 sessions in Phases 3 and 4, and 5 sessions in Phase 5.

Comparison of the EXT (dotted functions) and VI (solid functions) response durations of Phases 2 and 4 reveals that two of the subjects (R11 and R12) showed little, if any, change on this measure in either component of either phase. However, the other four subjects (R13, R14, R15, and R16) showed an increase in response duration in both of these phases, and this increase was confined primarily, if not exclusively, to the EXT component of the mult EXT VI condition.

8-Session Baseline

Inspection of the data of subjects given 8 sessions of baseline training (Figure 2) reveals results that are not as uniform as those obtained with the 20-25-session baseline.

A striking example of this is R2, who showed negative induction (i.e., a decrease in response rate in both the EXT and VI components) rather than positive contrast in Phase 2 and, with the possible exception of the very first session, no interaction (i.e., neither positive contrast nor negative induction) in Phase 4. Note, however, that this subject showed an increase in response duration in *both* the EXT and VI components in both phases.

The other five subjects showed the response rate pattern characteristic of positive contrast in Phase 2, but none of them recovered the response rate level of Phase 1 in Phase 3. More specifically, in Phase 3, one subject (R3) showed a further increase in response rate relative to the VI response rate level of Phase 2; one subject (R1) showed no change in response rate; two subjects (R4 and R5) showed small and short-lived baseline return effects; and one subject (R6) showed stable baseline return, but to a response rate only half-way between the levels of Phases 1 and 2. In Phase 4, all five of these subjects showed the response rate pattern characteristic of positive contrast; and in Phase 5, four of them (R1, R3, R4, and R5) recovered response rates at or near the Phase 3 level. Note also that R3 reproduced the positive contrast and baseline return effects of Phases 4 and 5 in Phases 6 and 7.

Three of these five subjects (R3, R4, and R5) showed a uniform response duration pattern. Specifically, the VI duration (solid functions) decreased across Phases 1 and 2, and stabilized in and remained relatively stable after Phase 3. Therefore, for these three subjects, the failure to recover the Phase 1 response rate level in Phase 3 was correlated with a decreasing VI duration in Phase 1, whereas the relatively large and stable baseline return effects in Phase 5 were correlated with relatively stable VI durations in Phase 3. Furthermore, in Phases 2 and 4, these three subjects showed an increase in response duration that was confined primarily to the EXT component of the mult EXT VI condition.

The other two subjects deviated from this pattern. R1 did show the increase in response duration that was confined to the EXT component of the mult EXT VI condition; but, unlike R3, R4, and R5, the VI duration in Phase 2 was relatively stable. However, it should be noted that R1 did show a subsequent decrease in VI duration in Phase 3 (relative to Phase 2), indicating that the VI duration would have decreased in Phase 2 had the EXT schedule not been administered. R6 showed the decrease in VI duration across Phases 1 and 2, but, unlike R3, R4, and R5, it showed an increase in response duration in Phases 2 and 4 that was confined primarily, if not exclusively, to the VI component of the mult EXT VI condition. This is particularly evident in Phase 4, since the VI duration was relatively stable in Phase 3. Although this particular finding is not easily explained, the clear-cut increase in VI duration in Phase 4 may be related to the fact that R6 showed a less stable baseline return effect in Phase 5 than it had in Phase 3.

DISCUSSION

The present findings confirm and extend those previously obtained by Gutman et al. (1975). In that study, a 23-session baseline produced positive contrast in Phase 2, the recovery of response rates at or near the Phase 1 level in Phase 3, and the reproduction of the positive contrast and baseline return effects in Phases 4 and 5. Such a pattern was shown by five of the six subjects given 20-25 sessions of baseline training in the present study. The prior study also used the 8-session baseline, and with it obtained weak baseline return effects in Phase 3, but relatively large and stable positive contrast and baseline return effects in Phases 4 and 5. Such a pattern was shown by four of the five subjects (that showed positive contrast) given 8 sessions of baseline training in the present study.

In the present study, the VI-duration pattern proved to be a good predictor of the magnitude and stability of the baseline return effect. In general, decreasing VI durations prior to the administration of the mult EXT VI condition were correlated with small and/or unstable baseline return effects after this condition, whereas stable VI durations prior to this condition were correlated with recovery of response rates at or near the baseline level. This relationship was not perfect, as is illustrated by R14 (Figure 1), who showed a stable VI duration at the termination of Phase 1, but only a small baseline return effect in Phase 3. However, it should be noted that with the 8-session baseline, several of the subjects (i.e., R3, R4, and R5; Figure 1) showed both of the relationships (i.e., weak returns in Phase 3 after unstable VI durations in Phase 1, and strong returns in Phase 5 after stable VI durations in Phase 3).

Thus the relationship between the number of sessions of baseline training and the magnitude and stability of the baseline return effect may in part hinge on a response topography factor. Perhaps a stable response topography is necessary (but not sufficient) prior to the introduction of the mult EXT VI condition if recovery of the baseline response rate is to occur after the positive contrast effect. This is entirely consistent with Bloomfield's (1967) observations in the pigeon. Bloomfield failed to obtain any evidence of baseline return in the mult VI VI condition of Phase 3 after having obtained the response rate pattern characteristic of positive contrast in the mult EXT VI condition of Phase 2. However, both positive contrast and baseline return were obtained in Phases 4 and 5, and these effects were reproduced in Phases 6 and 7. Bloomfield reported that the birds stood progressively closer to the key as training proceeded, and that they did not adopt their final positions until Phase 3. The distance between bird and key should affect the topography of the key peck. If so, an unstable response topography in Phase 1 may have preceded the lack of baseline return in Phase 3, but a stable topography in Phases 3 and 5 may have preceded the occurrence of baseline return in Phases 5 and 7.

It is not surprising that the baseline return pattern in Phase 3 can be predicted from the VI-duration pattern in Phases 1 and 2. A longer response duration should allow for less of an opportunity to press the bar, and hence should, on the average, produce a lower response rate than a shorter response duration (in the case of the pigeon, the probability of missing the key in a keypeck motion should increase as the distance between bird and key is increased). Consequently, if response duration is shorter in Phase 2 relative to Phase 1, the subject would seemingly have to (1) recover the response duration level of Phase 1, or (2) show negative contrast over and above baseline return¹ in order to recover the response rate level of Phase 1 in Phase 3. With stable VI durations prior to Phase 2, this may not be a problem. Judging from the data, 8 sessions of baseline training is not sufficient to obtain stable VI durations, whereas 20-25 sessions often is.

The present findings differ from but are consistent with those of Stern and Eckerman (1974) and Westbrook (1973). These investigators obtained a negative induction effect that coincided with an increase in response duration in both the EXT and VI components. In the present study, one subject did show the increase in response duration in both the EXT and VI components, and this subject also showed negative induction. However, most of the subjects showed positive contrast, and this effect for the most part coincided with increases in response duration that were confined primarily to the EXT

component of the mult EXT VI condition. These findings suggest that negative induction was obtained in the Stern and Eckerman (1974) and Westbrook (1973) studies because the treadle (or bar) holding conditioned in the EXT component generalized to and interfered with responding in the VI component. Furthermore, the light-noise discrimination used in the present study may have permitted the occurrence of positive contrast by limiting such generalization. If so, there should be some factor which could be used to differentiate between the light-noise discrimination used in the present study and the presence-absence discrimination used in the Stern and Eckerman (1974) study, both of which used rats, a barpress response, and a mult VI VI mult EXT VI procedure.

The factor in question may be excitatory (S+) stimulus control. Assume, for example, that the non-reinforced intervals of the VI schedule may be perceived by the subjects as being EXT. If so, the VI cue of the mult EXT VI condition would have to acquire a certain magnitude of S+ control in order to prevent response generalization to these non-reinforced intervals. Thus it is implied that the VI cue of the light-noise discrimination acquires stronger S+ control than the VI cue of the presence-absence discrimination, and tests of stimulus control should reveal this. For example, the stronger of two S+ cues should produce a larger additive summation effect if these cues are superimposed on (1) a second S+ cue (cf. Weiss, 1972) or (2) a different operant response (cf. Hearst & Patterson, 1973). It should be noted that this prediction is made independently of the magnitude of inhibitory (S-) stimulus control acquired by the EXT cues. This follows because it is the generalization of S- control, and not its strength per se, that is posited to produce negative induction.

Finally, to reiterate, it is our contention that the failure to obtain positive contrast does not imply that the procedure used lacks the conditions necessary for its occurrence. Rather, a procedure can in theory contain all of the conditions necessary for positive contrast (whatever those may be) and contain in addition other conditions that are sufficient to prevent its occurrence. If the latter are conceived of as the ones that produce negative induction, then the failure to obtain positive contrast is by itself uninterpretable. For example, the occurrence of no interaction (i.e., neither positive contrast nor negative induction) may indicate that (1) the conditions that produce positive contrast are absent, or that (2) they are in competition with the conditions that produce negative induction (and hence are neutralizing each other). The occurrence of negative induction may indicate that (1) the conditions that produce negative induction are present in the absence of those that

produce positive contrast, or (2) they strongly outweigh the conditions that produce positive contrast. In either event, an account of positive contrast need not concern itself with failures to obtain the effect, since these failures may implicate processes that prevent but do not contribute to its occurrence. Furthermore, it also follows that an account of positive contrast is not necessarily strengthened because it successfully explains such failures, especially if other accounts explain these failures more plausibly.

REFERENCE NOTE

1. Stern, S., & Eckerman, D. A. *Behavioral contrast in multiple schedules may result from persistence of topographical shifts in responding*. Paper presented at the Annual Meeting of the Eastern Psychological Association, Philadelphia, April 1974.

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NOTE

1. In prior studies we have used the term "negative contrast" to describe the effect of baseline return. However, negative contrast is an effect in its own right (i.e., an increase in response rate in the altered component and a decrease in the unaltered component), and therefore should be distinguished from a similar effect that occurs after positive contrast (sometimes) but is due simply to the removal of the treatment that produced positive contrast.

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