

CONDITIONED REINFORCEMENT AND CHOICE

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In a series of three experiments, rats were exposed to successive schedule components arranged on two levers, in which lever pressing produced a light, and nose-key pressing produced water in 50% of the light periods. When one auditory signal was presented only during those light periods correlated with water on one lever, and a different signal was presented only during those light periods correlated with nonreinforcement on the other lever, the former lever was preferred in choice trials, and higher rates of responding were maintained on the former lever in nonchoice (forced) trials. Thus, the rats preferred a schedule component that included a conditioned reinforcer over one that did not, with the schedules of primary reinforcement and the information value of the signals equated. Preferences were maintained when one or the other of the auditory signals was deleted, but were not established in naive subjects when training began with either the positive or negative signal only. Discriminative control of nose-key pressing by the auditory signals was highly variable across subjects and was not correlated with choice.

Key words: conditioned reinforcement, preference, chained schedules, information, stimulus control, rats

When a stimulus is paired with a primary reinforcer, and responses subsequently increase in rate or probability when they produce that stimulus, the stimulus is termed a conditioned reinforcer. Although conditioned reinforcement is central to many theoretical accounts of behavior, doubts have often been raised about the effectiveness, and even the existence, of the process. Many early studies employed extinction tests to obviate the confounding effects of primary reinforcement and obtained conditioned reinforcement effects that were weak, transient, and (in some cases) confounded with other processes (for review, see Kelleher and Gollub, 1962; Nevin, 1973). More recent research, involving behavior maintained by chained schedules or by brief stimuli in second-order schedules, has demonstrated reliable and durable reinforcement effects (for review, see Gollub, 1977), but the interpretation of these results is complicated by a host

of factors, including the contingencies of primary reinforcement, failures to discriminate paired and unpaired stimuli, and the nature of the stimulus (Nevin, 1969, 1973; Stubbs, 1971; Squires, Norberg, and Fantino, 1975). Most recently, conditioned reinforcement has been reinterpreted in terms of "informativeness" about the schedule of primary reinforcement (Hendry, 1969; Schuster, 1969); "signposts" or feedback indicating the appropriateness of a sequence of responses to the prevailing contingencies of primary reinforcement (Bolles, 1975); signalled reduction in the average time to primary reinforcement (Fantino, 1977); or "situation transition", where the transition is reinforcing but the stimuli signalling the transition have no reinforcing effect in their own right (Baum, 1973). All these accounts suggest that stimuli may exert reinforcement-like effects on responses that produce them, but that these effects actually reflect discriminative functions, signalling the prevailing contingencies of primary reinforcement, rather than any reinforcing value accruing to the stimuli *per se*.

What behavioral observations would support the notion that a stimulus may acquire reinforcing value *per se*? The notion of value is intimately related to preference: if outcome A is preferred to outcome B in an unbiased

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choice situation, A is by definition the more valuable outcome. To demonstrate that conditioned reinforcers are valued for their own sake, it is necessary to demonstrate a preference between two outcomes that are alike in all respects, except that one includes a conditioned reinforcer and the other does not. These conditions were achieved in an early study by Saltzman (1949), which involved choices between two goal boxes in a U-maze during experimental extinction, where one had been correlated with food reinforcement and the other was correlated with nonreinforcement during prior runway training. His data clearly showed strong preferences for the food-correlated goal box during 15 U-maze trials. Such preferences may, however, be transitory; it seems unlikely that they would be maintained throughout prolonged preference tests.

More recent attempts to examine preferences for conditioned reinforcers paired intermittently with primary reinforcers in concurrent-chained schedules (Schuster, 1969; Squires, 1972) have failed to demonstrate sustained preferences for conditioned reinforcers. Schuster's study arranged a concurrent-chains procedure where pigeons could produce either a simple variable-interval (VI) 30-sec schedule, in which food was preceded by a 0.7-sec signal, or a conjunctive schedule, in which signal plus food were available on an identical VI 30-sec schedule, and the signal alone was also available on a fixed-ratio (FR) 11 schedule. Although response rates were uniformly higher on the latter schedule, the pigeons generally preferred the former. Schuster reasoned that if the signal was a conditioned reinforcer, functionally similar to food, the schedule that arranged more-frequent signals should have been preferred. The failure to obtain such a result has been interpreted by Baum (1973) as decisive against the validity of the concept of conditioned reinforcement. However, there are two problems with the interpretation of Schuster's experiment. (1) The schedules of signal presentation were asymmetric: FR 11 in one case, and VI 30-sec in the other. Because ratio schedules generally establish and maintain higher rates than interval schedules, the higher rate in the former case is not surprising. Moreover, high response rates may be aversive (Fantino, 1968), and this factor may counteract a preference for the schedule

with extra conditioned reinforcers, as Gollub (1970, 1977) has argued. (2) The pairing conditions were asymmetric: intermittent pairing in one case, because pecking often produced signals on the FR 11 schedule that were not followed by food, and regular in the other. It is known that pairing probability affects choice (D'Amato, Lachman, and Kivy, 1958), and this could account for the observed preference away from the schedule with the more frequent signal presentations. Thus, Schuster's results are actually in accord with reasonable expectations based on the literature, and are not at all decisive against the validity of the concept of conditioned reinforcement.

Squires' (1972) study employed VI schedules of reinforcement for both signals and food in the terminal links of concurrent-chained schedules, thus avoiding the problem introduced by asymmetrical schedules in Schuster's work. In one of her experiments, Squires scheduled a stimulus every 15 sec on the average in one terminal link, where the same stimulus immediately preceded food at the end of that terminal link. The other terminal link scheduled a different stimulus every 15 sec on the average, while food was preceded by a brief blackout. All birds slightly preferred the latter condition, which involved two different stimuli, one of which was never paired with food while the other was regularly paired with food, over the former condition, in which a single stimulus was intermittently paired with food. Again, this result may be understood by noting that stimuli regularly paired with food are more effective conditioned reinforcers than those paired only intermittently.

A third relevant study, by Jenkins and Boakes (1973), scheduled stimulus changes and food independently of responding. As measured by orientation toward a key and by auto-shaped key pecking, their birds preferred a key that sometimes displayed a signal paired with food over a key on which the signal was uncorrelated with food, and they preferred the uncorrelated signal over one that was explicitly unpaired with food. Their experiment, which supports a simple pairing conception of conditioned reinforcement, is unique in its use of response-independent stimulus schedules.

The present report describes a series of studies that addressed the question of prefer-

ence for response-dependent conditioned reinforcers, using procedures designed to keep signal schedules and pairing conditions unconfounded, and with explicitly defined choice responses. The basic scheduling and pairing procedure is derived from an earlier study by Nevin (1969). In that study, rats were trained on a second-order chained schedule, in which completion of a heterogeneous *chain* fixed-interval (FI) 30-sec, FR 1 requirement was reinforced with water 50% of the time, and was not reinforced on the other 50%. When signals were added during only those terminal links in which a response could produce water, response rates in the initial FI 30-sec links increased two- to three-fold. When signals were added during only those terminal links in which responding did not produce water, initial-link rates did not increase. Signal schedules and water reinforcement frequency were the same in both signal conditions, and information about the prevailing contingencies of water reinforcement was equated for these conditions. Thus, signals reinforced responses that produced them only if they were paired with water reinforcement.

The present studies extend the earlier results by including choice trials, in which subjects could produce either a condition in which a stimulus was paired with water (while its absence was correlated with extinction), or a condition in which a different stimulus signalled extinction (while its absence was correlated with water). The schedules of water reinforcement and stimulus presentation were the same in either condition, and the two stimuli were equally informative (in the sense of reducing uncertainty) with respect to water reinforcement. The only difference between conditions was the pairing of the stimuli with water. Preference for the paired condition would constitute evidence that the stimulus had acquired reinforcing value.

EXPERIMENT I

METHOD

Subjects

Three male albino rats of the Sprague-Dawley strain served. They were about four months old at the start of pilot experimentation, and were maintained on a 24-hr water rhythm throughout the study, receiving 15 cc

of water in their home cages after each daily session.

Apparatus

The study was conducted in a two-lever rat chamber enclosed in a sound-attenuating shell. On the front wall of the chamber, two levers, each requiring 0.05 N to operate, were located 10 cm apart. A white pilot light was located 8 cm above each lever. Midway between them, a 5-cm diameter cylindrical tunnel 4 cm deep gave access to a water dipper (0.02 cc), protruding through the bottom 2 cm from the back when operated, and a standard pigeon key, which the rats would press with their noses through a 2-cm diameter aperture. A white pilot light was located behind the translucent nose key, and a light providing 35 lux illuminance at the cage floor was located behind a 10-cm diameter circle of milk plastic above the center of the chamber. Auditory signals were produced by a 60-Hz buzzer and a 2300-Hz Sonalert, mounted behind the front panel; their intensities, measured at the center of chamber, were 83 and 79 dB sound pressure level re 2×10^{-7} N/M² respectively. A dim houselight provided general illumination during experimental sessions. The experimental contingencies were arranged with conventional electromechanical equipment, and data were recorded on counters.

Procedure

All three rats were trained to press both levers with water reinforcement, and some preliminary work with concurrent schedules of signalled and unsignalled water reinforcement was conducted. No orderly data were obtained, so a new method was explored. The nose-key press was autoshaped through temporal pairings of keylight with water before training began on the final procedure.

The experiment involved three kinds of trials:

- (1) At the end of a 10-sec intertrial interval, the pilot light above the right-hand lever was illuminated and a VI 20-sec program tape began running. The first press to occur on the right lever after the VI program set up was followed by onset of the overhead and nose-key lights for 3 sec and, with equal likelihood (arranged by a probability generator) a 3-sec buzz or silence. If the buzz came on, water was delivered at the end of 3 sec if the rat pressed

the nose key at least once during the 3-sec period. If the buzz did not come on, water was not delivered, regardless of the rat's responses. A 10-sec intertrial interval followed the 3-sec light period, regardless of whether water was delivered. Responses on the left lever, or on the unlighted nose key, had no consequences.

(2) At the end of the 10-sec intertrial interval, the pilot light above the left lever was illuminated and an identical but independent VI 20-sec program tape began running. The first press to occur on the left lever after the VI program set up was followed by 3-sec illumination of the overhead and nose-key lights and, with equal likelihood, a 3-sec tone or silence. If the tone came on, water was not delivered regardless of the rat's behavior. If the tone did not come on, water was delivered at the end of the 3-sec light period if the rat made at least one response within that time. The 10-sec intertrial interval followed offset of the light. Responses on the right lever, or on the unlighted nose key, had no consequences.

(3) At the end of the 10-sec intertrial interval, both pilot lights were illuminated. If the rat pressed the right lever, the left light went out and Sequence 1 began. If the rat pressed the left lever, the right light went out and Sequence 2 began. Trials of this type are called choice trials in the text that follows; trials of Type 1 and 2 are called forced trials, and were arranged to ensure roughly equal exposure to both sets of signal-reinforcer contingencies.

Sessions consisted of 60 trials, arranged by a repeating quasirandom sequence, designed to provide 12 Type-1 trials, 12 Type-2 trials, and 26 Type-3 trials in each block of 50. The starting position in the sequence was varied randomly from session to session.

After 24 sessions with the procedure described above, right- and left-lever conditions were reversed, so that tone signalled water and buzz signalled extinction. Training under reversed conditions continued for another 24 sessions.

RESULTS

Because of their prior histories of reinforcement, all rats developed stable performances under these contingencies without special training. Rat U9 developed long latencies on all trial types during the reversal.

The principal data of interest are initial responses on the left or right levers during choice trials, response rates on the left and right levers during forced trials, and the discriminative control over nose-key pressing during light periods by buzz and tone. Response rates were not computed for choice trials because, unlike forced trials, they always began with a response, rather than an initial latency. The raw data were pooled for the last five sessions of both initial and reversed training conditions, and provide the basis for the computations reported here.

Figure 1 presents the results for choices of the right lever, and response rates expressed as the relative rate of responding on the right lever. All subjects preferred the right lever in choice trials; further, they responded at a higher rate on the right than on the left lever in forced trials during the first condition, when right-lever responses produced the buzz that signalled water. Right-lever preferences reversed for Rat U7, and decreased for Rats U8 and U9, when the pairing relations were reversed. All three subjects reversed their relative rates in forced trials. Thus, both preferences and response rates were related to the pairing conditions. These results suggest that buzz and tone functioned as conditioned reinforcers when paired with water.

Interestingly, control of choice and rate by the signals functioning as reinforcers was not correlated with their discriminative control over nose-key pressing. Discrimination indices were computed by dividing the rate of nose-key responding in the presence of the 3-sec buzz by the sum of the rates of nose-key re-

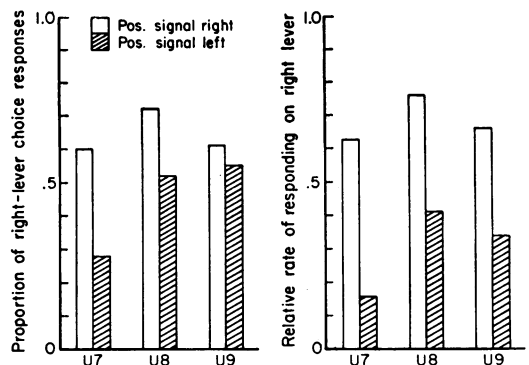


Fig. 1. Lever preference in choice trials and relative response rate in forced trials during initial and reversed conditions of signal-water pairing in Experiment I. Data are presented separately for individual subjects.

sponding in the presence and absence of buzz, for all right-lever trials. A corresponding index was computed for tone for all left-lever trials. During the first condition, when the buzz signalled water availability while the tone signalled extinction, the index for buzz was high while the index for tone was low, indicating appropriate stimulus control of nose-key responding. However, when conditions were reversed, both indices remained near 0.50, indicating little if any control by the signals. These data are summarized in Figure 2. It appears that reversal of discriminative control of responding is not a necessary condition for reversal of conditioned reinforcement effects in this situation.

EXPERIMENT II

Experiment I demonstrated preferences for the right lever and higher relative response rates on the right lever when right-lever responding occasionally produced a signal paired with water and left-lever responding occasionally produced a signal for extinction. The rate effect was reversible and the preference was partially reversible when pairing conditions were reversed, despite a general failure of stimulus control during the reversal phase. Interpretation of these results is somewhat complicated by the facts that the subjects were not naive and that there was no estimate of lever preference or of response rate in the absence of signals. Experiment II replicated Experiment I with naive subjects and with no-signal baseline conditioning preceding each assessment of the effects of the signals. A final

phase of the study explored the effects of deleting either the positive or the negative signal.

METHOD

Subjects

Five experimentally naive albino rats of the Sprague-Dawley strain were approximately four months old at the beginning of experimentation. They were maintained on a 24-hr water rhythm throughout the study, receiving 15 cc of water in their home cages after each daily session.

Apparatus

As in Experiment I.

Procedure

Preliminary training consisted of autoshaping the nose-key press to the lighted nose-key, and then hand-shaping presses on the right and left levers, with illumination of the nose-key and water availability as the reinforcer. The final procedure was approximated in stages: (1) two simple, regularly reinforced lever-press—nose-key chains with the lights above the levers coming on in irregular order to signal the effective lever; (2) VI 20-sec reinforcement of lever pressing with onset of the overhead and nose-key lights, with water delivered at the offset of the 3-sec light period if at least one key press occurred; (3) water reinforcement at the end of only 50% of the light periods; and (4) introduction of choice trials with both lever lights illuminated. This procedure, termed the no-signal baseline condition, is identical to the procedure of Experiment I, except that buzz and tone were never presented.

After 24 sessions of training on the no-signal baseline, the buzz was sounded whenever right-lever responses produced a light period that was scheduled to end with water delivery if the subject pressed the key, and a tone was sounded whenever left-lever responses produced a light period that was scheduled not to end with water delivery. This condition is identical to the first condition of Experiment I.

After 24 sessions of training with the buzz serving as the positive signal on the right, buzz and tone were discontinued and 24 sessions of the no-signal baseline condition were conducted. Then, buzz and tone were re-instated with their pairing relations to water delivery reversed, so that tone now served as the posi-

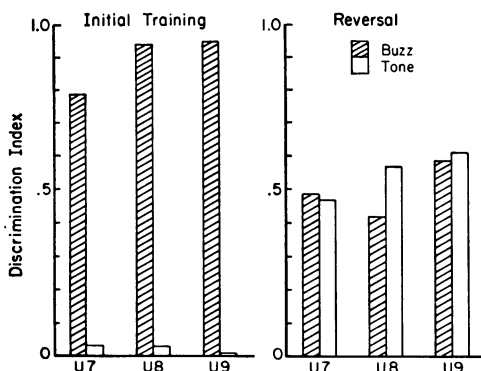


Fig. 2. Discrimination indices for responding to buzz and tone during initial and reversed conditions of signal-water pairing in Experiment I. Data are presented separately for individual subjects.

tive signal on the left, exactly as in the reversal condition of Experiment I.

When the reversal phase was completed, 24 sessions were conducted with the tone discontinued, so that only the negative signal, buzz, was available on the right. Finally, the tone was re-instated as the positive signal on the left while the buzz was discontinued for 24 sessions. These final conditions were intended to assess the separate contributions of the negative and positive signals in this situation.

Throughout the study, sessions consisted of 50 trials according to the sequence employed in Experiment I. Sessions were conducted daily, except for occasional holidays.

RESULTS

Data were analyzed in three-session blocks throughout the study. The proportion of right-lever choices, averaged across rats, is presented in Figure 3. On the average, the right lever was pressed in 40 to 50% of the choice trials during the no-signal baseline conditions. The proportion increased when signals were added with the positive signal on the right, and decreased when signals were added with the positive signal on the left. The proportion of right-lever responses remained low when the positive signal was deleted, leaving only the negative signal following right-lever presses. There were no consistent changes in preference when the negative signal was deleted and the positive signal followed presses on the left lever.

The left-hand panel of Figure 4, which is based on data for the final three sessions of each baseline and signal condition, shows these preference effects for individual subjects. Adding both signals had quite uniform effects, relative to baseline: every subject exhibited a preference shift toward the lever that produced the positive signal. There was some variation across subjects when one or the other signal was deleted: for example, Rat C5 returned to its baseline level when the positive signal was removed, and Rat C4 exhibited a weaker preference when the negative signal was removed. In general, though, it appears that either the positive or the negative signal alone was sufficient to maintain the preference established earlier by both signals.

The right-hand panel of Figure 4 presents the relative rate of responding on the right lever during forced trials, also for the last

three sessions of each condition. With the exception of Rat C1, positive signal on the right, relative rates on the lever that produced the positive signal increased when signals were added. All rats exhibited higher relative rates on the right lever when the right lever produced the positive signal, than when the left lever produced the positive signal. Relative response rates were not systematically affected by removing one or the other signal: all subjects continued to respond at relatively higher rates on the lever that did not produce the negative signal, or that did produce the positive signal.

Averaged discrimination indices for buzz and tone are plotted in three-session blocks throughout all signal conditions in Figure 5. Comparable indices were computed for no-signal baseline conditions, but are not presented because they never departed appreciably from 0.50, as they should not in the absence of signals. During the initial signal condition, the index rose systematically for the positive signal (buzz), but never fell appreciably below 0.50 for tone. All five subjects learned to respond differentially in the presence and absence of buzz, but only one achieved consistent differential responding in the presence and absence of tone. During the reversal, with tone positive, the average trend was toward less responding in the presence of tone than its absence, while on average, the rats continued to respond more in the presence of buzz than its absence. Although neither effect was large nor entirely consistent across subjects, they are noteworthy because they are exactly opposite to expectations based on the signal-reinforcement relations. The failure of appropriate stimulus control to develop during the reversal replicates the findings of Experiment I. The failure of the tone to develop consistent control over responding during the initial signal condition, however, does not replicate the results of Experiment I. Perhaps the earlier histories of the subjects in Experiment I were important for their later discrimination performances. The clear discrimination data of Experiment I suggest that the failures of stimulus control in Experiment II are not attributable to the physical properties of the stimuli.

When the positive signal, tone, was removed, all subjects gradually acquired differential responding to the presence and absence of the

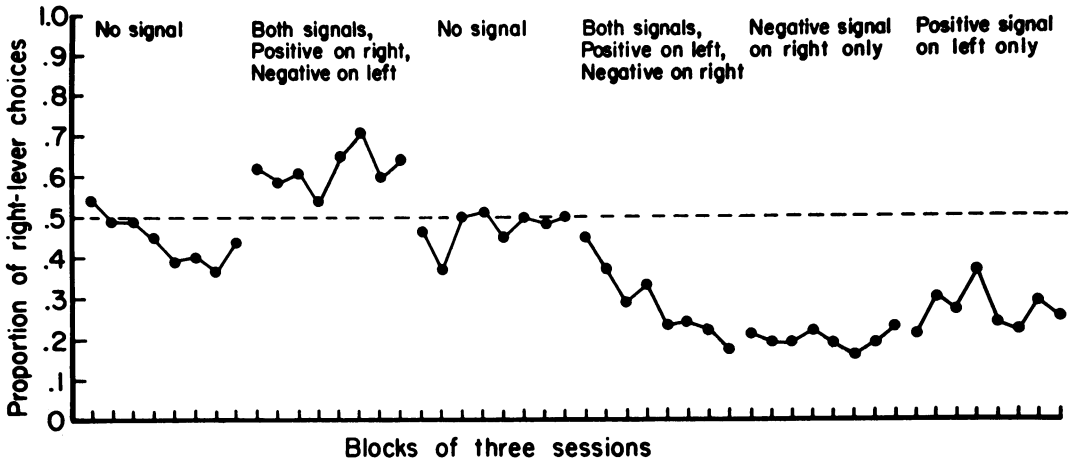


Fig. 3. Lever preference on choice trials throughout successive conditions of Experiment II. Data are averages for all five rats.

negative signal, buzz. However, when the buzz was discontinued and the positive signal, tone, was re-instated, only one subject gave evidence of consistent differential responding. The slight upturn in the average data at the very end of training reflects shifts in performance of two other subjects, and it may be that all of the subjects would have exhibited appropriate stimulus control with additional training.

The discrimination indices presented in Figure 5 describe differential nose-key responding (or its absence) to stimuli produced by presses on the same lever: buzz *versus* silence on the right, and tone *versus* silence on the left. An alternative index can be computed to examine differential responding to the various stimulus conditions across levers: for correct responses relative to the sum of responses in the presence of buzz and tone, and for correct

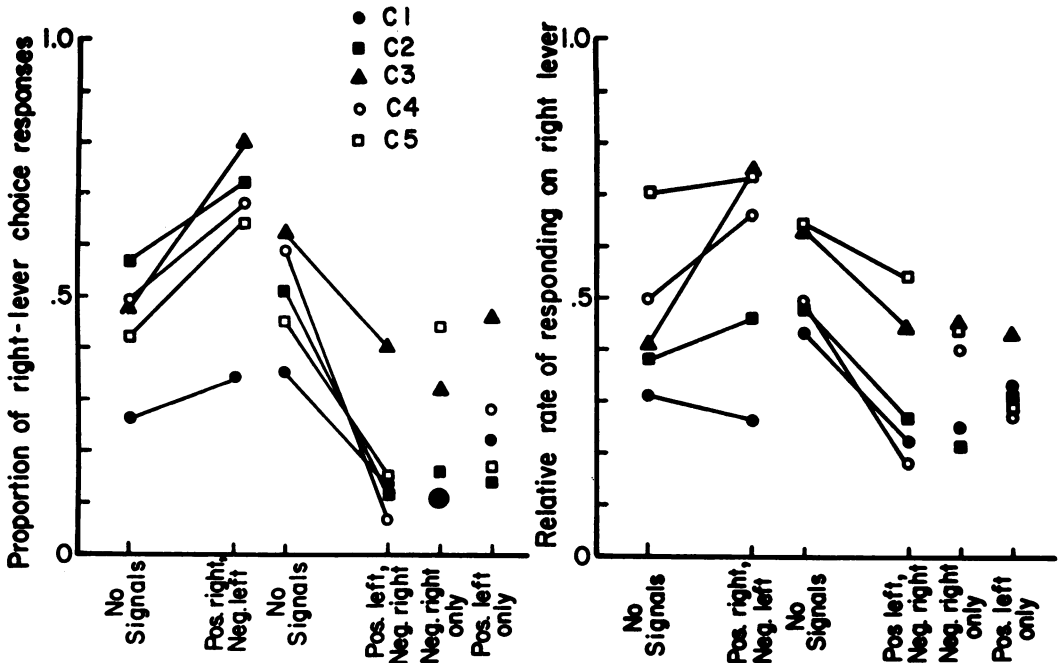


Fig. 4. Individual data for the final three sessions of each condition of Experiment II. The left panel presents lever preferences in choice trials and the right panel presents relative response rates in forced trials.

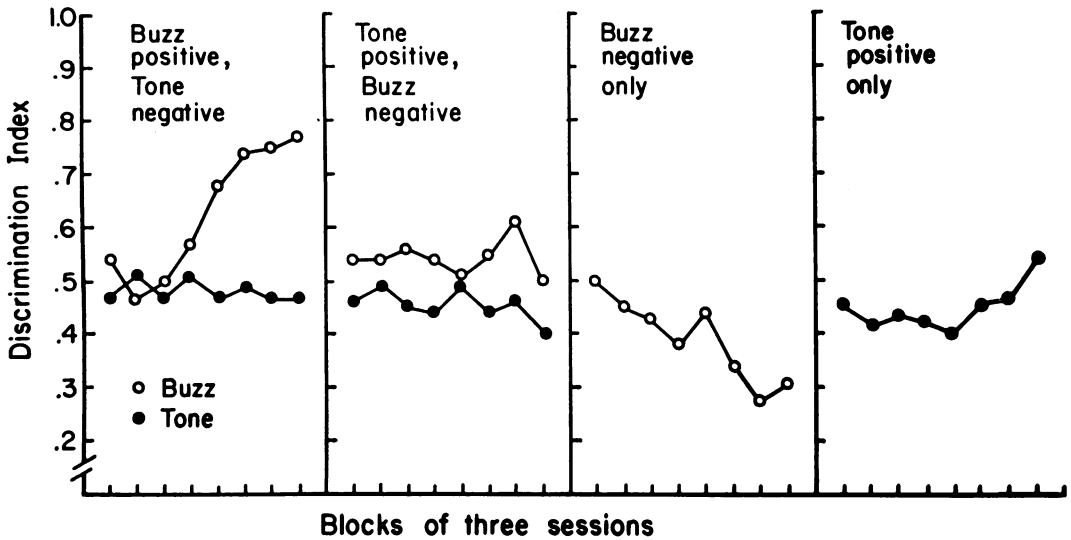


Fig. 5. Discrimination indices during the signalled conditions of Experiment II. Data are averaged separately for buzz and tone for all five rats.

responses relative to the sum of responses in the presence of light plus silence—a condition that is correlated with reinforcement if produced by one lever, and with extinction if produced by the other. (Responses followed by reinforcement are designated as correct responses.) When the data were examined in this way, the most striking result was the diversity of individual patterns of performance. Rat C3, for example, responded more to the negative auditory signal than to the positive signal in both conditions (discrimination indices below 0.50). At the same time, C3 discriminated well between the two kinds of silent period during the first signal condition, but not during the second. Rat C1 discriminated both signals and silent periods during the first condition, but neither signals nor silent periods during the second condition. Rat C5 discriminated only the two kinds of silent periods during the first signal condition, and only the signals during the second condition. We have been unable to discern any correlation between these diverse patterns of stimulus control over nose-key responding, and choices or rates of responding on the levers that produce the discriminative stimuli for nose-key responding. Accordingly, we conclude, as in Experiment I, that the reinforcing effect of stimuli signalling the availability of primary reinforcement is totally independent of control by those stimuli over responses in their presence.

EXPERIMENT III

The maintenance of consistent preferences away from the negative signal alone, or for the positive signal alone, raises the question of whether similar preferences could be established by either signal alone without prior training. In brief, does the initial demonstration of preference for the positive signal depend on scheduling the negative signal also, within the same period of training? Experiment III addressed this question.

METHOD

Subjects

Eight experimentally naive male albino rats of the Sprague-Dawley strain served. They were about four months old at the beginning of experimentation, and were maintained on a 24-hr water rhythm throughout the study, receiving 15 cc of water in their home cages after each daily session.

Apparatus

As in Experiments I and II.

Procedure

Initial training was as described in Experiment II. When performance on the unsignalled baseline procedure was established, 24 regular sessions of no-signal baseline training were conducted as in Experiment II. The rats were then divided randomly into four groups

of two, and the buzz was introduced as follows: Group 1A: buzz positive on left, no signal on right; Group 1B: buzz positive on right, no signal on left; Group 2A: buzz negative on left, no signal on right; Group 2B: buzz negative on right, no signal on left. These conditions replicate the final two phases of Experiment II, except that only the buzz was employed, and the conditions were counterbalanced across lever positions.

After 24 sessions of training with these conditions, the buzz was discontinued for 24 sessions of no-signal baseline training. Finally, the significance of buzz was reversed and tone was introduced for the other lever, establishing the following conditions: Group 1A: buzz negative on right, tone positive on left; Group 1B: buzz negative on left, tone positive on right; Group 2A: buzz positive on right, tone negative on left; Group 2B: buzz positive on left, tone negative on right. Note that these new conditions, while reversing the significance of the buzz, retain the relations between levers and positive or negative signals as arranged in the first signal condition with buzz only. These final conditions, which remained in effect for 24 sessions, replicate the two-signal procedure of Experiments I and II.

Throughout the study, sessions consisted of 50 trials, arranged as in Experiments I and II, and were conducted daily with few exceptions.

RESULTS

Analysis of the data showed that lever position was not a relevant variable. Accordingly, Groups 1A and 1B, and Groups 2A and 2B, were combined for final analysis. One subject, Rat 20 in Group 2B, did not always complete its sessions within 2 hr during the final condition; accordingly, its data are incomplete.

Figure 6 exhibits the proportion of responses on lever 2 (left for Groups 1A and 2B, right for Groups 1B and 2A) over the course of training, in three-session blocks. Data have been averaged separately for the groups that initially produced the positive signal only, and those that produced the negative signal only. The figure shows that during the initial signal condition, neither group departed appreciably from its baseline preference levels: that is, neither the positive signal alone, nor the negative signal alone, sufficed to establish a clear lever preference. When both signals were introduced after an intervening baseline pe-

riod, the subjects that had previously been exposed to the negative signal only exhibited a clear shift in preference: there was no overlap between the ranges or preference values for the final three blocks of sessions and those for the final three blocks of baseline for any of the four subjects. By contrast, the subjects that had been exposed to the positive signal only were little affected on the average, and only one subject had no overlap in preference ranges.

Individual data for the last three sessions of each condition are presented in Figure 7. In the first signal condition, subjects that produced only the positive signal exhibited small inconsistent shifts in preference, while those with the negative signal were more variable. When both signals were introduced in the second signal condition, two subjects that had previously experienced only the positive signal exhibited preference shifts toward the lever that produced the positive signal, while the other two shifted in the opposite direction. All those that had experienced the negative signal exhibited substantial preference shifts toward the lever that produced the positive signal. The average value of the shift for the latter group was 0.21, with a range from 0.14 to 0.30. These results may be compared with those obtained during the first signal condition of Experiment II, which was identical to the second signal condition of Experiment III. In Experiment II, the average preference shift, relative to baseline, was 0.20, with a range of 0.08 to 0.32. It appears that prior experience with only the negative signal had no effect on later performance with both signals. By contrast, prior exposure to the positive signal interfered with the usual preference in the two-signal situation, at least for two rats. We are at a loss to account for this.

Individual relative-rate data for Experiment II appear in the right-hand panels of Figure 7. (Note that no data are plotted for Rat 20, because although it emitted sufficient choice responses to give a reliable measure of preference, its rates in forced trials occasionally fell below 0.1 responses per minute.) The rate data are less clear than those of the previous experiments, and are not always well correlated with preference data.

Average discrimination indices are presented for both groups in Figure 8. In the first signal condition, subjects with only the positive sig-

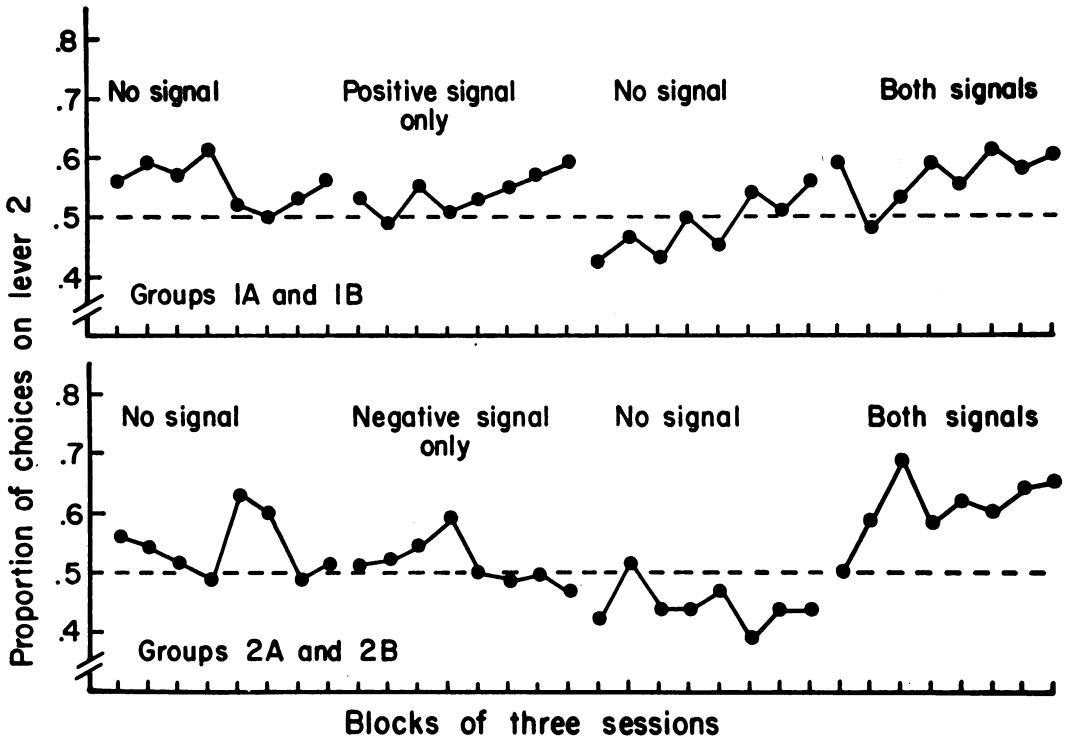


Fig. 6. Lever preference in choice trials throughout the course of Experiment III. During the first signal condition, Groups 1A and 1B produced positive signals by responding on Lever 2, while Groups 2A and 2B produced negative signals by responding on Lever 1. During the second signalled condition, all subjects produced positive signals on Lever 2 and negative signals on Lever 1. Data are averaged separately for Groups 1A and 1B, in the upper panels, and for Groups 2A and 2B, in the lower panels.

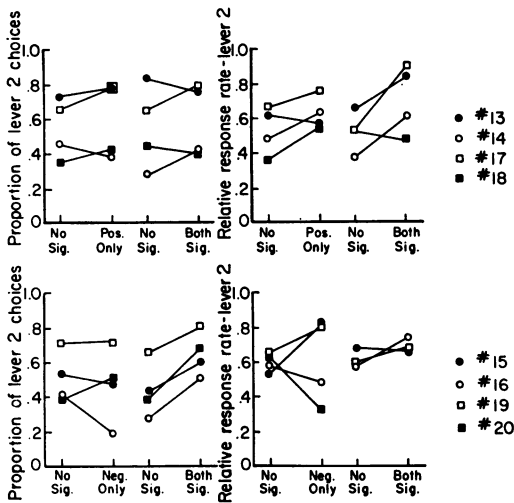


Fig. 7. Individual data for the final three sessions of each condition of Experiment III. Groups 1A and 1B are in the upper panels, and Groups 2A and 2B are in the lower panels. Lever preferences in choice trials are presented in the left panels, and relative response rates in forced trials are presented in the right panels.

nal did not learn to respond differentially in its presence, and subjects with only the negative signal did not learn to respond differentially in its absence. When both signals were introduced, neither group acquired consistent differential responding to either signal.

As might be expected from Experiments I and II, individual data on discriminative control of nose-key responding are not helpful in understanding the pattern of preferences. For example, Rats 13 and 17, which exhibited similar preference shifts in the first signal condition with positive signals only, had discrimination indices of 0.75 (well above chance) and 0.19 (well below chance), respectively, for buzz *versus* silence produced by Lever 2. When both signals were introduced, Rat 13 was the only one to exhibit better-than-chance discrimination with respect to both signals, but its preference shifted away from the positive signal. All subjects in the group that first experienced only the negative signal exhibited slightly better-than-chance performance with

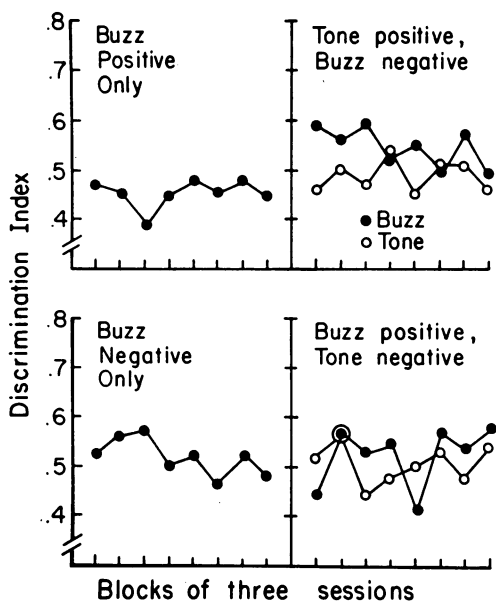


Fig. 8. Discrimination indices during the signalled conditions of Experiment III. Data are averaged for each signal for Groups 1A and 1B in the upper panels, and for Groups 2A and 2B in the lower panels.

respect to the positive signal, and slightly worse-than-chance performance with respect to the negative signal when both signals were presented, but in no case did the index depart by more than 0.13 from chance.

To summarize the relation between discriminative performance and preference, the data of all individual subjects in Experiment II and III are presented in Figure 9. The ordinate values represent the shift in preference from baseline, and the abscissa values represent an overall discrimination index for nose-key performance when both signals were presented. The index was computed by summing correct nose-key presses in the presence of the positive signal and in the absence of the negative signal, and dividing by the sum of all nose-key presses. (In effect, this computation pools the separate indices plotted in Figures 5 and 8.) Clearly, there is no relation between these variables.

DISCUSSION

Our basic procedure arranged that responding would produce a 3-sec light period after 20 sec on the average, an auditory signal during 50% of the light periods, and water reinforcement at the end of 50% of the light periods.

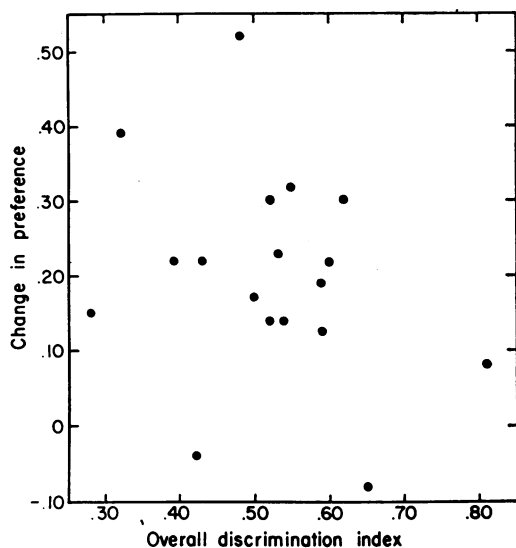


Fig. 9. The difference between lever preferences during the last three baseline sessions and during the last three sessions of all conditions of Experiments II and III, in which both positive and negative signals were presented, plotted against overall discrimination performance during the latter sessions.

Conditions differed for the two levers, in that one produced an auditory signal that always preceded water, and the other produced a different signal that never preceded water. In choice trials, all subjects in Experiments I and II responded more often on a given lever when it led to the condition with the positive signal paired with water, than when it led to the negative signal paired with extinction. This result provides clear evidence of preference for conditioned reinforcement, with all other factors equated. If preference is taken as a measure of value, it is evident that conditioned reinforcers are valued over signals that are equally informative about the availability of primary reinforcement, but are not paired with primary reinforcement.

The assertion that the positive and negative signals are equally informative is based on the concept of information as the reduction of uncertainty. The probability of water, given a light period, was always 0.50. When the positive signal was present, the probability increased to 1.00 (certain reinforcement), and when the negative signal was present, the probability decreased to 0.00 (certain nonreinforcement). Thus, uncertainty about whether the trial would terminate with water was equally reduced by either signal.

Jenkins and Boakes (1973) distinguished between uncertainty about *whether* a trial would end with food, and *when* food would be presented. Because trial duration was variable in their study, only the positive signal gave reliable information about when food would be presented (in the negative case, food was un-signalled, and in the uncorrelated case, the signal preceded food on only 50% of the trials). If preference depended on the reduction of temporal uncertainty with respect to food, the observed preference for the positive signal may not have depended on conditioned reinforcement, in the sense of signal-food pairing. This ambiguity was eliminated in the present study by arranging that every trial would terminate with a 3-sec light period. Therefore, both the positive-signal lever trials and negative-signal lever trials were equally informative about when a trial would end (signalled by light), and whether it would end with reinforcement or nonreinforcement (signalled by buzz and tone). Preference for the positive signal attests to the power of simple signal-reinforcer pairing in establishing and maintaining conditioned reinforcement.

In addition to demonstrating the establishment of preferences for the positive signal over the negative signal, Experiment II demonstrated the maintenance of preferences when either the positive signal or the negative signal was deleted. In these cases, information is no longer equated across conditions: if the positive signal is deleted, for example, the negative-signal condition is more informative. The maintenance of a preference away from the negative signal is consistent with the notion that stimuli correlated with nonreinforcement are aversive (*e.g.*, Dinsmoor, Browne, and Lawrence, 1972; Wagner, 1969). Apparently, this aversiveness is sufficient to override the advantage in informativeness of the negative-signal condition. Maintenance of preference for the positive-signal condition over a no-signal condition is not surprising, because the signal is both paired with primary reinforcement and the only source of information about the outcome of a trial.

In view of the arguments above, it is surprising that in Experiment III neither the positive signal alone nor the negative signal alone sufficed to establish consistent preferences in naive subjects. Perhaps, as Jenkins and Boakes (1973) suggested, a positive stimu-

lus cannot become an effective conditioned reinforcer unless a negative stimulus also occurs. Matters are not clarified by the finding that subsequent introduction of both positive and negative signals established consistent preferences for the subjects previously exposed to negative signals alone, but not for those exposed to positive signals alone. This result requires replication and analysis before any definitive conclusions can be drawn.

In addition to choice data, we recorded the rates of responding on the levers that produced positive and negative signals, and found that the rate of responding on one lever, relative to that on the other, was higher when responding occasionally produced the positive signal than when it occasionally produced the negative signal. This result held for all subjects in Experiments I and II, but was less clear in Experiment III, where the choice data were also less clear. At least the first two experiments, then, obtained agreement between choices and relative response rates measured in separate trials. This result, which is entirely consistent with the notion that the positive signal served as a conditioned reinforcer, does not parallel the findings of Schuster (1969) and Squires (1972). In Schuster's study, for example, response rates were higher in a terminal link that included an FR 11 schedule of conditioned reinforcement than in a terminal link that did not make conditioned reinforcers available until immediately before delivery of food, on a VI schedule. His subjects generally preferred the latter condition, however. As indicated in the introduction, his results may be understood by considering both the differences in schedules of conditioned reinforcement and the probabilities of pairing the conditioned reinforcer with food. In our study, the consistency of rate and choice measures probably depended on the use of identical stimulus presentation schedules, so that only the conditions of pairing varied across levers.

Finally, our data reveal a rather spectacular lack of correlation between the conditioned reinforcing effect of a signal and the discriminative control of responding in its presence. In the first phase of Experiment I, appropriate control over nose-key responding was established by both the positive and negative signals, but no consistent evidence of stimulus control appeared when the roles of the signals

were reversed. In the first signal phase of Experiment II, the positive signal acquired appropriate control over nose-key responding, while the negative signal did not—a result that is consistent with the feature-positive effect reported by Jenkins and Sainsbury (1970)—but again, control was lost when the roles of the signals were reversed. There was no consistent evidence of stimulus control during any phase of Experiment III, but such control as was evidenced by individual subjects was not correlated with their preference data. All in all, our study gives no support for any theory that invokes differential responding in the presence and absence of a signal as a necessary condition for effective conditioned reinforcement.

The frequent failures of appropriate stimulus control by the auditory signals may be attributable in part to the nature of the discrimination contingencies and the required response. Only a single nose-key press was required during a positive keylight period, and it could occur at any time, with water being presented at the end of the 3-sec period. Nose-key presses during negative keylight periods had no consequences, either immediate or remote: that is, there was no immediate blackout or delayed initiation of the next schedule cycle if errors occurred. Thus, the differential feedback for responding during positive and negative periods was minimal. Moreover, as noted briefly in the Method section, the nose key was physically close to the water dipper, and nose-key pressing was readily autoshaped by pairing nose-key light with water. Under these circumstances, it is not surprising that control of nose-key pressing by diffuse auditory signals was weak.

It may be asked why, in our study, pairing water with light plus sound after responding on one lever established that stimulus condition as a reinforcer, while pairing water equally often with light plus the absence of sound after responding on the other lever did not, although it is a logically equivalent condition. Actually, these stimulus conditions are equivalent only if one assumes that they function as unique configurations, rather than as combinations of elements. Viewing the component stimuli as elements, the probabilities of pairing with water for light, positive signal, and negative signal are 0.50, 1.00, and 0.00 respectively. If conditioned reinforcing effectiveness is positively related to pairing probability, and

if the effectiveness of independent elements summates to give an overall effect, then clearly the compound of positive signal and light is more effective than the compound of negative signal and light, even when both are mixed with light-only trials as consequences on their respective levers. The proposed summation of conditioned reinforcing effects parallels the summation of associative strengths conditioned to the elements of a compound stimulus in the Rescorla-Wagner theory of classical conditioning (1972), and it may be that their model will have at least heuristic value in further studies of conditioned reinforcement.

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