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# The Effects of Pipradrol on the Acquisition of Responding with Conditioned Reinforcement: A Role for Sensory Preconditioning

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**Abstract.** Previous studies have shown that pipradrol enhances the acquisition of responding with conditioned reinforcement. The present experiments replicated this finding and assessed the possible role of nonspecific stimulus change, feeding in the test environment and prior exposure to the conditioned stimulus. The test procedure consisted of three phases: Operant rates of pressing two levers, one of which produced a 3-s tone, were measured in the pre-exposure phase; the tone was paired with food in the four conditioning sessions; and conditioned reinforcement was demonstrated in the test phase by a relative increase in pressing the tone lever. A group ($N = 8$) receiving food but no tone during the conditioning phase also increased responding on the tone lever in the test phase and this effect was enhanced in a group ($N = 8$) receiving pipradrol prior to the test. A group ($N = 8$) receiving neither tones nor pellets during conditioning and pipradrol prior to test failed to show a change in lever bias, ruling out the possibility that pipradrol produced a nonspecific enhancement of responding for stimulus change. It was hypothesized that the conditioned reinforcement effect seen in the food-alone groups resulted from sensory preconditioning. According to this hypothesis, the tone was conditioned to environmental stimuli during the pre-exposure phase; subsequent presentation of pellets resulted in a learned association between environmental stimuli and food, leading to increased responding for the tone in the test phase. The results of two control experiments supported this view. One group ($N = 8$) received no tone in the pre-exposure phase, pellets alone in the conditioning phase and then pipradrol prior to test. The second group ($N = 8$) received pellets alone in the conditioning phase, but under altered environmental stimulus conditions, and then was given pipradrol prior to test. Neither group showed evidence of conditioned reinforcement. It was concluded that pipradrol enhanced acquisition of responding with conditioned reinforcement even if the conditioned reinforcing stimulus was established with sensory preconditioning procedures.

**Key words:** Conditioned reinforcement – Sensory preconditioning – Pipradrol – Psychomotor stimulants – Rats

Stein (1964) proposed that psychomotor stimulant drugs such as *d*-amphetamine and pipradrol increase the effectiveness of primary reinforcing stimuli. This effect was observed with the negative reinforcer, electric shock (Verhave, 1958) and with positive reinforcers, including electrical stimulation of the brain (Stein, 1962) and heat (Weiss and Laties, 1963). Hill (1970) extended this hypothesis by suggesting that psychomotor stimulants also potentiate the effectiveness of conditioned reinforcing stimuli. This conclusion was based on the observation that an appropriate dose of pipradrol enhanced responding in extinction when a response-contingent conditioned reinforcer was intermittently presented; on the other hand, the same dose of pipradrol decreased responding when conditioned reinforcement was absent. This effect was replicated by Robbins (1975).

The method employed by Hill (1970) to study conditioned reinforcement was based on the original investigation of Bugelski (1938) and has been classified by Mackintosh (1974) as the established response extinction procedure. However, this procedure no longer is viewed as an unequivocal demonstration of conditioned reinforcement because of possible confounding with stimulus generalization decrement. Mackintosh (1974) suggested that a better procedure for the study of conditioned reinforcement is the new response extinction procedure. With this procedure, conditioned reinforcement is demonstrated by showing

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that a stimulus that has been associated with reinforcement can itself reinforce a previously unlearned response. Skinner (1938) employed this method with rats by first giving magazine training and then showing that the magazine click could be used to reinforce the learning of a lever-press operant.

Using the new response extinction procedure, Robbins (1976, 1978) and Robbins and Koob (1978) found that pipradrol enhanced the acquisition of responding with conditioned reinforcement; control groups ruled out the possibility that pipradrol produced a nonspecific preference for stimulus change. Thus, the original observations of Hill (1970) have been confirmed in a paradigm that is not subject to the same criticism as the established response extinction procedure.

Beninger and Phillips (1980), using a variation of the new response extinction procedure, similar to that of Stein (1958) and Knott and Clayton (1966), showed that the establishment of conditioned reinforcement based on food was blocked by injection of the neuroleptic pimozide. Rats were pre-exposed to a chamber with two levers, one of which produced a tone. Following determination of the operant rate of pressing each lever, the tone was paired with food with the levers absent. The levers were then re-introduced to the chamber during a test session and conditioned reinforcement was observed as a change in the proportion of presses on the tone lever. If pimozide (1.0 mg/kg) was injected during the pairing phase, no conditioned reinforcement was observed in the test. Control groups indicated that this blockade of conditioned reinforcement was not produced because of state dependent learning (Overton, 1974) or a drug-related impairment of eating.

Pimozide has been shown to produce a fairly specific blockade of dopamine (DA) receptors (Pinder et al., 1976); thus, DA may play a role in the process of establishing a neutral stimulus as a conditioned reinforcer (Beninger and Phillips, 1980). The psychomotor stimulant pipradrol is known to enhance the release of catecholamines from a reserpine-sensitive storage pool (Scheel-Kruger, 1971). Possibly, the enhanced acquisition of responding with conditioned reinforcement reported by Hill (1970) and Robbins (1975, 1976, 1978) is related to the effects of pipradrol on DA.

Experiment 1 was carried out to replicate the previously reported effects of pipradrol on the acquisition of a new response with conditioned reinforcement. The procedure of Beninger and Phillips (1980) was employed with pipradrol being injected during the test phase. Having replicated the Hill (1970) effect in experiment 1, additional experiments were carried out to determine more precisely what was learned in this paradigm and what aspect of learning was affected by the drug. Related experiments have examined the dose-response effects of pipradrol, cocaine and *d*-amphetamine on this phenomenon (in preparation). Only a 10 mg/kg dose of pipradrol was used in the present experiments because it has been found consistently to enhance the acquisition of new responding with conditioned reinforcement.

## Materials and Methods

*Subjects.* Sixty-eight male albino rats of the Wistar strain were housed individually in a climatically controlled colony room kept on a 12-h light-dark cycle. The rats (305 – 420 g) were maintained at 80% of free-feeding weight throughout the experiment.

*Apparatus.* The experimental environments consisted of four similar Plexiglas chambers (30.0 × 21.5 × 46.5 cm) each housed in a ventilated sound-attenuating box and illuminated by an overhead light. Two of the chambers had wax paper-covered wooden floors and two had grid floors. Each chamber was equipped with two removable levers (7.7 × 4.4 cm), one being located in the middle of each 21.5 cm end at a height of 4.0 cm. The force requirement for the levers was about 0.10 N. In the middle of one of the sides at a height of 1.5 cm was a feeder cup. A 2900 Hz tone generator (Sonalert) was mounted in the ceiling of each sound-attenuating box. Environmental contingencies and data collection were controlled by solid state switching and timing devices (BRS/LVE) for one chamber and by a Data General Nova 3 computer for the remaining three.

*Procedure.* In a series of five experiments, each of eight different groups was tested according to an experimental design with three distinct phases. The first group in experiment 1 was included to demonstrate that this experimental procedure could be used to establish conditioned reinforcement. The following paragraphs present a detailed account of the procedure used to train this group. A description of the procedural variations used in training and testing the remaining groups in each experiment appears in the appropriate section below.

The three phases of the experiment were referred to as the pre-exposure, conditioning and test phases. The pre-exposure phase consisted of six 40-min sessions of exposure to the chamber with the two levers present. There was one session per day for 3 days, 2 days in the home cage then the remaining three sessions on the next 3 days. During this phase, depressions of one of the levers (the tone lever) resulted in a 3-s presentation of the tone while depressions of the other level (the no-tone lever) had no pre-arranged consequences. Previous studies (Beninger and Phillips, 1980) revealed that almost all rats showed a preference for the same side; therefore the tone lever was always placed on the nonpreferred side. The dependent variables were the number of responses on each side.

The conditioning phase consisted of four 60-min sessions. There was one session per day for the 2 days following the pre-exposure phase, then 2 days in the home cage followed by the remaining sessions on the next 2 days. During the conditioning phase the levers were absent from the chambers and Plexiglas plates covered the resulting apertures. During each session the 3-s tone was presented 80 times according to a random time 45-s schedule; i.e., the average intertone interval was 45 s. Each tone presentation during the first conditioning session terminated with the delivery of one 45 mg Noyes Precision Food Pellet and pellet delivery occurred only after a random 33% of the tone presentations in the next three sessions. This partial pairing procedure was employed because it has been demonstrated to produce more durable conditioned reinforcement (Knott and Clayton, 1966; Zimmerman, 1959, 1963).

The test phase consited of one 40 min session which occurred on the next day. The two levers were again present in the chambers and

again one produced the 3-s tone. For any rats that had averaged more responses on the tone lever during the last three pre-exposure sessions the tone lever was moved to the nonpreferred side for the test session. Conditioned reinforcement was observed as a relative increase in the number of responses made on the tone lever during the test phase as compared to the pre-exposure phase.

*Data Analysis.* The purpose of the pre-exposure phase was to familiarise the rats with the experimental environment and to determine the rate of pressing on the tone and no-tone levers prior to conditioning. These initial lever-pressing rates (presses per session) were calculated by averaging the number of presses on each lever over the last three sessions of the pre-exposure phase. Lever-pressing rates for the test phase were simply the number of presses on each lever during the one test session. Thus, the data consisted of two pairs of numbers for each rat.

The data for each group were subjected to a two-way analysis of variance with repeated measures on both variables (levers and phases). When the increase in number of responses on the tone lever from the pre-exposure phase to the test phase was greater than the increase on the no-tone lever, a significant interaction would be observed. In such cases it was concluded that conditioned reinforcement was demonstrated. The groups that received pipradrol in the test phase showed a large increase in overall responding on both levers and a large increase in the variance associated with each lever. Thus, to reduce the difference in the variances associated with the mean response rates in the two phases, the data for all groups were transformed to square roots prior to statistical analysis.

*Experiment 1.* A number of authors have reported that pipradrol enhances conditioned reinforcement as tested with the established response extinction procedure (Hill, 1970; Robbins, 1975). The purpose of this experiment was to demonstrate conditioned reinforcement in nondrug animals using the new response extinction procedure and to investigate the effects of pipradrol on this phenomenon.

Twenty rats were randomly assigned to one of two groups; the vehicle group ($N=8$) and the pipradrol group ($N=12$). The training of the vehicle group already has been described. The training of the pipradrol group was similar except that an IP injection of 10 mg/kg pipradrol HCl (Merrell) dissolved in distilled water preceded the test session by 15 min.

The mean square root of number of responses on the tone and no-tone levers in the pre-exposure and test phases for the vehicle and pipradrol groups is shown in Figure 1. The vehicle group showed a greater increase in responding on the tone lever than on the no-tone lever following conditioning, thereby demonstrating that the tone had become a conditioned reinforcer. The pipradrol group showed an increase in responding on both levers but the increase was far greater for the tone than for the no-tone lever, showing a strong conditioned reinforcement effect.

These observations were confirmed by statistical analyses. Analysis of variance of the square roots of the scores for the vehicle group revealed a significant lever-phase interaction ($F=5.76$, $df=1,7$, $P<0.05$) confirming that the tone had become a conditioned reinforcer. Analysis of the square roots of the response totals of the pipradrol group revealed a significant increase in overall responding from pre-exposure to test ($F=45.16$, $df=1,11$, $P<0.001$) and a significant interaction of phases-levers ($F=21.97$, $df=1,11$, $P<0.001$) indicating conditioned reinforcement to the tone.

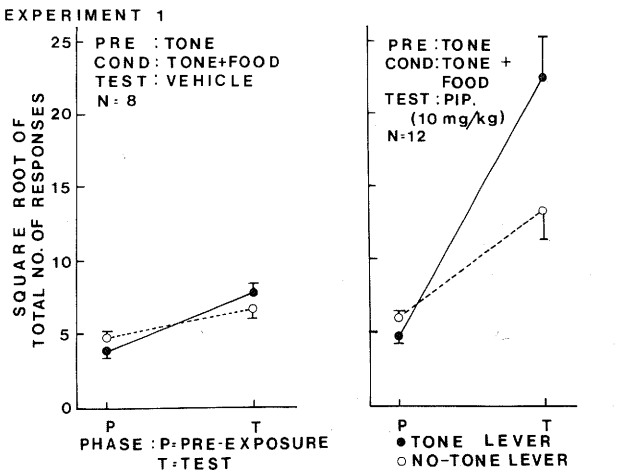


**Fig. 1.** Mean square root (± SEM) of number of responses on the tone and no-tone levers in the pre-exposure and test phases for the vehicle (left) and pipradrol (right) groups in experiment 1. Both groups showed a greater increase in responding on the tone lever than on the no-tone lever ($P<0.05$, 0.001 respectively) showing that the tone had become a conditioned reinforcer

To compare the magnitude of the conditioned reinforcement effect between the two groups, the square roots of the response totals were subjected to a three-way analysis of variance with repeated measures on two variables. The variables analysed were groups, levers and phases, the latter two being those with repeated measures. This analysis revealed a significant three-way interactionn ($F=8.98$, $df=1,18$, $P<0.008$) indicating that the two-way interaction of levers and phases (which is taken as evidence of conditioned reinforcement) differed for the two groups. This effect confirms that the drug produced an enhancement of conditioned reinforcement in the pipradrol group.

The observation of conditioned reinforcement in the vehicle group replicated our earlier findings (Beninger and Phillips, 1980) and confirmed the usefulness of the procedure employed for studying this phenomenon. The enhancement of the effect by piradrol was in good agreement with the data from a number of other laboratories (Hill, 1970; Robbins, 1975, 1976, 1978; Robbins and Koob, 1978).

*Experiment 2.* The results of experiment 1 were consistent with the hypothesis that pipradrol enhances conditioned reinforcement. However, other interpretations have not been ruled out. Possibly pipradrol produces a nonspecific preference for stimulus change.

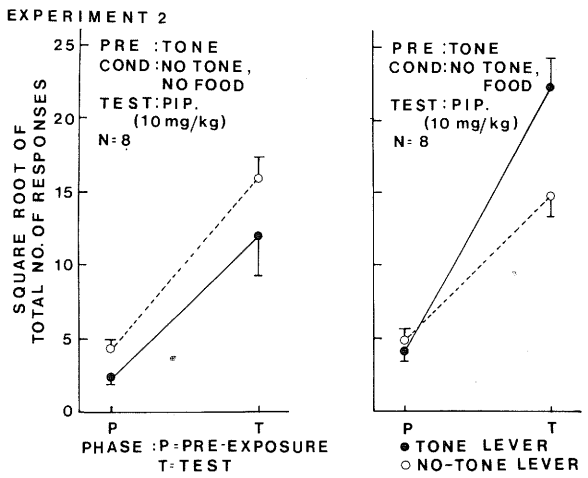


**Fig. 2.** Mean square root (± SEM) of number of responses on the tone and no-tone levers in the pre-exposure and test phases for the no tone-no food (left) and food-alone (right) groups in experiment 2. Both groups received 10.0 mg/kg pipradrol prior to the test session. There was no significant difference in the amount of increase in responding on the levers in the left panel ($P > 0.4$); the increase in responding on the tone lever was greater than on the no-tone lever in the right panel ($P < 0.02$)

A group receiving no tones and no food in the conditioning phase and then pipradrol in the test was included in experiment 2 to test this hypothesis. Alternatively, pipradrol may produce a preference for stimulus change only after feeding has occurred in the experimental environment. To test this possibility, a group receiving food, but no tones, in the conditioning phase and then pipradrol prior to the test was included in experiment 2.

Sixteen rats were randomly assigned to one of two groups; the No tone-no food group ($N = 8$) and the food-alone ($N = 8$) group. Both of these groups received the three phases of training as described previously, with the following variations. The no tone-no food group received no tones or food pellets during the four sessions of the conditioning phase and was IP injected with pipradrol (10 mg/kg) 15 min prior to the test session. The food-alone group received food pellets during the conditioning phase in a fashion similar to the vehicle group except that tones never occurred. This group also was IP injected with pipradrol (10 mg/kg) 15 min prior to the test session.

The mean square root of number of responses on each lever in each phase for the no tone-no food and food-alone groups is shown in Figure 2. Both groups showed an overall increase in responding from the pre-exposure to the test phase, but while the no tone-no food group showed no relative change in the number of presses on each lever the food-alone group showed a relatively greater increase in pressing the tone lever than the no-tone lever.

These observations were confirmed by the results of statistical analyses. The square roots of the response totals for each group were subjected to a two-way analysis of variance with repeated measures on both variables (levers and phases). Both groups showed a significant increase in overall responding from pre-exposure to test ($F = 18.85$, $df = 1,7$ $P < 0.003$ for no tone-no food and $F = 195.08$, $df = 1,7$, $P < 0.001$ for food-alone). The phase-lever interaction for the no tone-no food group was insignificant ($F = 0.65$, $df = 1,7$, $P > 0.4$), whereas this interaction was significant for the food-alone group ($F = 9.05$, $df = 1,7$, $P < 0.02$), indicating a change in the proportion of responses made on the tone lever from pre-exposure to test.

The results of experiment 2 indicated that the apparent enhancement of conditioned reinforcement by pipradrol took place even if tone-food pairings never occurred in the conditioning phase. This observation brought into question the need for pairing the tone and pellets in this phase. The failure of the no tone-no food group to show a change in lever bias from pre-exposure to test suggested that pipradrol produced its effect only if the animals previously were fed in the test environment. The remaining experiments tested this hypothesis.

*Experiment 3.* Previous interpretations of the pipradrol effect have suggested that the drug enhances a conditioning effect that has already occurred, but is small (Lyon and Robbins, 1975; Robbins, 1976). Thus, the relative increase in responding on the tone lever observed in the food-alone group while drugged in the test phase of experiment 2 may have occurred because simple feeding in an environment previously associated with tones in some way produced a relative change in tone-lever preference even in undrugged animals. If this is the case it is possible that a group that received food alone in the conditioning phase and then was tested without drug in the test phase might show a small relative increase in pressing the tone lever. Experiment 3 tested this possibility.

Eight rats were assigned to the food-alone control group. This group received the same treatment in the pre-exposure and test phases as the vehicle group. In the conditioning phase this group received food pellets according to the same random 45-s schedule as the vehicle group, with 80 pellets presented during the first conditioning session and 33% of that number during the next three sessions; tones never were presented in this phase.

The mean square root of number of responses on each lever in each phase is shown in Figure 3. The data indicate a relative increase in pressing the tone lever from pre-exposure to test. Analysis of variance of the

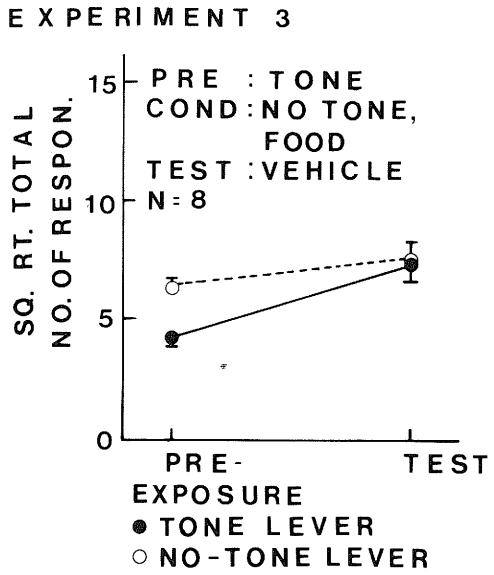


**Fig. 3.** Mean square root (± SEM) of number of responses on the tone and no-tone levers in the pre-exposure and test phases for the food-alone control group in experiment 3. The increase in responding on the tone lever was greater than on the no-tone lever ($P < 0.05$)

square roots of the totals for the food-alone control group revealed a phase-lever interaction ($F = 10.77$, $df = 1,7$, $P < 0.05$) confirming the significance of this relative increase.

The results revealed a change in preference for the tone lever by nondrugged animals given food alone in the conditioning phase. Their only experience with the tone occurred in the pre-exposure phase in the same environment in which they were fed subsequently. Thus, the enhancement in responding on the tone lever observed in the food-alone group tested with pipradrol in experiment 2 could be viewed as an enhancement of the small effect observed in the food-alone control group in this experiment.

To what can this effect of feeding on tone preference be attributed? Tones were not paired with pellets in the conditioning phase for either the food-alone group (experiment 2) or the food-alone control group (experiment 3), yet preference for the tone lever was observed in the test phase for both groups. Two observations contradict the possibility that these effects can be attributed to an increased preference for stimulus change produced by pipradrol: (1) The change in preference for the tone lever in the food-alone control group (experiment 3) occurred when they were undrugged in the test phase; (2) the no tone-no food group (experiment 2) failed to show a change in lever preference in the test phase when drugged.

Sensory preconditioning may provide one possible interpretation of the results of the food-alone and food-alone control groups (Brogden, 1939; Seidel, 1959; Thompson, 1972 for reviews). Thus, during the pre-exposure phase, intermittent tones produced by lever presses became associated with other environmental stimuli, such as the texture of the floor, general level of illumination, background sounds and odors. During the conditioning phase, food was associated with these environmental stimuli. In the test phase, the animals learned to lever-press for the tone because it was associted with stimuli that signalled food. The following two experiments tested this possibility.

*Experiment 4.* It was suggested above that the change in preference for the tone lever observed in the food-alone groups might have occurred because of sensory preconditioning. If this hypothesis is correct, it should be possible to weaken or eliminate the effect by altering, in the conditioning phase, the environmental cues that were present during the pre-exposure phase. This was done for one group in experiment 4 by changing the chamber illumination and floor texture from the first to the second phase. A group that received tone-food pairings in the presence of the changed environment (CE) stimuli in the conditioning phase was added to determine if the contingency between the tone and food resulted in any learning when sensory preconditioning was weakened.

Sixteen rats were randomly assigned to one of two groups; the CE-pairing group ($N = 8$) and the CE-food alone group ($N = 8$). Both these groups underwent the pre-exposure phase as described in Methods. During the conditioning phase the environment for each group was changed. Four rats in each group had been pre-exposed to a chamber with a grid floor and four to a chamber with a paper-covered wooden floor. For each group the conditioning phase was conducted in the other environment and, in addition, the house lights that remained on during the pre-exposure and test phases were turned off. Thus, the CE-pairing group received the conditioning phase in the CE with tone-pellet pairings occurring, as described for the Vehicle group in the Method section. The CE-food alone group also was exposed to the conditioning phase in the CE but received only pellets and no tones. For the test phase, both groups were returned to their original environmental conditions and IP injected with pipradrol (10 mg/kg).

The mean square root of number of responses on each lever in each phase for the CE-pairings and CE-food alone groups is shown in Figure 4. Both groups showed an increase in overall responding from pre-exposure to test. However, while the CE-food alone group showed no relative change in pressing the tone lever, the CE-pairing group increased their response rate on the tone lever more than on the no-tone lever from pre-exposure to test.

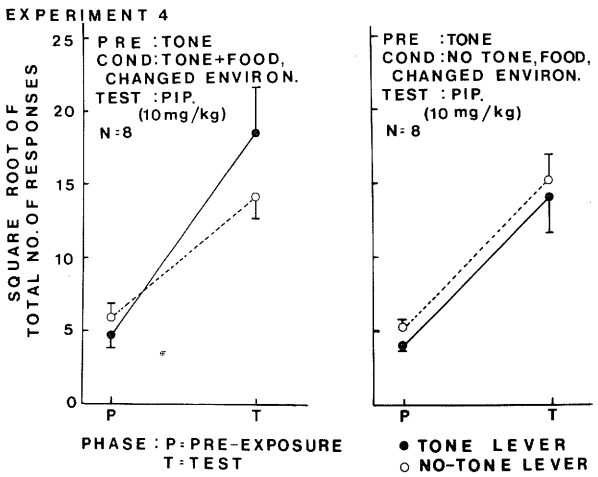


**Fig. 4.** Mean square root (± SEM) of number of responses on the tone and no-tone levers in the pre-exposure and test phases for the CE-pairing (left) and CE-food alone (right) groups in experiment 4. Both groups were injected with 10.0 mg/kg pipradrol prior to the test session. The increase in responding on the tone lever was marginally greater than on the no-tone lever in the left panel ($0.05 < P < 0.10$); there was no significant difference in the amount of increase in responding on the two levers in the right ($P > 0.9$)

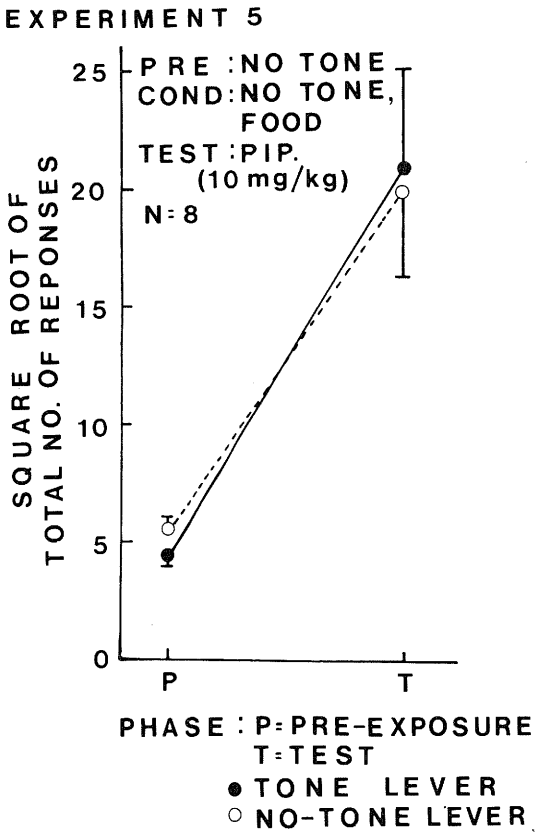


**Fig. 5.** Mean square root (± SEM) of number of responses on the tone and no-tone levers in the pre-exposure and test phases for the no tone-pre-exposure-food alone group in experiment 5. A 10 mg/kg dose of pipradrol was given prior to the test phase. There was no significant difference in the increase in responding on the two levers ($P > 0.6$)

Two-way analysis of variance of the square roots of the response totals for each phase revealed a significant overall increase in responding on both levers from pre-exposure to test ($F = 23.12$, $df = 1,7$, $P < 0.002$ for CE-pairing and $F = 58.46$, $df = 1,7$, $P < 0.001$ for CE-food alone). The phase-lever interaction for the CE-pairing group approached significance ($F = 3.79$, $df = 1,7$, $0.05 < P < 0.10$) whereas the interaction for the CE-food alone group was insignificant ($F < 1$, $df = 1,7$, $P > 0.05$).

The results revealed that the pipradrol-produced enhancement of the relative increase in responding on the tone lever that occurred after feeding alone in the conditioning phase (observed in experiment 2) was attenuated if the feeding occurred in a different environment (the CE-food alone group). A weak change in preference for the tone lever was observed if pellets and tone were paired in the CE (the CE-pairing group).

The change in preference for the tone lever in the CE-pairing group indicated that, in the absence of mediating environmental stimuli, the association of the tone with food did produce a small conditioned reinforcement effect. The complete absence of any preference change in the CE-food alone group supported the hypothesis that the changed preference for the tone lever in the test phase, oberserved in the food-alone and food-alone control groups, was mediated by sensory preconditioning of the tone to environmental stimuli. Experiment 5 was a further test of this hypothesis.

*Experiment 5.* The CE-food alone group (experiment 4) showed that feeding in the conditioning phase failed to produce a change in preference for the tone lever in the test phase if the environmental stimuli associated with the pre-exposure and conditioning phases were different. This observation supported the hypothesis that sensory preconditioning mediated the conditioning effect in the food-alone groups. As a further test of this hypothesis, in experiment 5 the tone was not presented in the pre-exposure phase. Subsequent presentations of pellets alone during the conditioning phase should not result in an increase in responding for the tone in the test phase since the tone will not have been preconditioned to the (unchanged) environmental stimuli.

Eight rats were assigned to the no-tone pre-exposure-food alone group. This group received the same number of pre-exposure sessions as the vehicle group but tones were not presented when either lever was depressed. In the conditioning phase, this group received food pellets according to the random 45-s schedule in the same fashion as the vehicle group, but

tones never were presented. All rats were IP injected with pipradrol (10 mg/kg) 15 min prior to the test session.

The mean square root of number of responses on each lever in each phase is shown in Figure 5. The data showed an overall increase in responding from pre-exposure to test; however, there was no statistically significant relative increase in responding on the tone lever. Analysis of variance of the square roots of the response totals for the no-tone pre-exposure-food alone group supported this description of the data. Thus, there was an overall effect of phases ($F = 26.99$, $df = 1,7$, $P < 0.001$) whereas the phase-lever interaction was insignificant ($F < 1.0$, $df = 1,7$, $P > 0.05$).

The results of experiment 5 were in good agreement with the data of the CE-food-alone group from experiment 4. The presentation of food pellets but no tones in the conditioning phase failed to result in increased responding on the tone lever in the test phase either if the environmental stimuli associated with pre-exposure and conditioning were different or if the tone was absent during the pre-exposure phase. Thus, the conditioned reinforcement seen in the food-alone groups (experiments 2 and 3) seemed to be mediated by sensory preconditioning of the association between environmental stimuli and the tone.

## Discussion

The procedure employed here to test for conditioned reinforcement has been used previously by several experimenters (Beninger and Phillips, 1979; Knott and Clayton, 1966; Stein, 1958): The results for the vehicle group demonstrated conditioned reinforcement and were in agreement with these data. However, additional experiments showed that a positive correlation of tone and food in the conditioning phase was not required to produce the apparent conditioned reinforcement effect in the test phase. In fact, when environmental stimuli were constant throughout the experiment, a relative increase in responding on the tone lever in the test phase occurred in groups that were fed but never received the tone in the conditioning phase (food-alone and food-alone control groups, experiments 2 and 3).

Further experiments revealed that the increased preference for the tone lever in the test phase did not occur simply as a result of feeding in the conditioning phase. Thus, the group receiving food in the presence of environmental stimuli different from those associated with the pre-exposure and test phases (the CE-food alone group in experiment 4) failed to change lever preference in the test phase. Similarly, the group that was fed in the environment associated with the pre-exposure and test phases but never received tones during the pre-exposure sessions (the no-tone pre-exposure-food alone group in experiment 5) failed to alter lever preference in the test. From these results it seemed that sensory preconditioning (Brogden, 1939; Seidel, 1959; Thompson, 1972) was obtained in this paradigm.

The prototypical sensory preconditioning experiment was done by Brogden (1939) and involved three phases. During the pre-exposure phase two neutral stimuli ($CS_1$ and $CS_2$) were paired. During the conditioning phase, $CS_2$ was paired with an unconditioned stimulus (US) that reliably produced a response. The test phase involved presentations of $CS_1$. Sensory preconditioning, i.e. learning the association between $CS_1$ and $CS_2$, was said to have occurred if the response originally produced by the US now was elicited by $CS_1$. In the present context, it would appear that during the pre-exposure phase, the association of the tone ($CS_1$) and environmental stimuli ($CS_2$) was learned. During the conditioning phase the food-alone groups learned the association of the environmental stimuli with the food reinforcer. In the test phase, the tone was demonstrated to be a conditioned reinforcer: Thus, the tone became a conditioned reinforcer through sensory preconditioning in the food-alone groups. Thus, this is a demonstration of conditioned reinforcement based on sensory preconditioning of the conditioned stimulus rather than direct pairing of the stimulus with primary reinforcement.

It is worth noting that the direct pairing of the tone stimulus with food also is a sufficient procedure for establishing the tone as a conditioned reinforcer. This effect was observed marginally in the CE-pairing group (in experiment 4) that received tone-pellet pairings in the presence of environmental stimuli different from those present during the pre-exposure and test phases. The results of the CE-food alone group indicated that conditioned reinforcement did not occur when food alone was presented under CE conditions; nevertheless, when the tone-pellet association was made under these conditions the tone did acquire some conditioned reinforcing properties. Beninger and Phillips (1980) reported that the tone failed to become a conditioned reinforcer if presentations of the tone and food were negatively correlated. This finding also is consistent with the suggestion that the contingency between the tone and food is an important element of this conditioning procedure.

The present data indicate clearly that pipradrol produced an enhancement of the conditioned reinforcement effect. This was observed in the pipradrol (experiment 1), food-alone (experiment 2) and CE-pairings (experiment 4) groups and confirmed the findings of Hill (1970), Robbins (1975, 1976, 1978) and Robbins and Koob (1978). Control groups ruled out the possi-

bility that pipradrol simply enhanced responding that produced stimulus change in an environment in which feeding occurred previously; thus, no enhancement of responding on the tone lever was observed in the no-tone pre-exposure-food alone group in experiment 5. This observation was consistent with Robbins and Koob's (1978) report that pipradrol only stimulated increased responding on a lever that produced a stimulus previously associated with reinforcement, and not on a simultaneously present lever that produced a different stimulus. Also, the failure of pipradrol to enhance responding on the tone lever in the no tone-no food group (experiment 2) ruled out the possibility of a nonspecific effect of the drug on tone-lever responding. This result was consistent with a similar control experiment reported by Robbins (1978).

There has been some debate regarding the best explanation of the pipradrol-produced enhancement of responding with conditioned reinforcement. On the one hand, Hill (1970) has suggested that pipradrol enhances the reinforcing properties of conditioned reinforcers resulting in higher levels of responding on the conditioned reinforcement lever. On the other, it has been argued that pipradrol causes a general increase in certain classes of responses with response selection being dependent in part on environmental contingencies (Lyon and Robbins, 1975; Robbins, 1976). This latter point of view was supported by Robbins (1976): Thus, when a pipradrol-treated animal was required to perform a chain of responses for conditioned reinforcement, almost all responding occurred on the final component of the chain and fewer conditioned reinforcers actually were obtained. The present results could be explained by this hypothesis. They showed, in addition, that the tendency to respond for conditioned reinforcement could be established by sensory preconditioning, as well as by direct pairing of the conditioned reinforcing stimulus with primary reinforcement and that this effect was enhanced by pipradrol.

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